LHC: Status and Outlook

UNIVERSIDAD AUTONOMA DE MADRID

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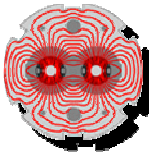
CERN, Geneva
Madrid, March 10, 2010

Major LHC challenges



High design Centre-of-mass energy of 14 TeV in given (ex LEP) tunnel

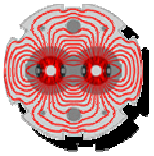
- **Magnetic field of 8.33 T with superconducting magnets**
- **Helium cooling at 1.9 K**
- **Large amount of energy stored in magnets**
- **"Two accelerators" in one tunnel with opposite magnetic dipole field and ambitious beam parameters pushed for very high of luminosity of 10^{34} cm^{-2} s^{-1}**
- **Many bunches with large amount of energy stored in beams**

Complexity and Reliability

- **Unprecedented complexity with 10000 magnets powered in 1700 electrical circuits, complex active and passive protection systems, ….**

- **Emittance conservation** $\varepsilon_N = \beta \gamma \varepsilon$, related to phase space density conservation, Liouville constant "intrinsic" normalized emittance ε_N, real space emittance ε decreases with energy
- **in absence of major energy exchange in synchrotron radiation / rf damping**
- **clean, perfectly matched injection, ramp, squeeze, minimize any blow up from: rf,**
- **kicking beam, frequent orbit changes, vibration, feedback, noise,..**
- **dynamic effects - persistent current decay and snapback**
- **non-linear fields (resonances, diffusion, dynamic aperture, non-linear dynamics)**

Beam parameters, LHC compared to LEP



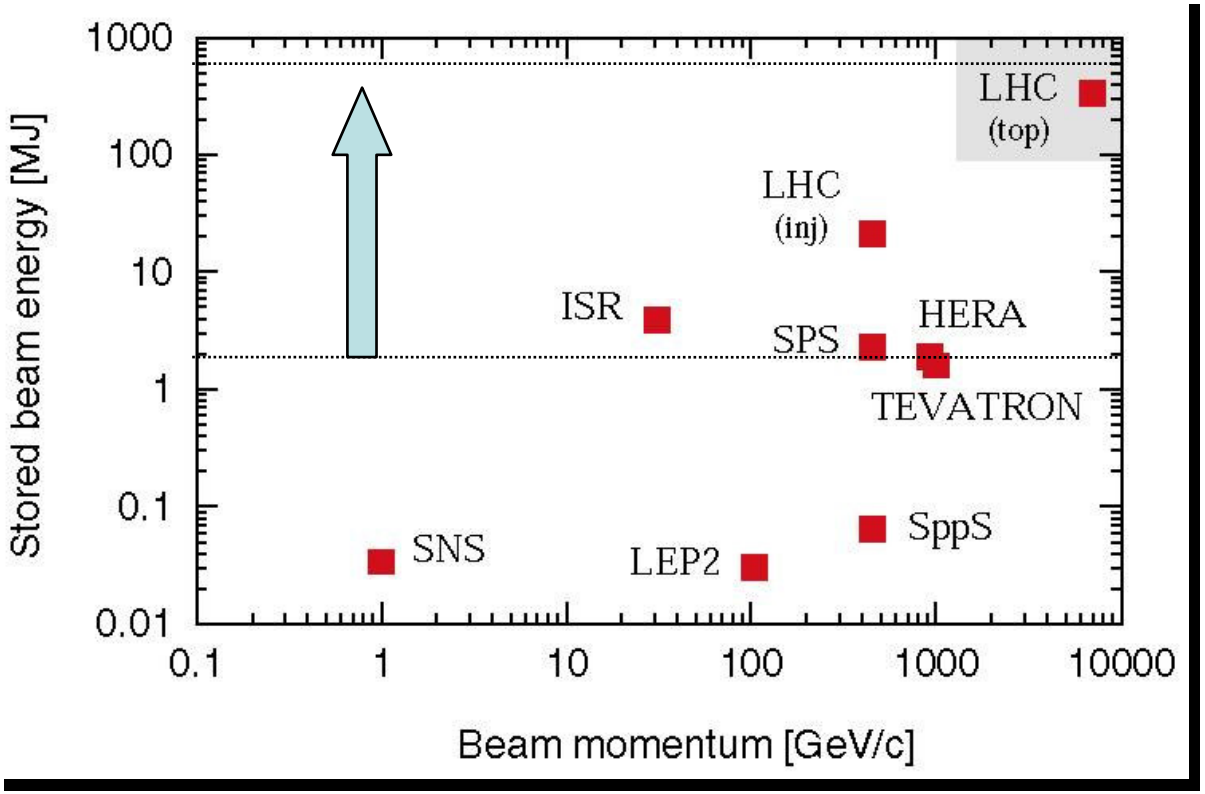
	LHC	LEP2
Momentum at collision, TeV/c	7	0.1
Nominal design Luminosity, $cm^{-2}s^{-1}$	1.0E+34	1.0E+32
Dipole field at top energy, T	8.33	0.11
Number of bunches, each beam	2808	4
Particles / bunch	1.15E+11	4.20E+11
Typical beam size in ring, μm	200 – 300	1800/140 (H/V)
Beam size at IP, μm	16	200/3 (H/V)

- **Energy stored in the magnet system:** **10 GJoule** Airbus A380, 560 t at 700 km/h
- **Energy stored in one (of 8) dipole circuits: (sector)** **1.1 GJ**
- **Energy stored in one beam:** **362 MJ**
  20 t plane
- **Energy to heat and melt one kg of copper:** **0.7 MJ**

the LEP2 total stored beam energy was about 0.03 MJ

The total stored energy of the LHC beams

Nominal LHC design: 3.2 × 10^{14} protons accelerated to 7 TeV circulating at 11 kHz in a SC ring



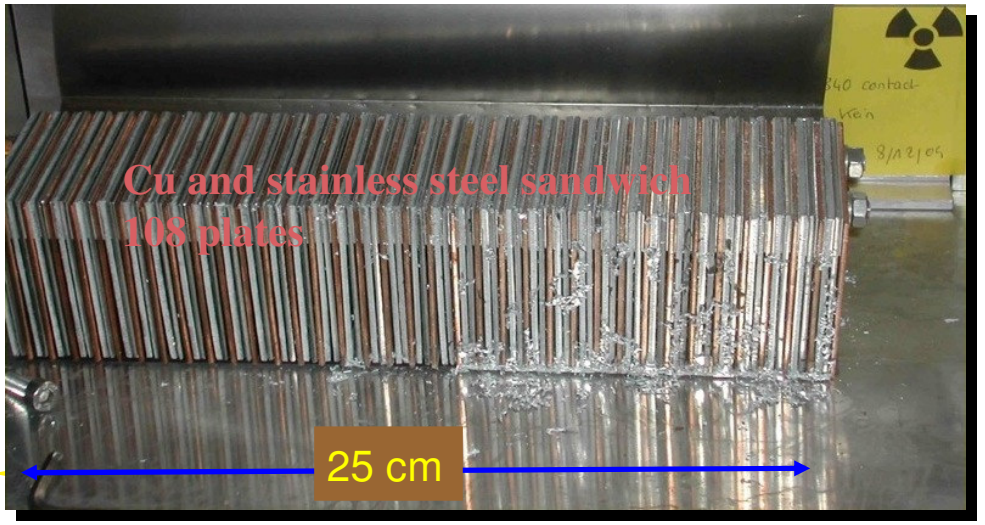
LHC: > 100 × higher stored energy and small beam size: ~ 3 orders of magnitude in energy density and damage potential. Active protection (beam loss monitors, interlocks) and collimation for machine and experiments essential.
Only the specially designed beam dump can safely absorb this energy.

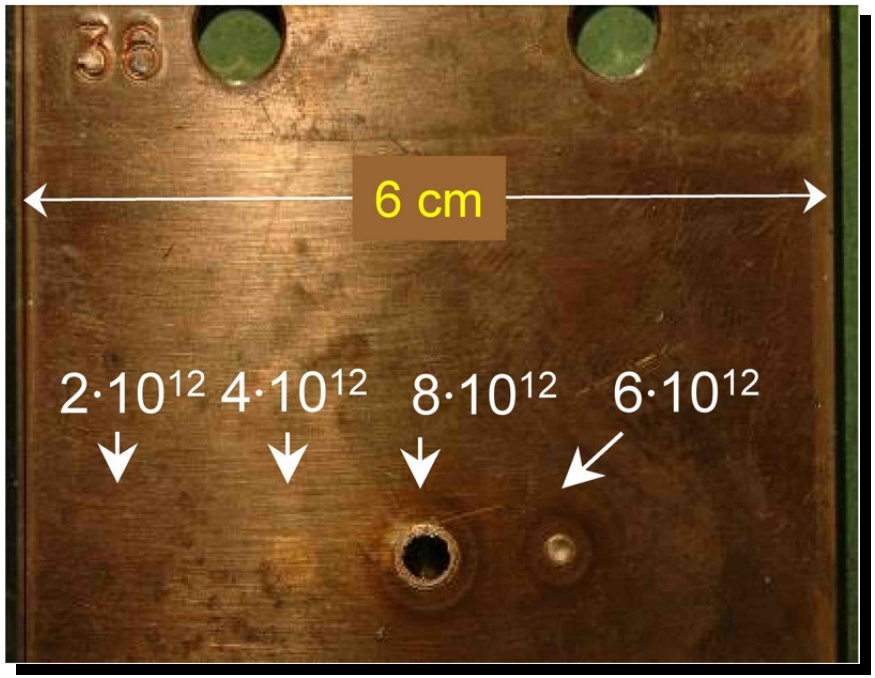
Damage potential : confirmed in controlled SPS experiment

controlled experiment with beam extracted from SPS at 450 GeV in a single turn, with perpendicular impact on Cu + stainless steel target

450 GeV protons

r.m.s. beam sizes $\sigma_{x/y} \approx 1$ mm





SPS results confirmed :

8×10^{12} clear damage 2×10^{12} below damage limit

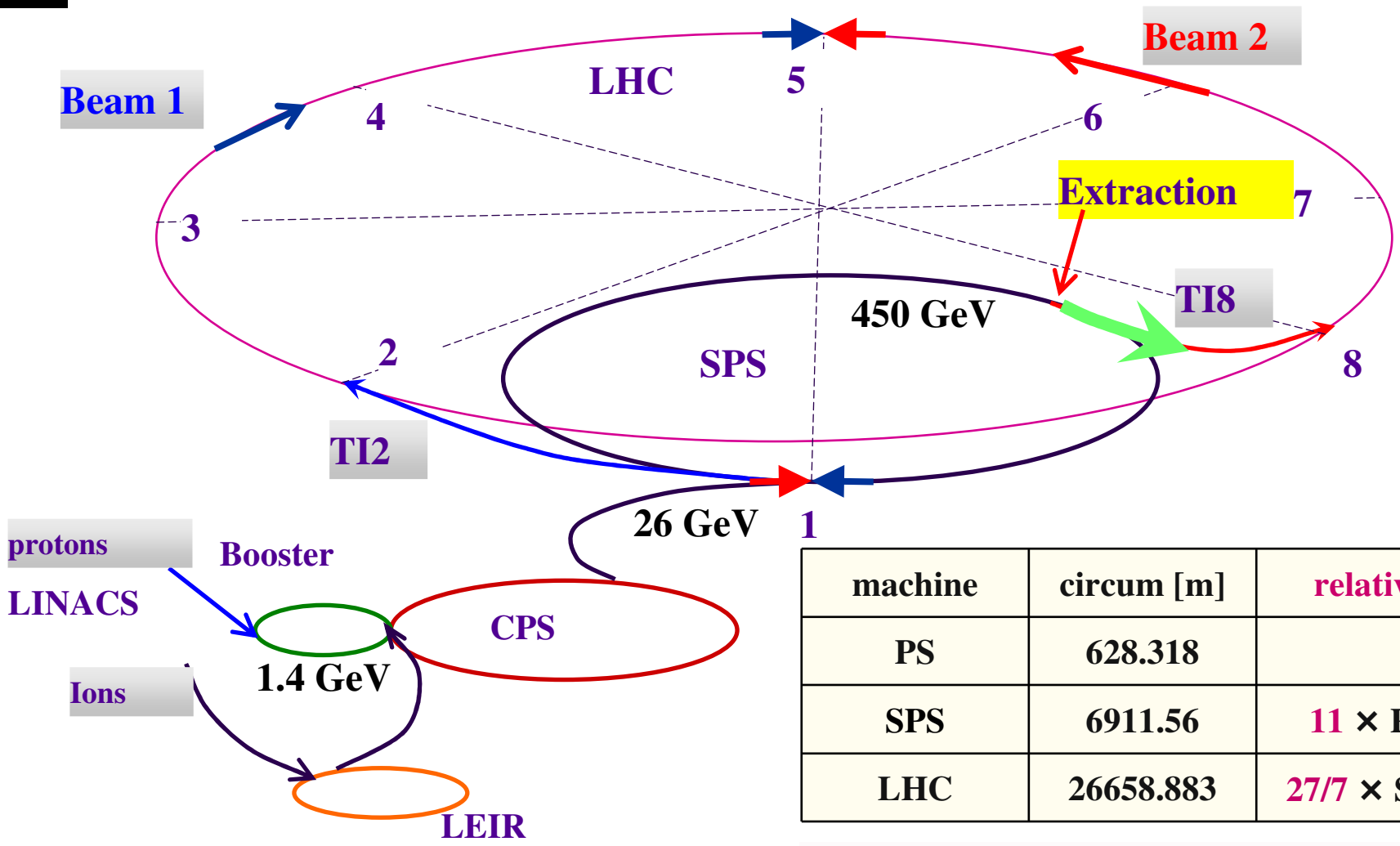
for details see V. Kain et al., PAC 2005 RPPE018

For comparison, the LHC nominal at 7 TeV :
$2808 \times 1.15 \times 10^{11} = 3.2 \times 10^{14}$ p/beam

at $< \sigma_{x/y} > \approx 0.2$ mm

over 3 orders of magnitude above damage level for perpendicular impact

The CERN accelerator complex : injectors and transfer



machine	circum [m]	relative
PS	628.318	
SPS	6911.56	11 × PS
LHC	26658.883	27/7 × SPS

simple rational fractions for synchronization
on a single frequency
tor at injection

Beam size of protons decreases with energy : area $\sigma^2 \propto 1 / E$

Beam size largest at injection, using the full aperture

Critical Issues

Past

- **QRL cryo-line (He supply)**
- **DFB power connections, warm to cold transition**
- **Triplet quadrupoles - differential pressure**

More recent

- **PIM** plug in module with bellow, systematically checked / repaired after warm up using "ping-pong" ball with RF-emitter : polycarbonate shell, ⌀ 34 mm, 15 g, 2h battery powered, 40 MHz emitter, signals recorded by LHC BPM
- **Vacuum leaks, condensation - humidity sector 3/4**
- **Magnet powering** check / correct : min/max, cabling - polarity
- **Single event upset,** radiation to electronics, shielding etc
- **Magnet re-training** magnets quenching below what was reached in SM18

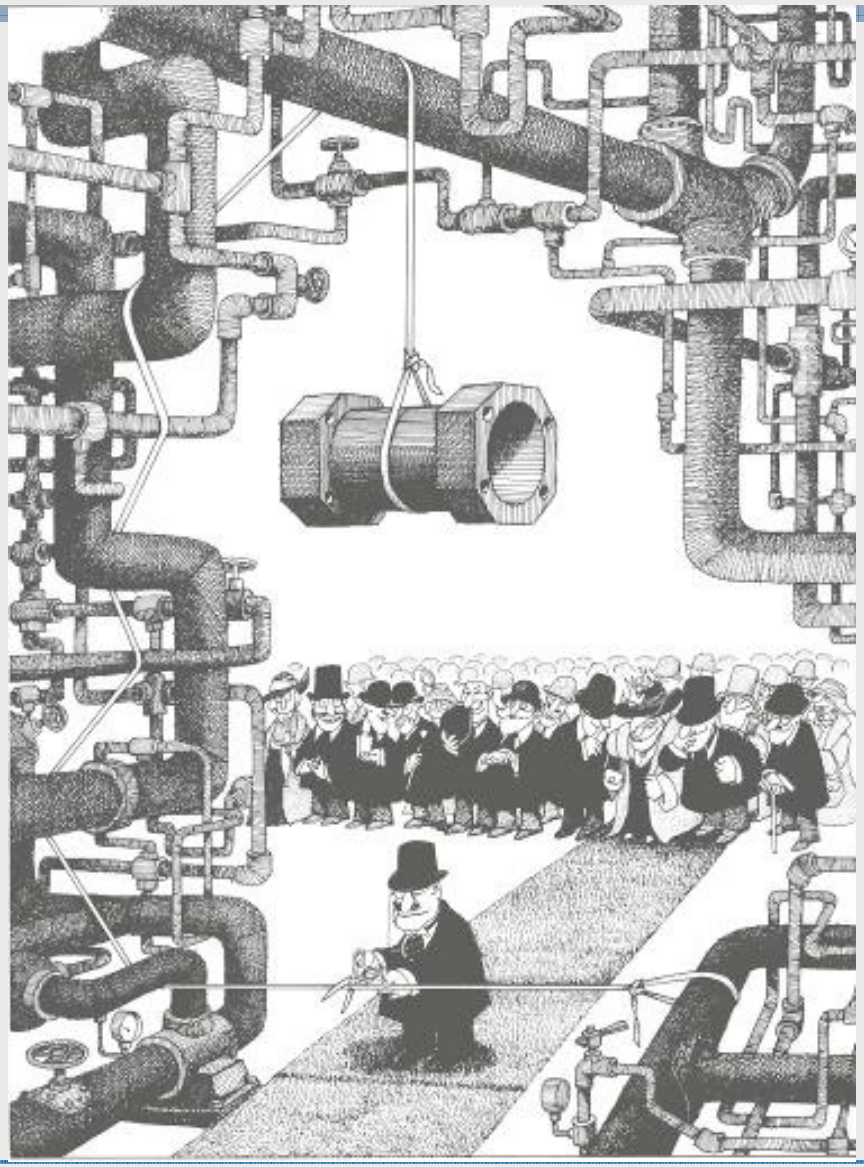
10 September 2008

10:30 beam 1 3 turns

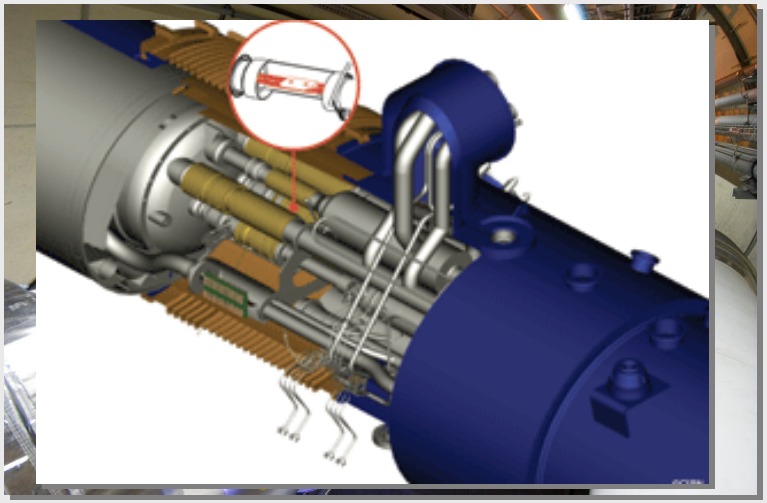
15:00 beam 2 3 turns

22:00 beam 2 several 100 turns

few days later…

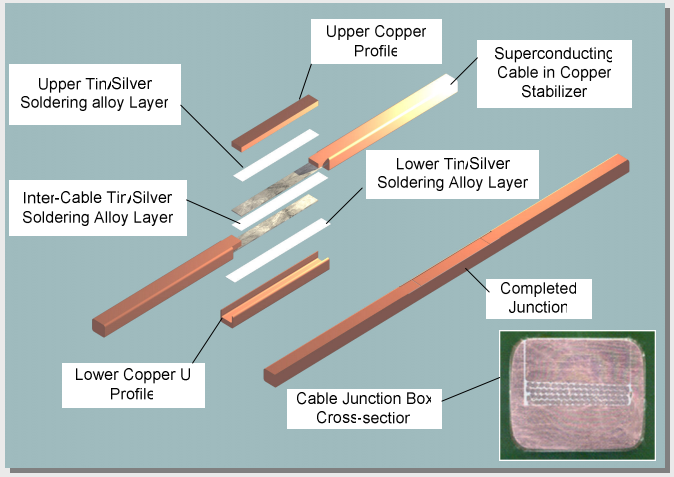


September 19, 2008: incident in sector 3-4



The incident was traced to a faulty electrical connection between segments of the LHC's superconducting cable (busbars)

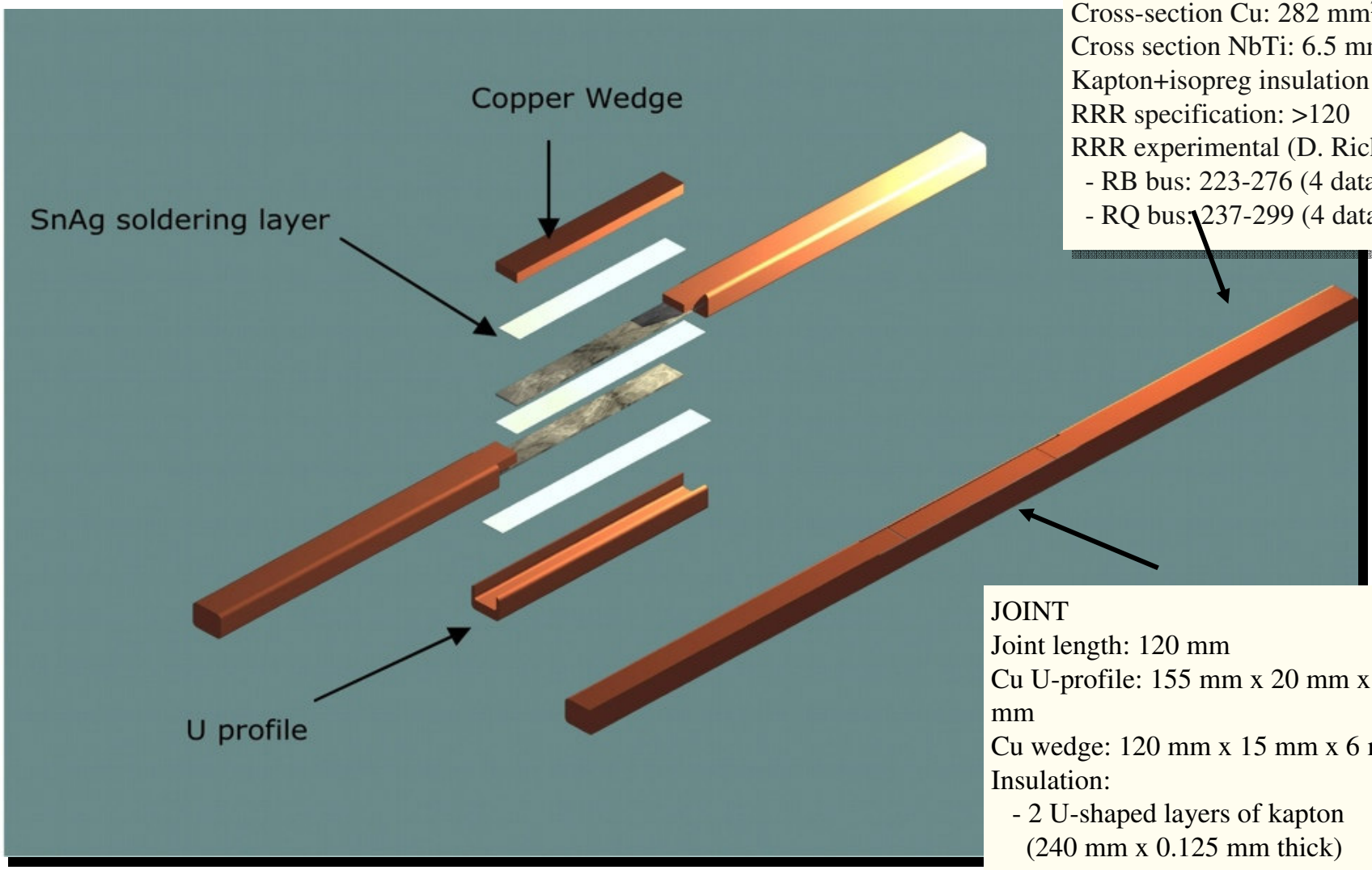
High impact was caused by collateral damage



2 most severely damaged interconnects

53 Magnets (along a zone of about 700 m) to be removed from tunnel and repaired/exchanged (a few % of entire LHC)

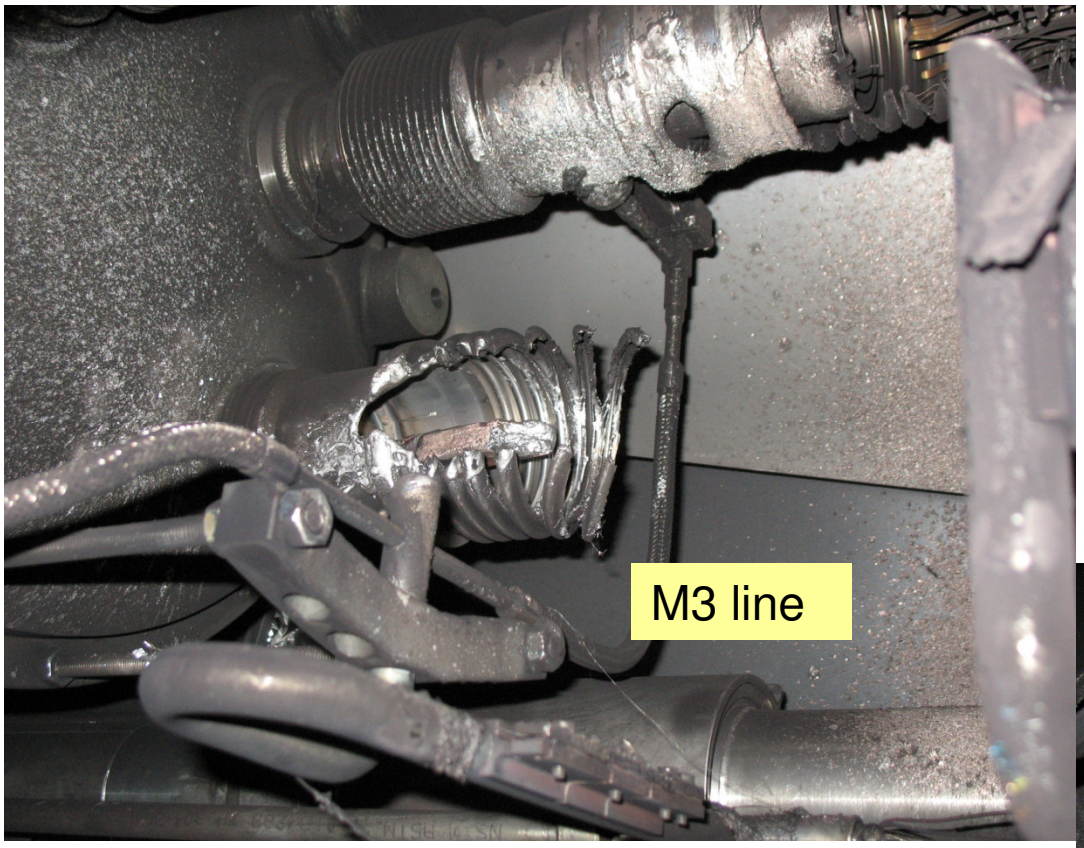
Busbar Splice



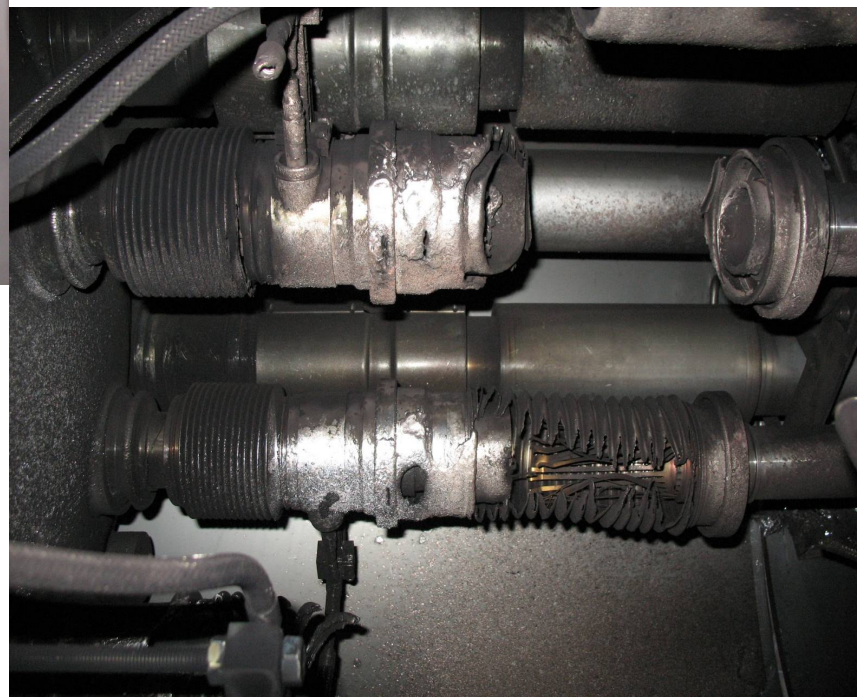
BUS
Cross-section Cu: 282 mm^2
Cross section NbTi: 6.5 mm^2
Kapton+isopreg insulation
RRR specification: >120
RRR experimental (D. Richter)
- RB bus: 223-276 (4 data)
- RQ bus: 237-299 (4 data)

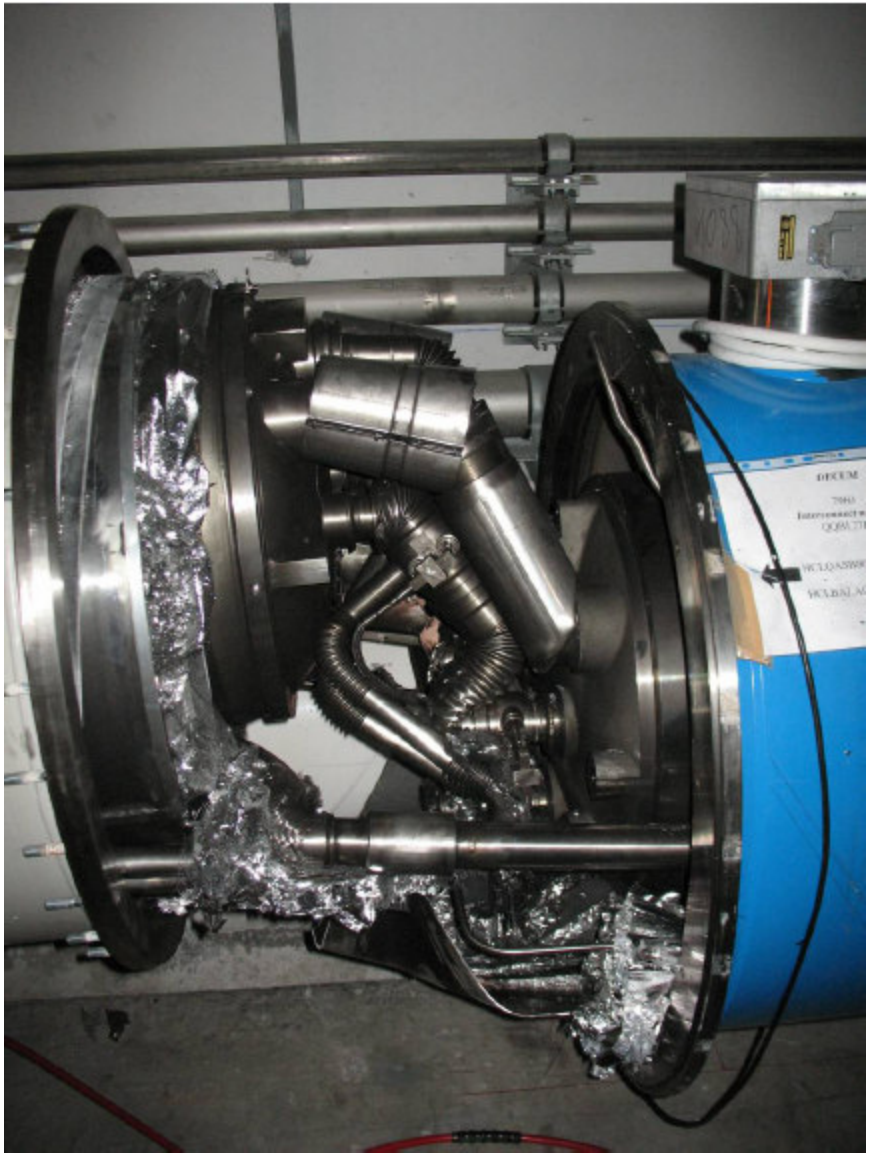
JOINT
Joint length: 120 mm
Cu U-profile: 155 mm x 20 mm x 16 mm
Cu wedge: 120 mm x 15 mm x 6 mm
Insulation:
- 2 U-shaped layers of kapton (240 mm x 0.125 mm thick)
- 2 U-shaped layers of G10 (190 mm x 1 mm)

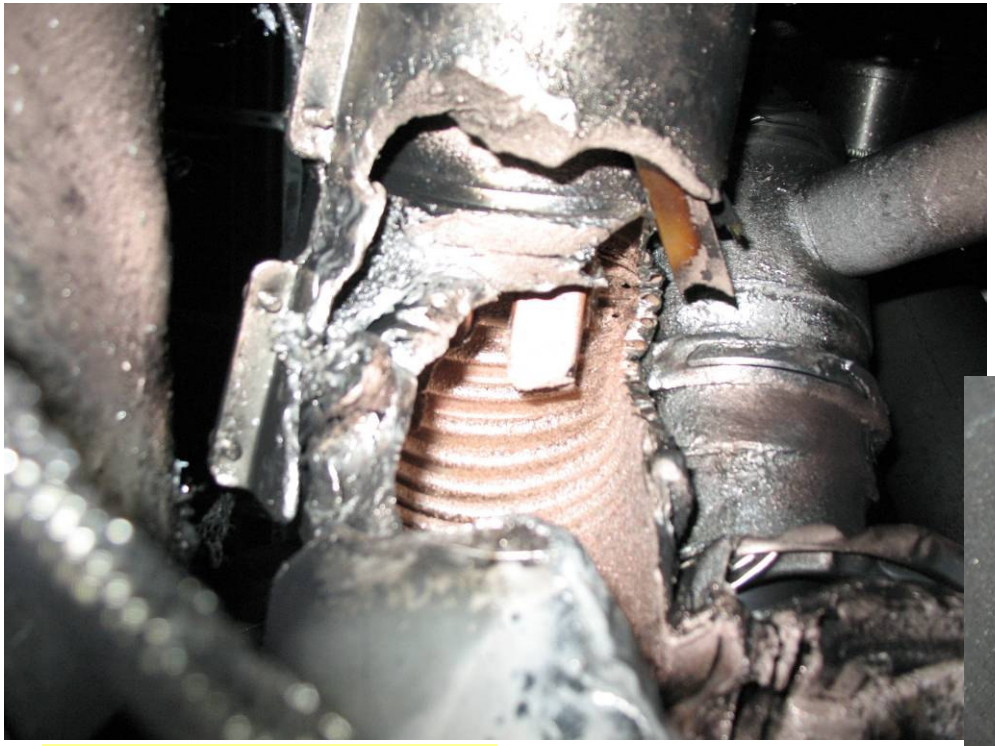
Electrical arc between C24 and Q24



V lines







QQBI.27R3 M3 line

QBBI.B31R3 M3 line

Bringing back the LHC: how was it done?

Five Phases:

1.Repair of sector 34

2.Consolidation and Avoidance of collateral damage

3.Hardware Commissioning

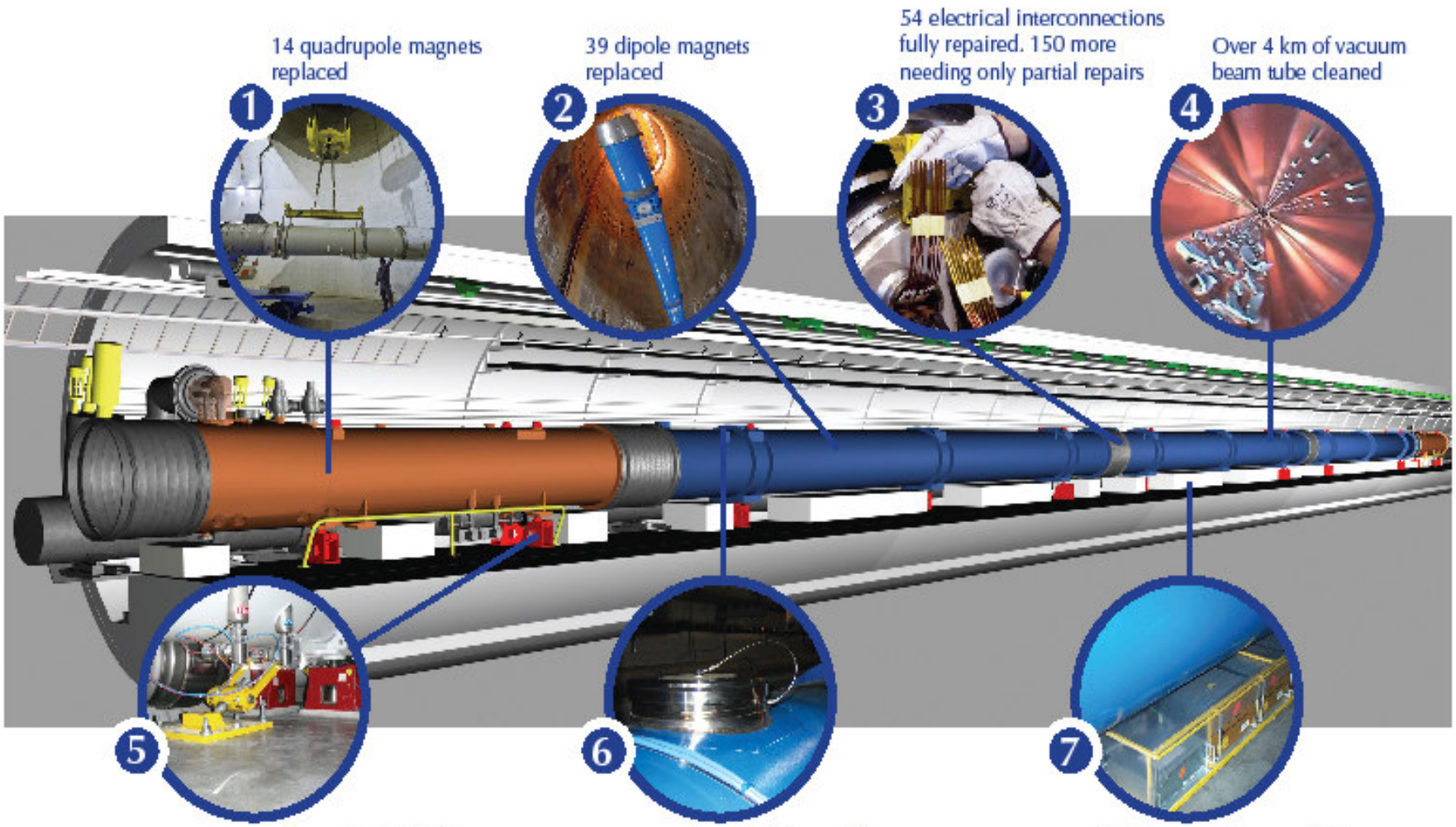
4.Preparations for Beams (long term)

5.Operation with Beams

Phase 1 and 2
Repair and Consolidation

Phase 1 +2

The LHC repairs in detail



CERN

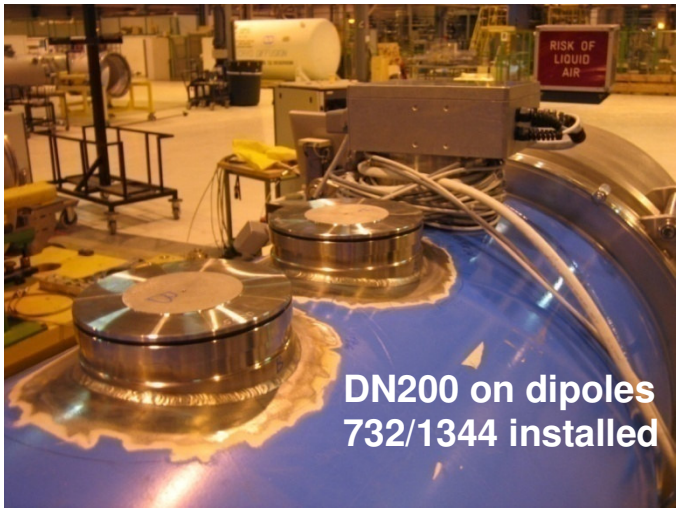
+ cryogenics!

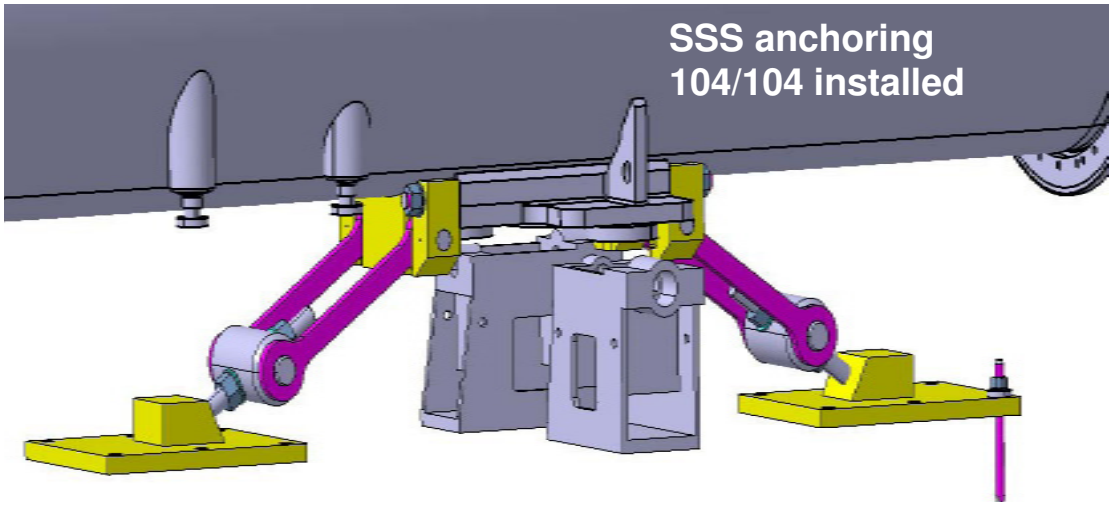
sector 3-4 : Magnet repair in SMI2

18

Last Repaired Magnet (SSS) going down (30/4/2009)

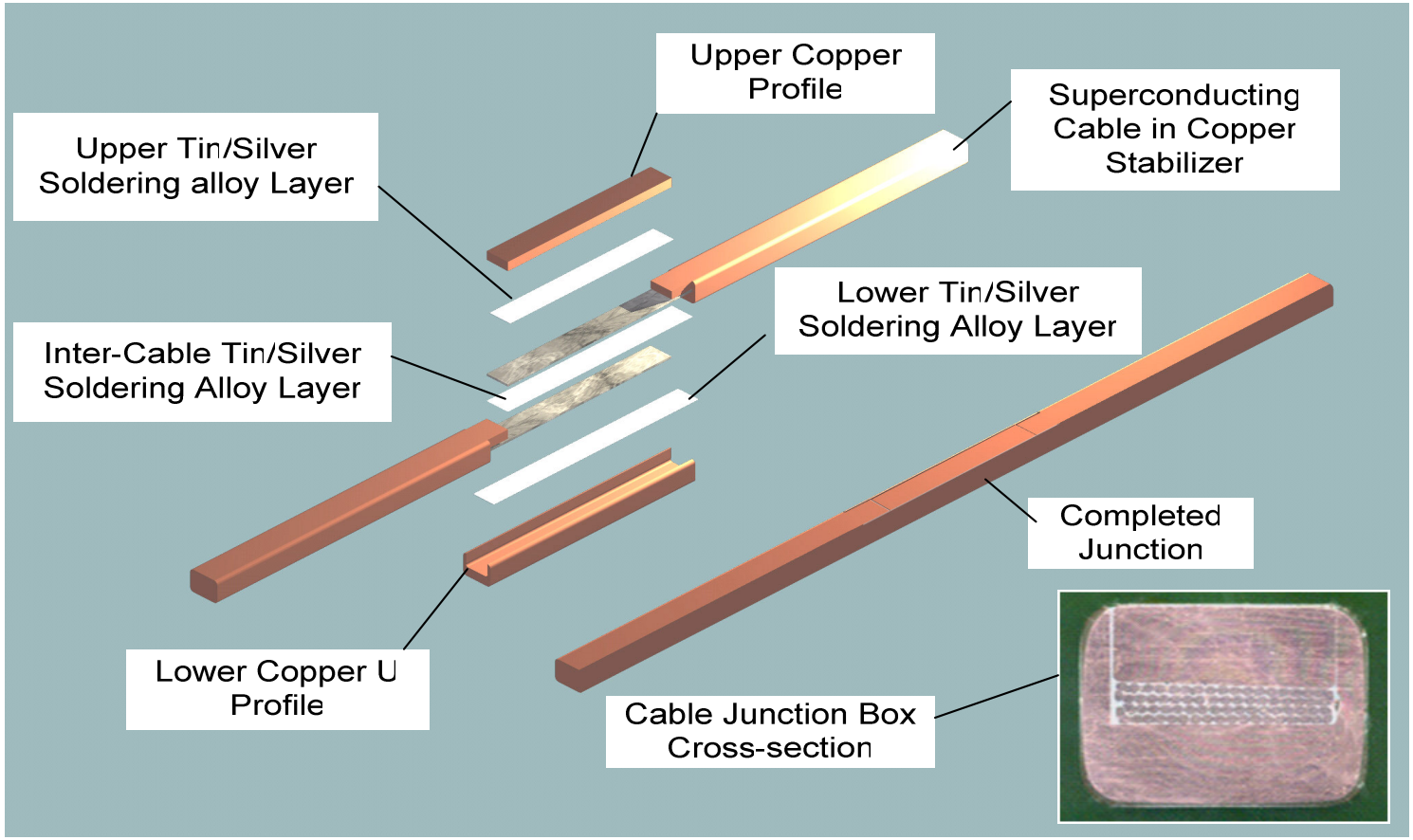
Magnet protection and anchoring

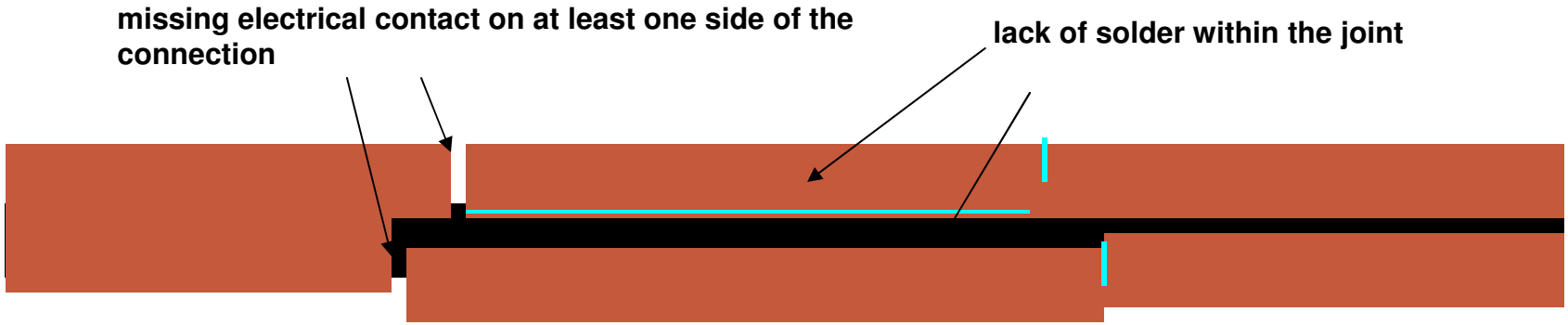


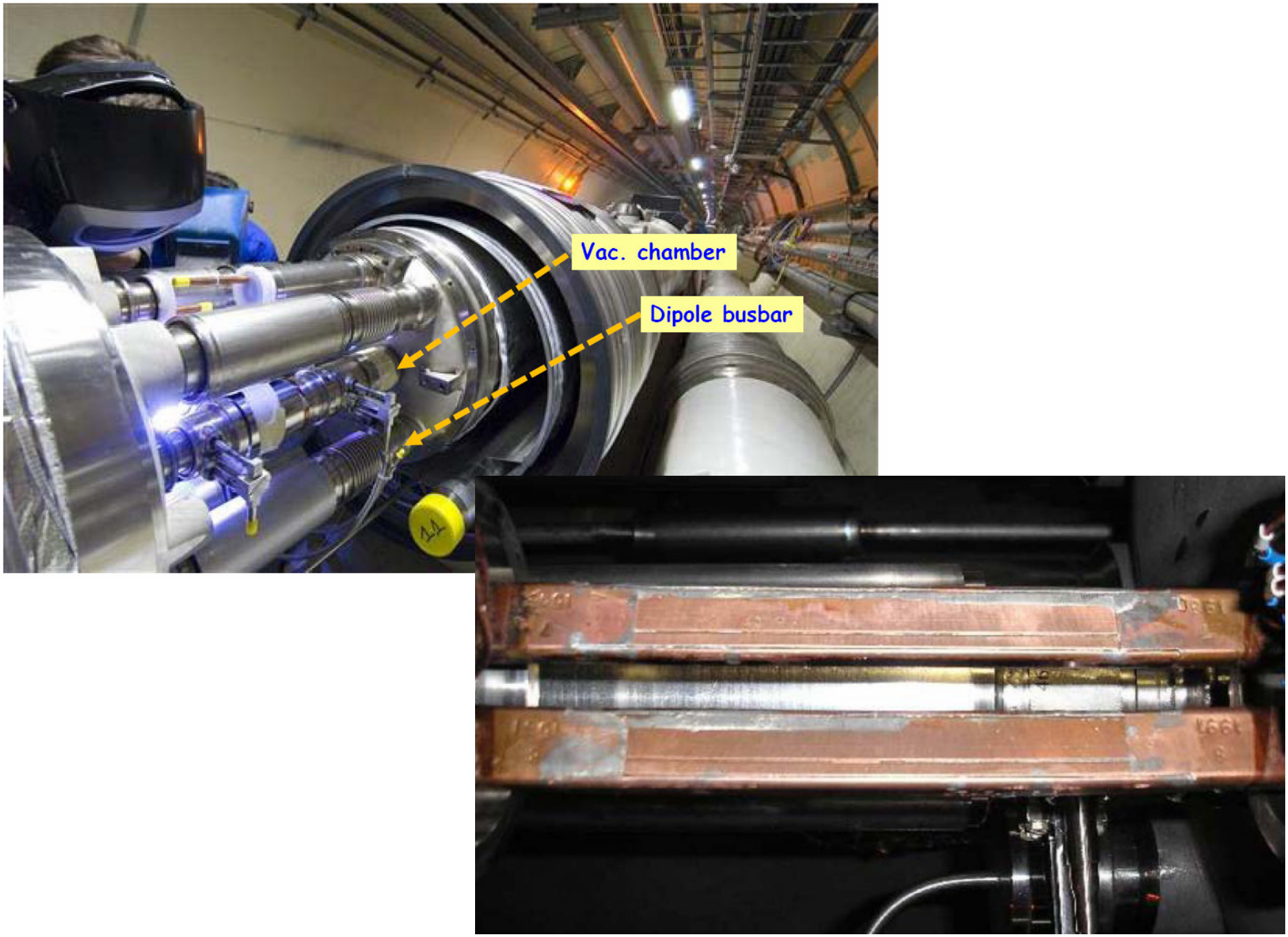



A

Show sample


Upper Copper Profile
Superconducting Cable in Copper Stabilizer
Upper Tin/Silver Soldering alloy Layer
Lower Tin/Silver Soldering Alloy Layer
Inter-Cable Tin/Silver Soldering Alloy Layer
Completed Junction
Lower Copper U Profile
Cable Junction Box Cross-section

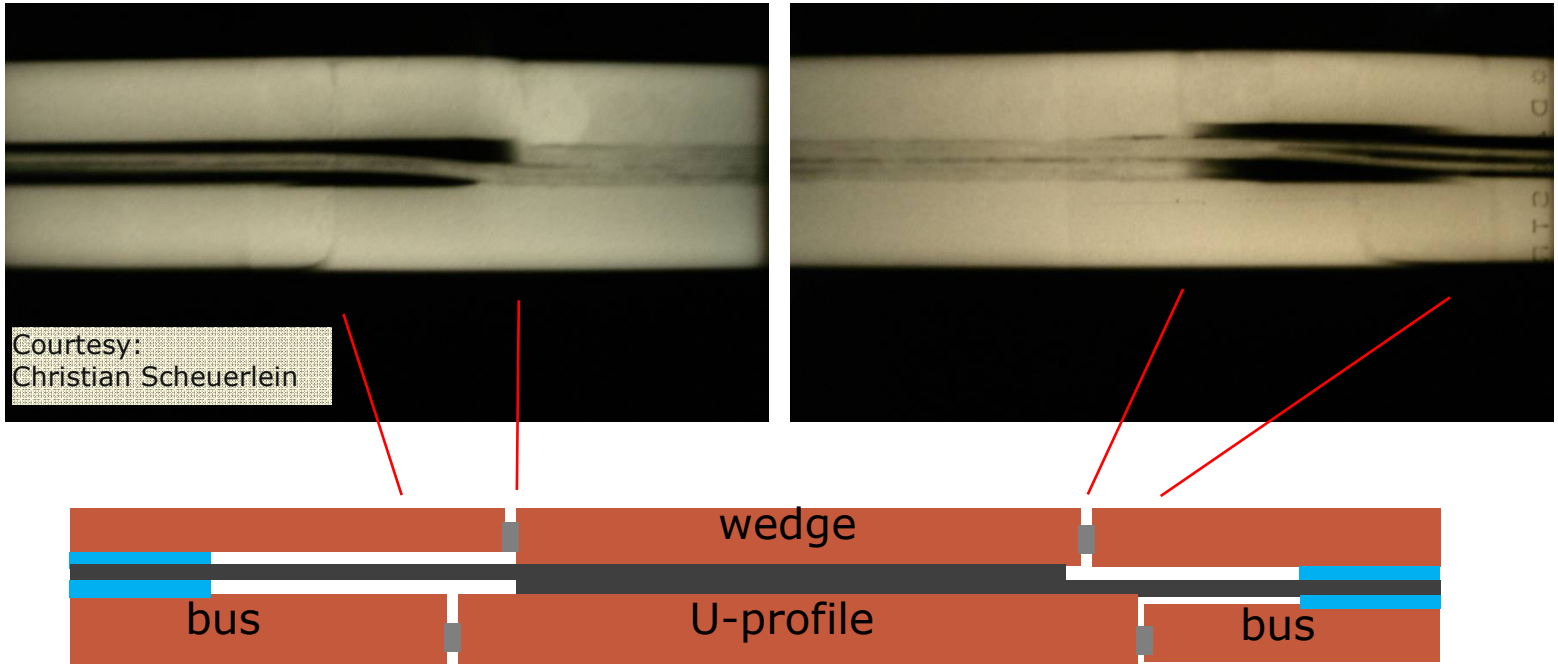

missing electrical contact on at least one side of the connection
lack of solder within the joint


Vac. chamber
Dipole busbar

Busbar Splice

normal conducting, soldered electrical connection between SC cables

1684 units × 6 ≈ 10 000 splices at magnet interconnects; 1/3 dipole, 2/3 quads



A. Siemko et al. LMC 5/08/09

possible problems in soldering :

overheating - SnAg loss

too cold - SnAg unmelted, poor connection

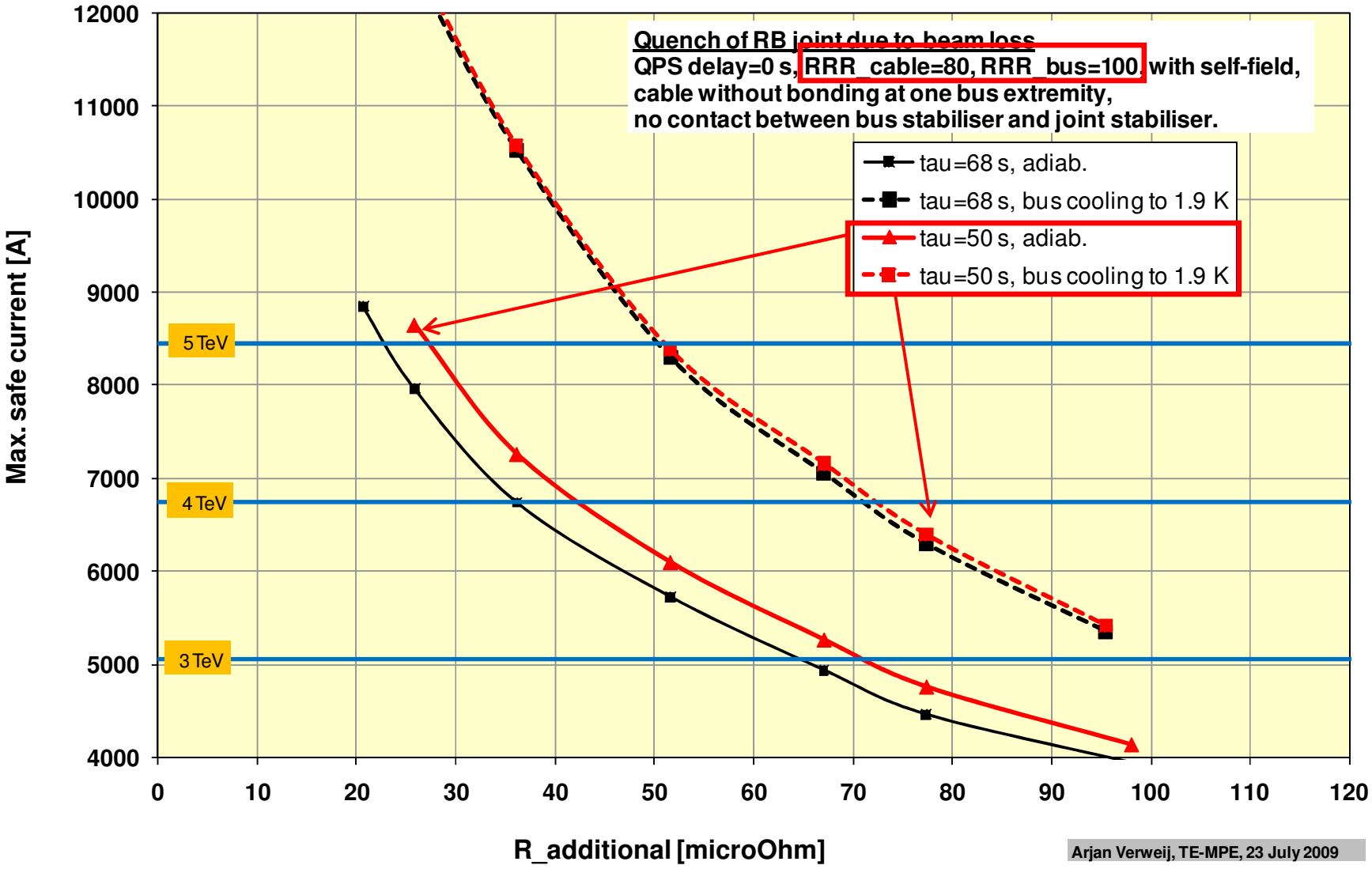
Now possible to diagnose : X-ray, ultrasound, resistance measurement.

Most reliable : resistance measured at room temperature

good : 10 $\mu\Omega$ dipole (RB) , 17 $\mu\Omega$ quadrupole (RQ).

Measured in 5 sectors which were warmed up. Fixed all above ~ 40 $\mu\Omega$. Other sectors measured at 80 K

RB: case 1 (instantaneous quench in busbar/magnet)



Thermal propagation time (for case 2)

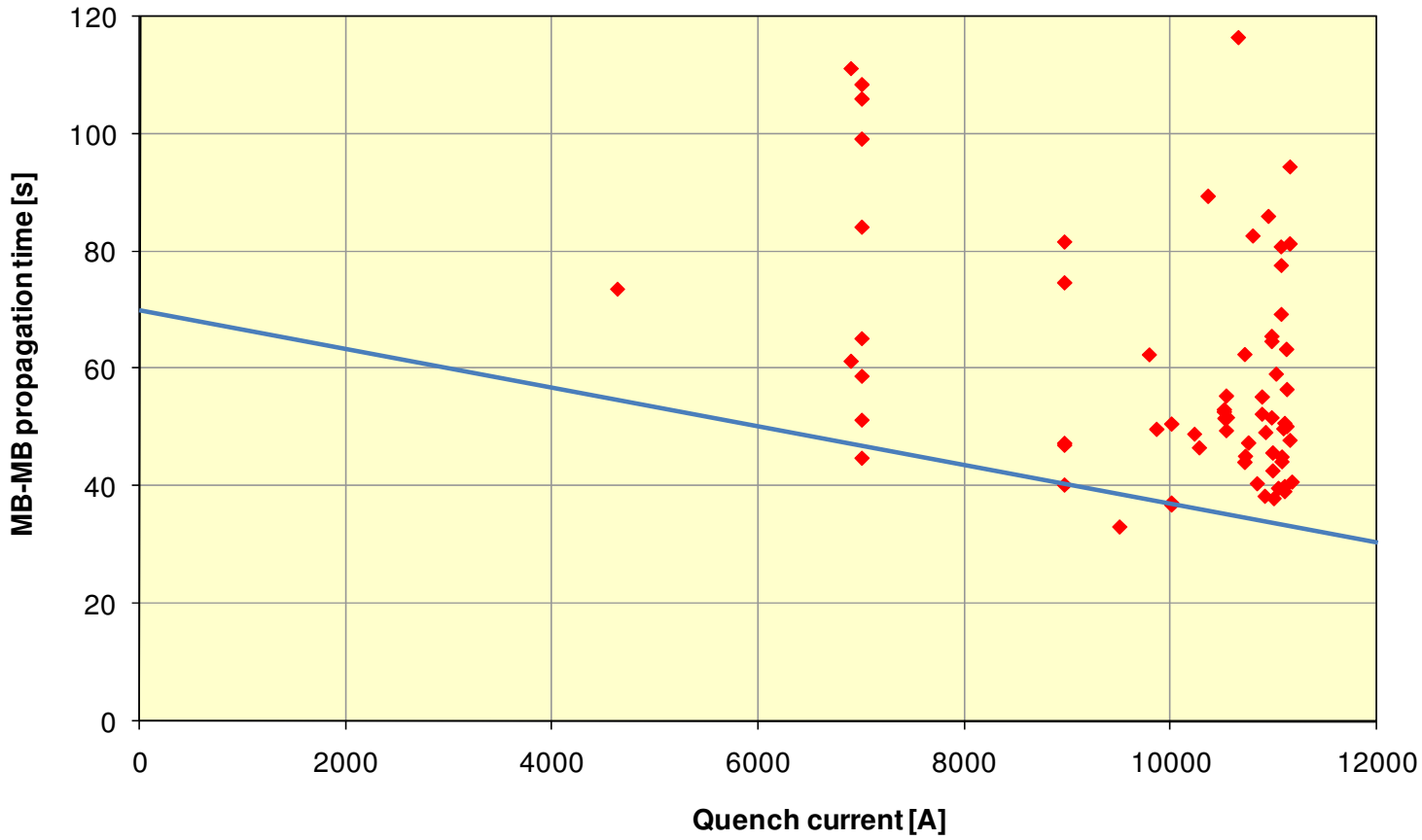
Experience from HWC for RB quenches at 7-11 kA.

Assume that the joint quenches after half the MB-MB thermal propagation time,

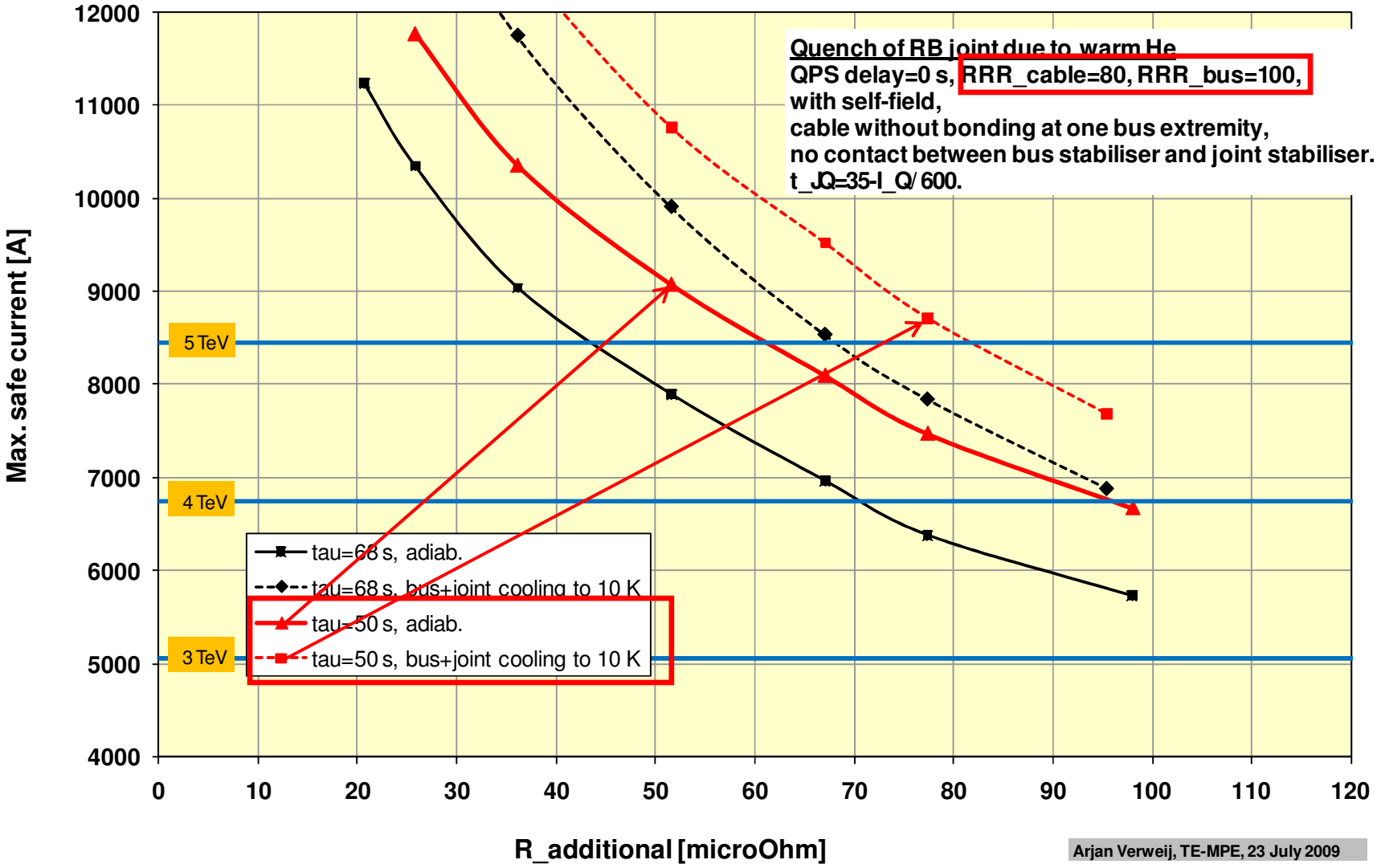
so $t_{JQ}=0.5*(70-I_Q/300)$

?

Maybe possible to get more accurate value from thermal analysis…..



RB: case 2 (quench propagation from magnet to busbar)



Enhanced QPS

Role of the Enhanced QPS System

- To protect against the new 'problems' discovered in 2008
  - The Aperture-Symmetric Quench feature in the Main Dipoles and
  - Defective Joints in the Main Bus-bars, inside or in-between the magnets.

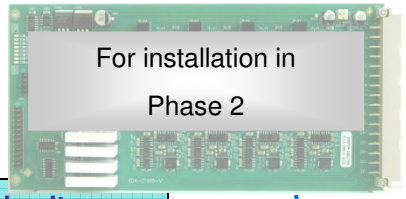
Reminder

QPS Upgrade also allows

- precision measurements of the joint resistances at cold (sub-nΩ range) of every Busbar segment. This will allow complete mapping of the splice resistances (the bonding between the s.c. cables).

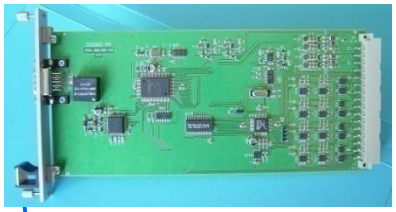
- To be used as the basic monitoring system for future determination of busbar resistances at warm (min. 80 K), to measure regularly the continuity of the copper stabilizers.

The nQPS project



DQQTE board for ground voltage detection

(total 1308 boards, 3 units/crate)

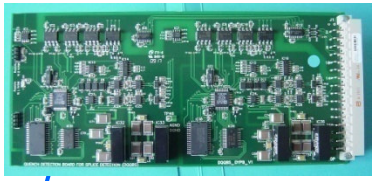


DQAMG-type S controller board

1 unit / crate, total 436 units

DQLPUS Power Packs

2 units / rack (total 872 units)



DQQBS board for busbar splice detection

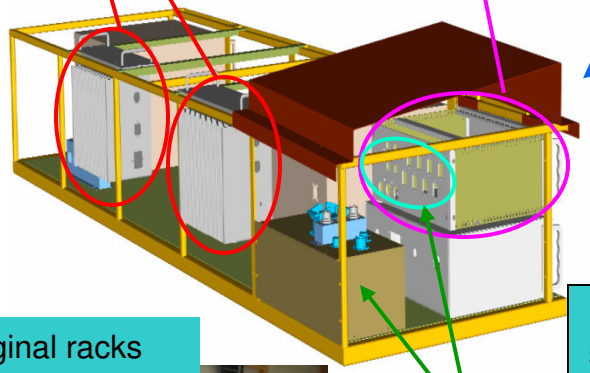
5 such boards / crate, total 2180 units

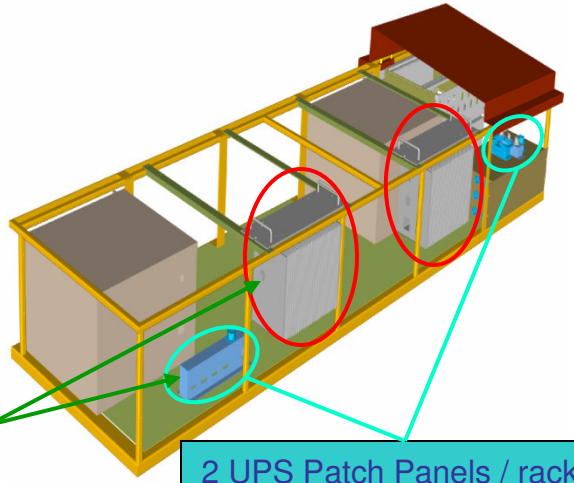
DQLPU-type S crate

total 436 units

DQQDS board for SymQ detection

4 boards / crate, total 1744



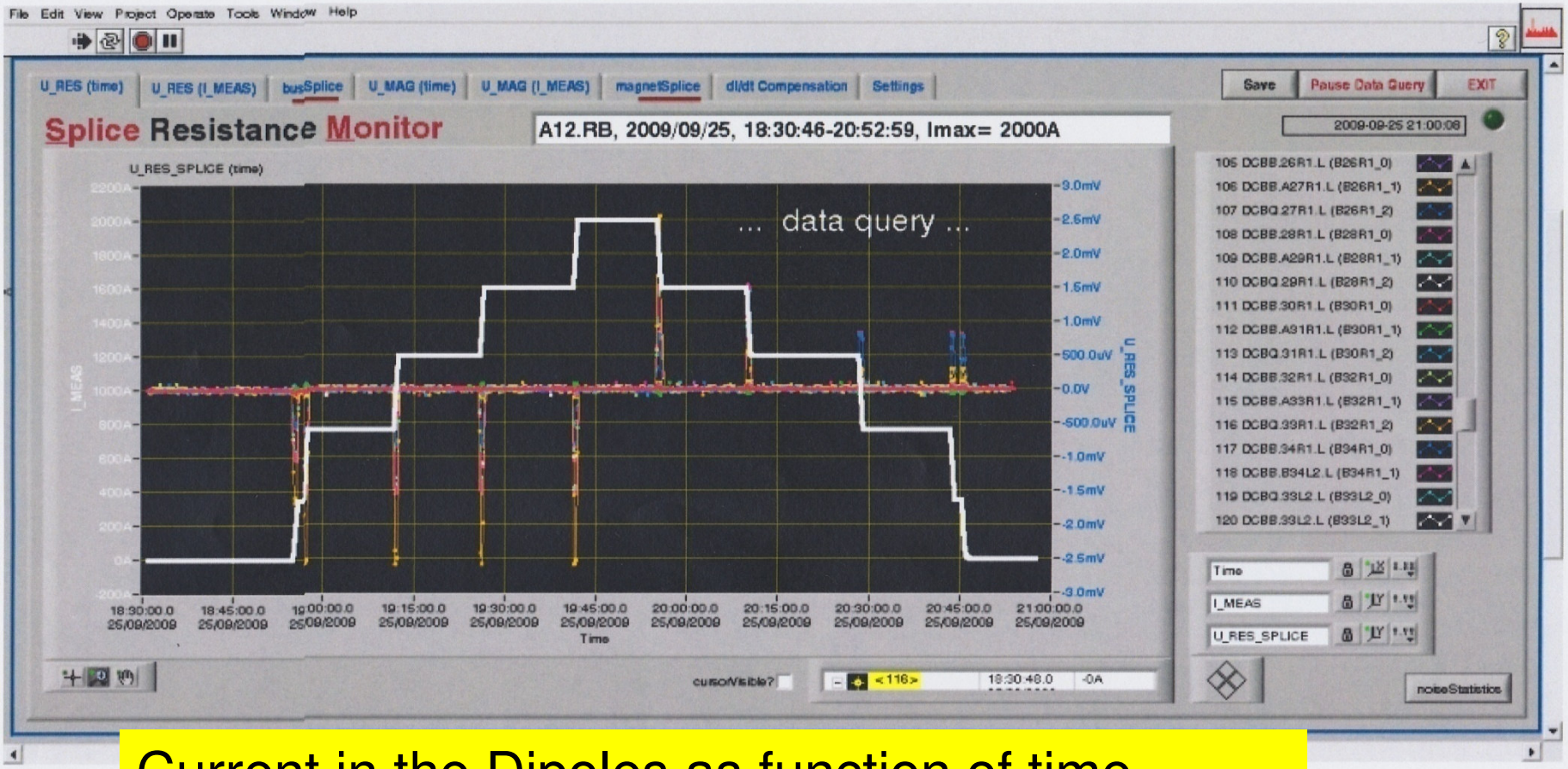


Original racks

'Internal' and 'external' **cables** for sensing, trigger, interlock, UPS power, uFIP (10'400 + 4'400)

2 UPS Patch Panels / rack &
1 Trigger Patch Panel / rack
total 3456 panel boxes

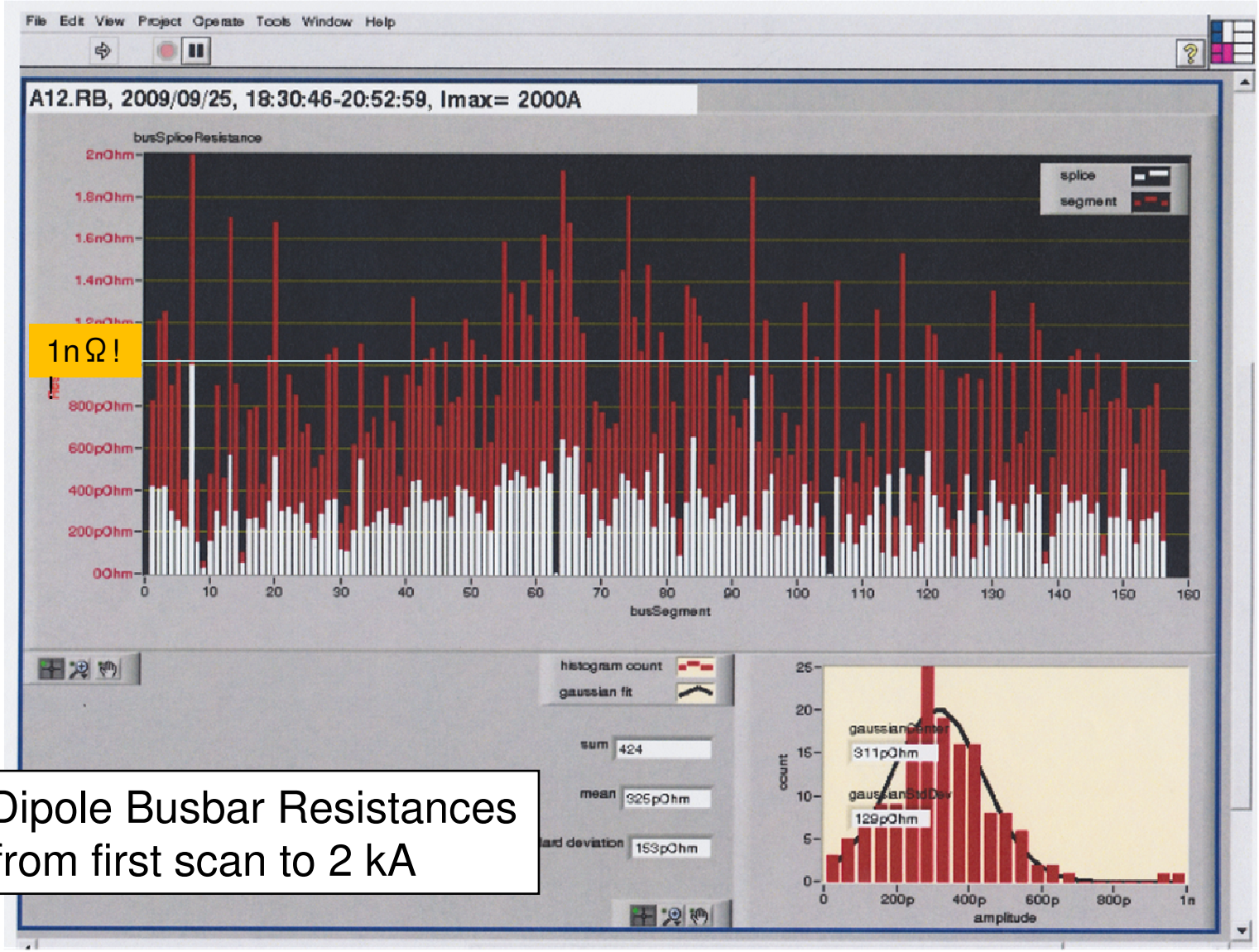
Pyramid for Splice Mapping



Current in the Dipoles as function of time

Splice Mapping of Dipoles

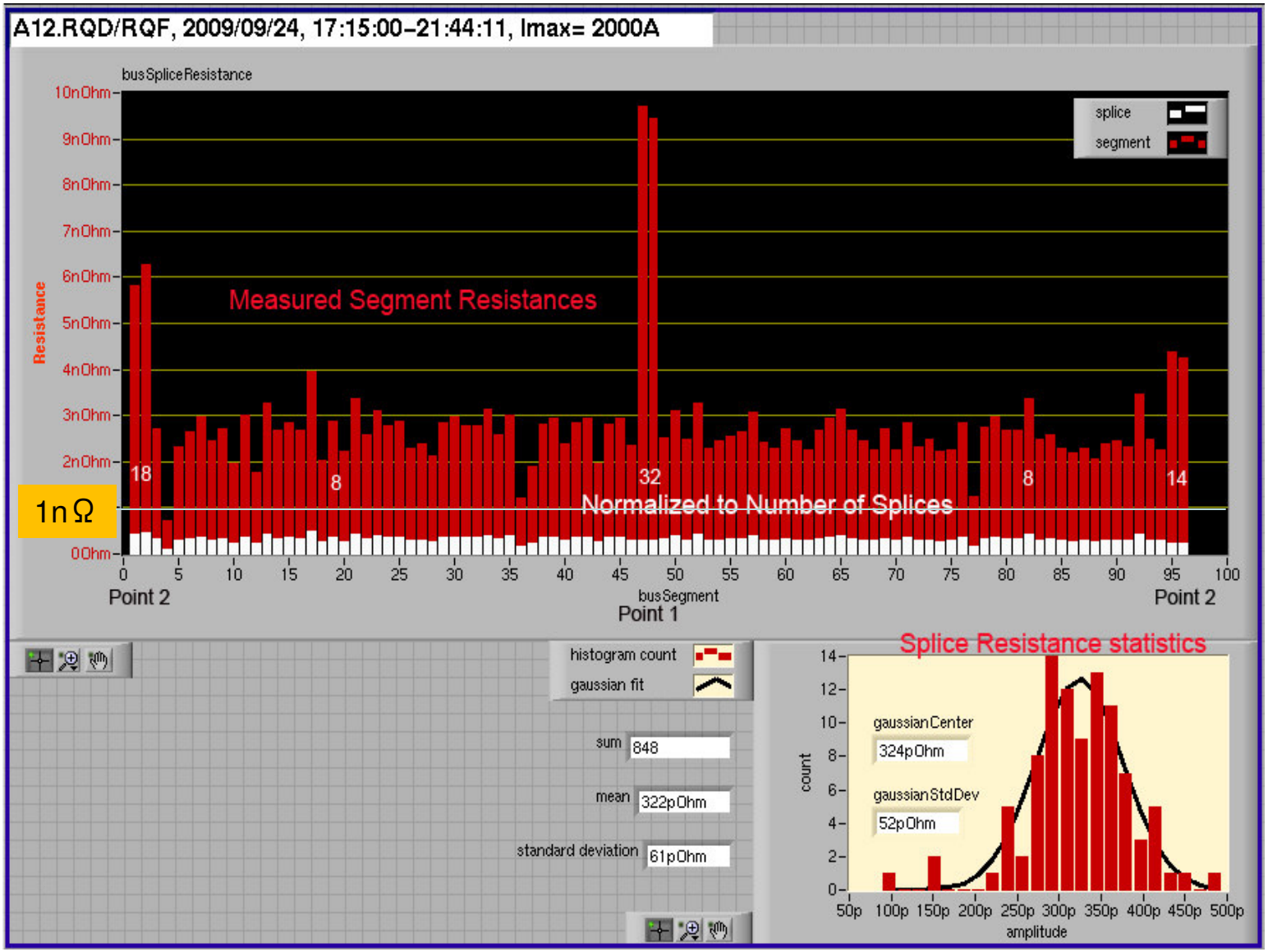
QPS team

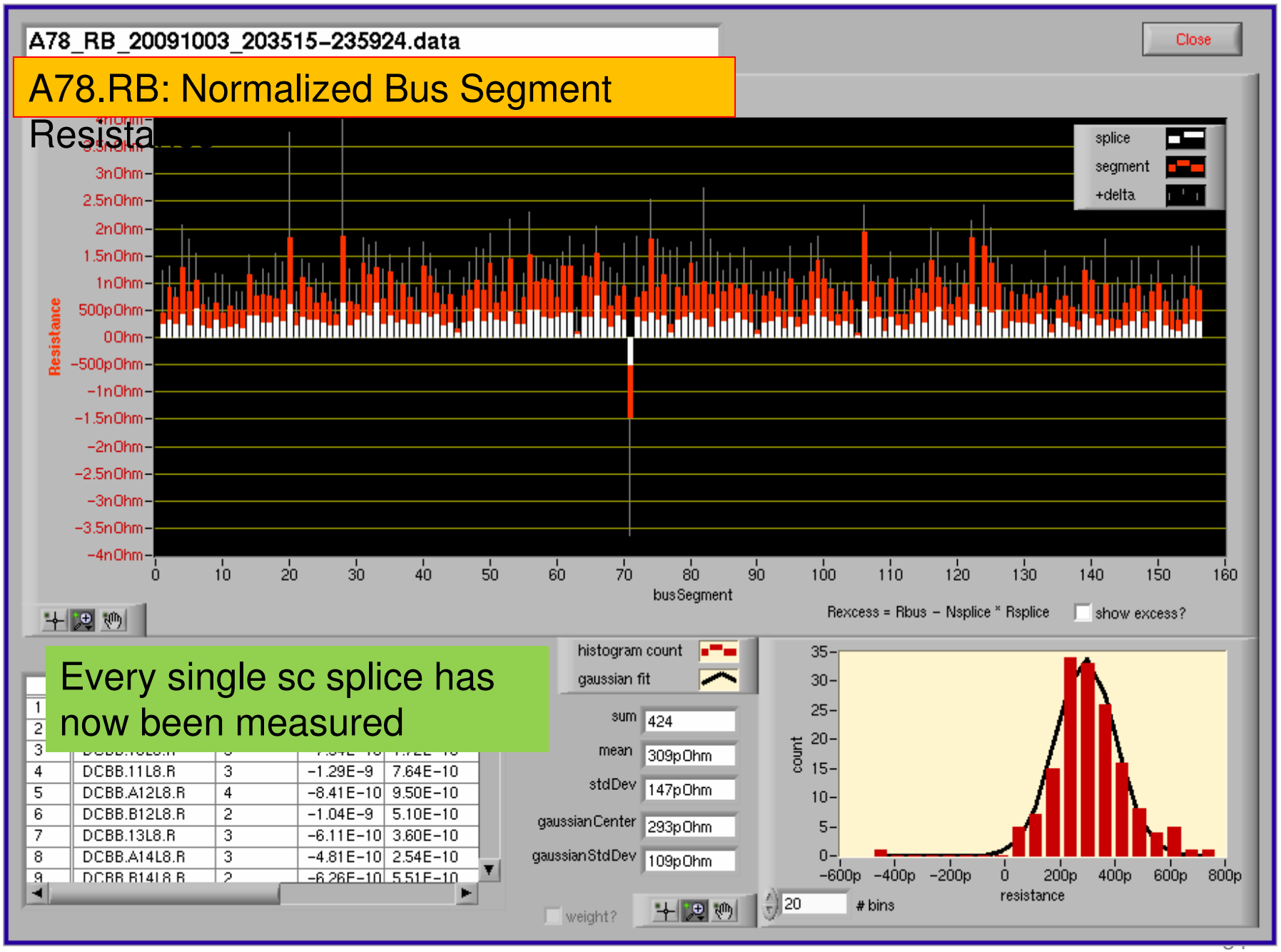


First Dipole Busbar Resistances from first scan to 2 kA

Splice Mapping of Quadrupoles

QPS team




A78_RB_20091003_203515-235924.data
Close
A78.RB: Normalized Bus Segment Resista
splice
segment
+delta
Resistance
busSegment
Rexcess = Rbus − Nsplice * Rsplice
show excess?
Every single sc splice has now been measured
histogram count
gaussian fit
sum 424
mean 309pOhm
stdDev 147pOhm
gaussianCenter 293pOhm
gaussianStdDev 109pOhm
weight?
count
resistance
bins
20
DCBB.11L8.R 3 -1.29E-9 7.64E-10
DCBB.A12L8.R 4 -8.41E-10 9.50E-10
DCBB.B12L8.R 2 -1.04E-9 5.10E-10
DCBB.13L8.R 3 -6.11E-10 3.60E-10
DCBB.A14L8.R 3 -4.81E-10 2.54E-10

LHC: a spectacular comeback!

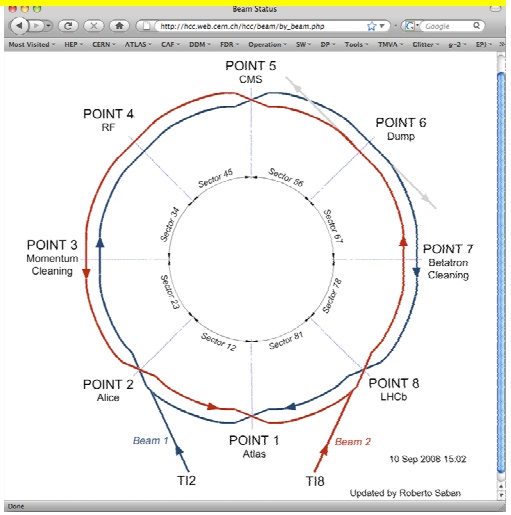
Friday November 20

18:30 Beam 1

- 19.00 beam through CMS (23, 34, 45)
  - beam1 through to IP6 19.55 Starting again injection of Beam1
  - corrected beam to IP6, 7, 8, 1

2h10 for 27km: 12.5km/h average speed

- 20.40 Beam 1 makes 2 turns
  - Working on tune measurement, orbit, dump and RF
  - Beam makes several hundred turns (not captured)
    - Integers 64 59, fractional around .3 (Qv trimmed up .1)
- 20.50 Beam 1 on beam dump at point 6
- 21.50 Beam 1 captured



22:15 Beam2

- 23.10 Start threading Beam2
  - Round to 7 6 5 2 1

1h25 for 27km: a bit faster

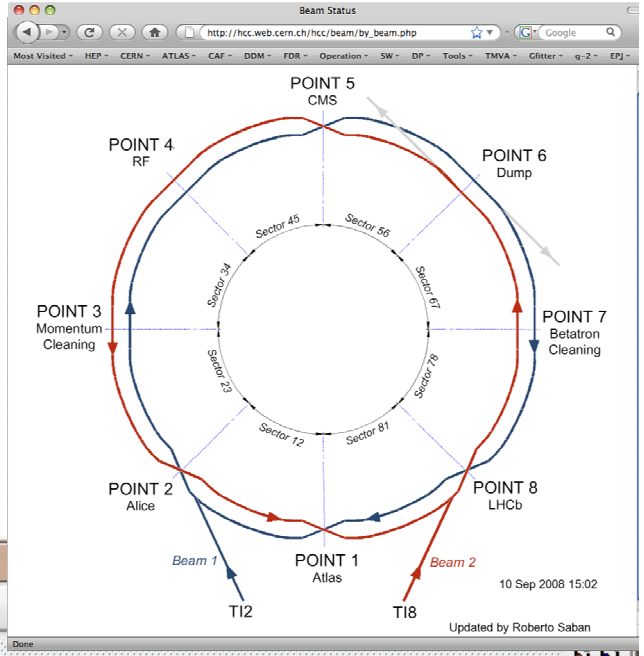
- 23.40 First Turn Beam2
  - Working on tune measurement, orbit, dump and RF
  - Beam makes several hundred turns (not captured)
    - Integers 64 59, fractional around .3 (Qv trimmed up .05)
- 24.10 Beam 2 captured

Beam threading

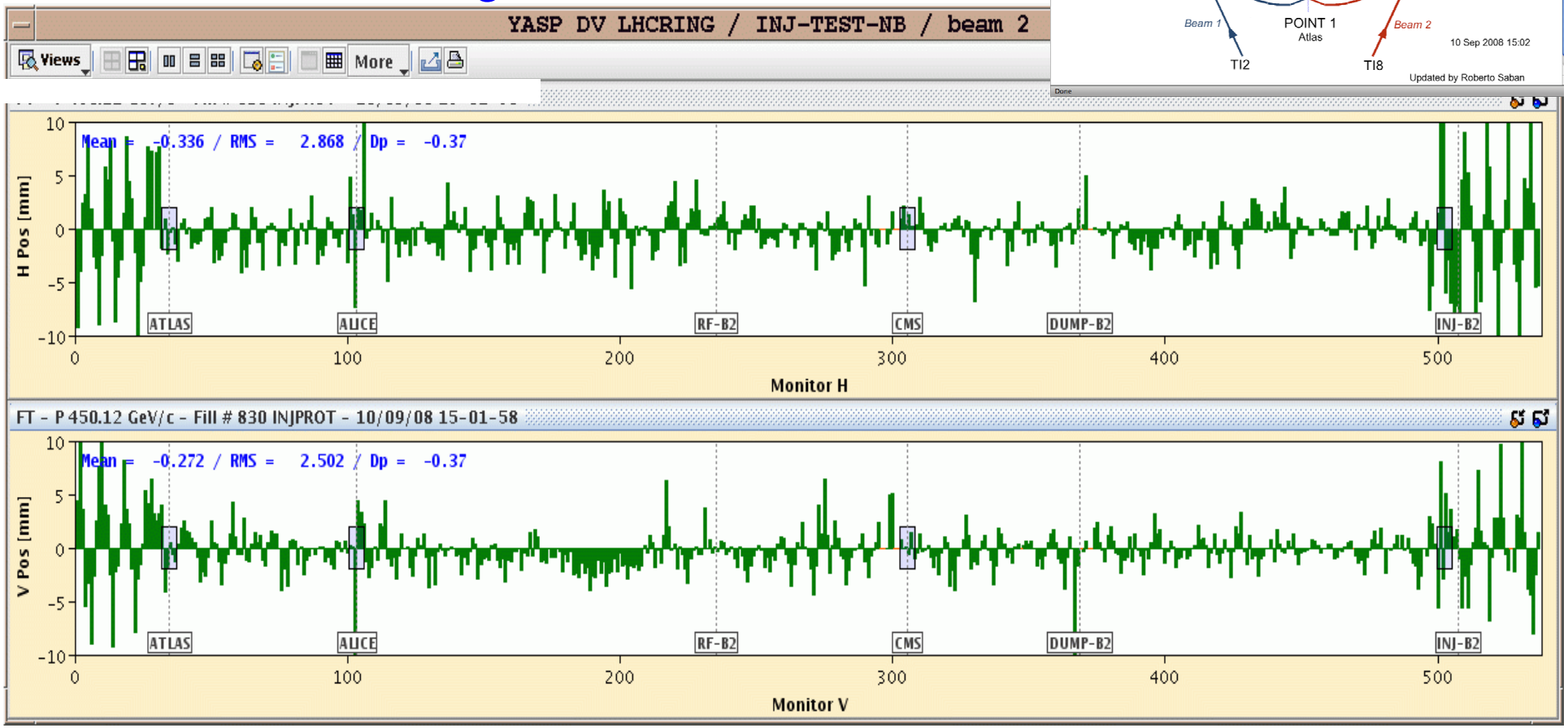
Threading by sector:

- One beam at the time
- Beam through 1 sector (1/8 ring),

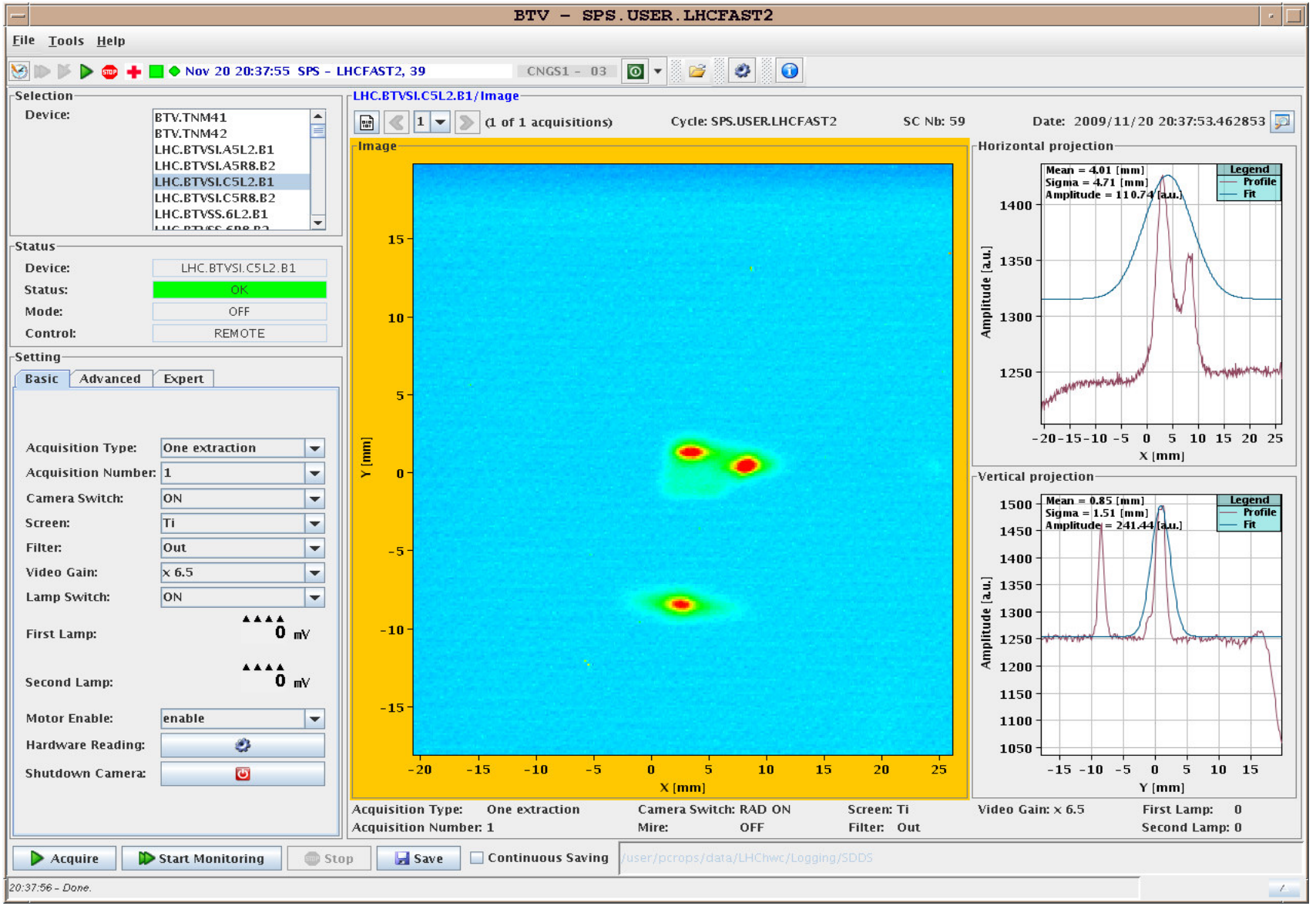
correct trajectory, open collimator and move on.

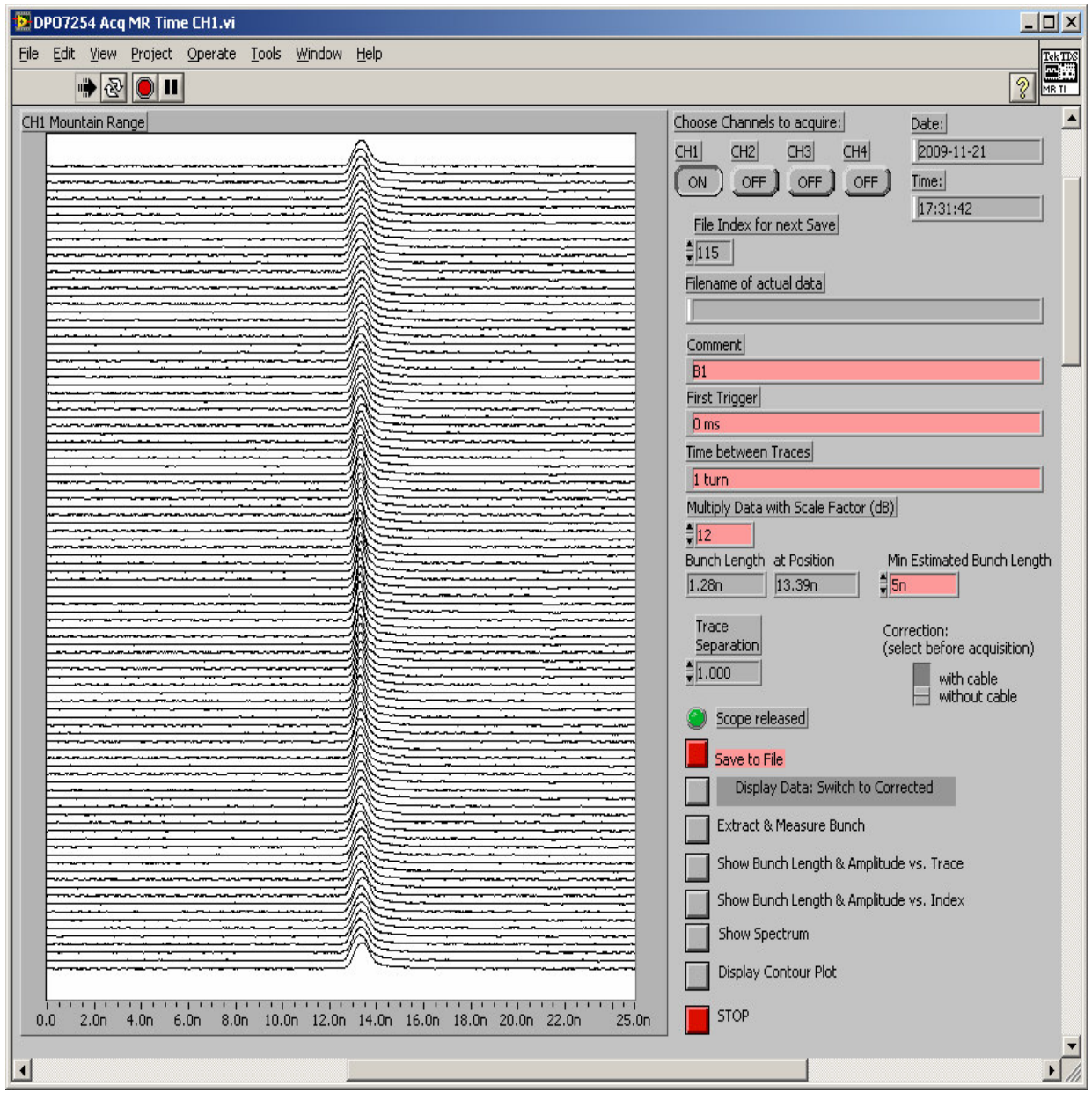


Beam 2 threading



Friday: 8:15pm: Beam 1 First 2 turns

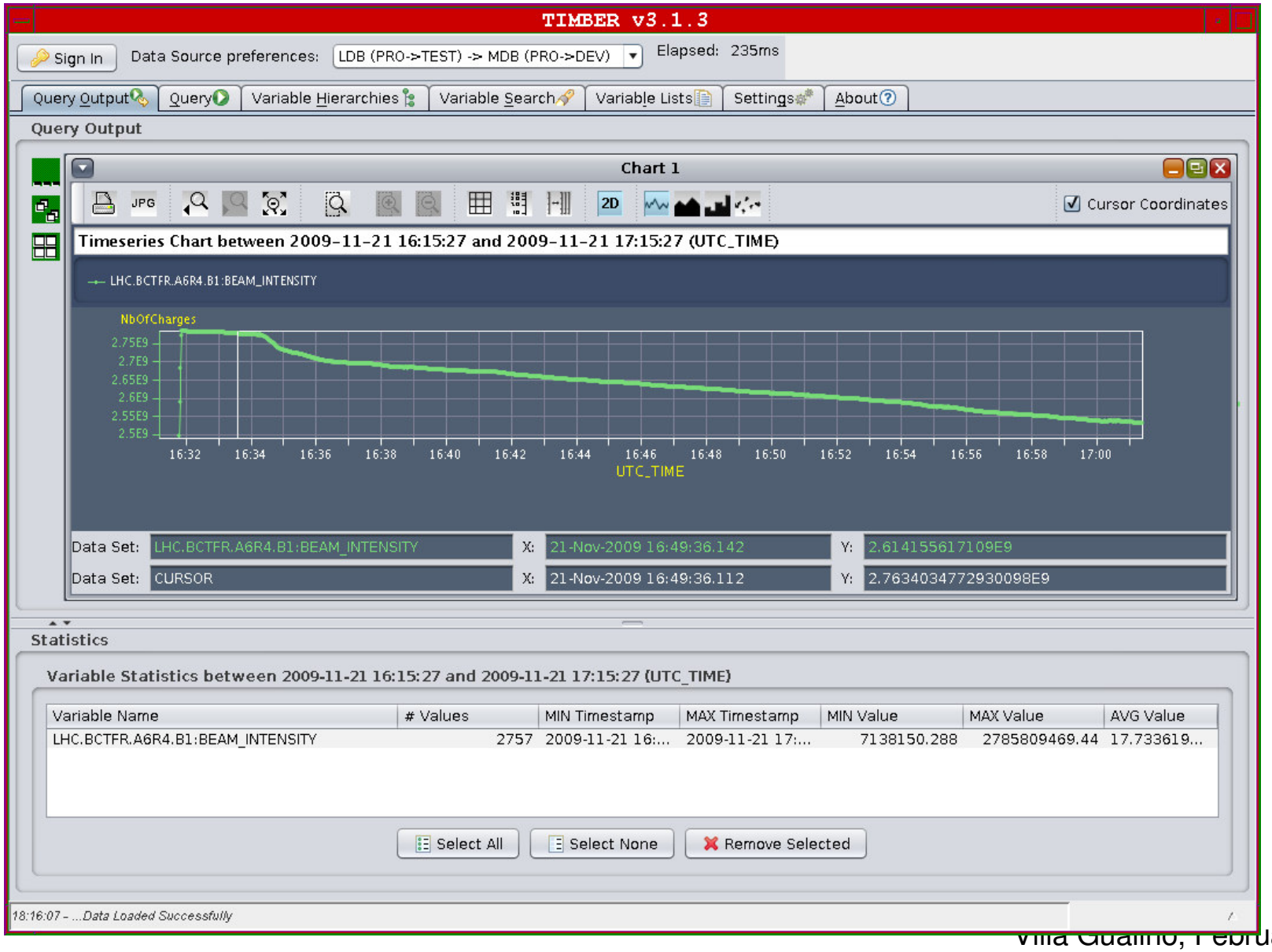




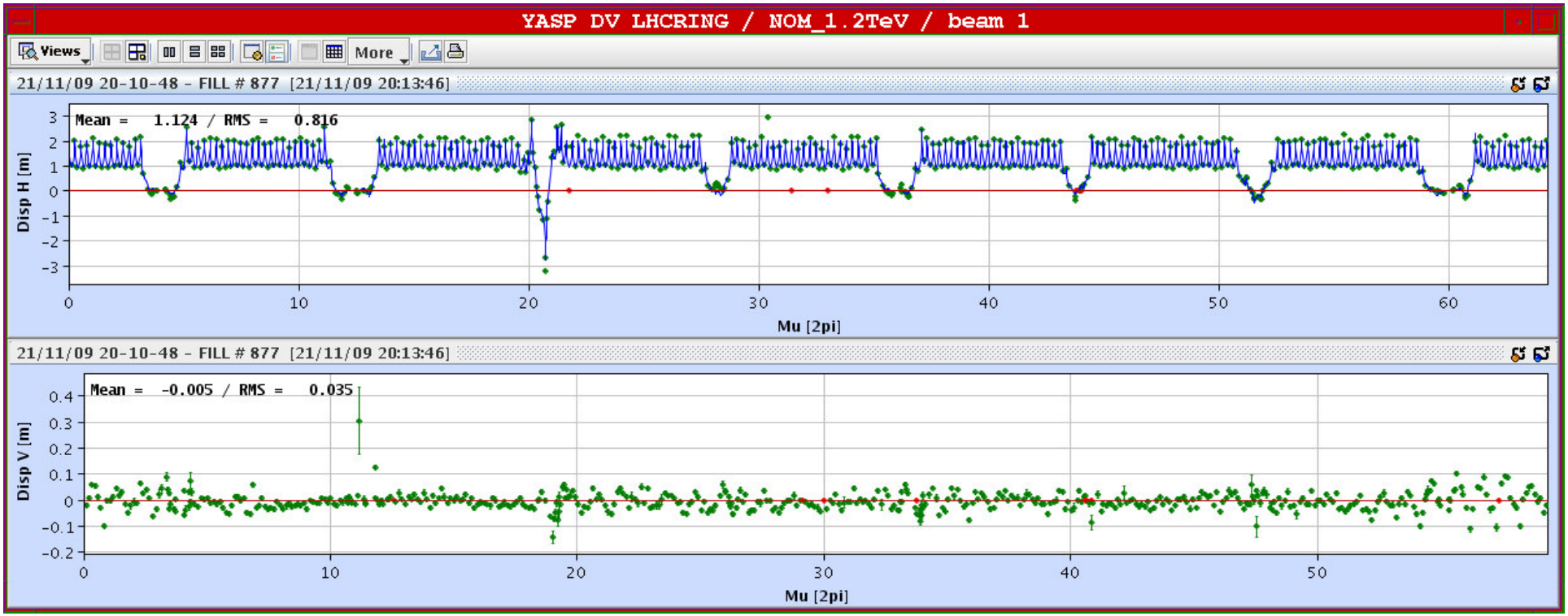
Beam is circulating and stable

- magnets
- power supplies
- vacuum
- RF
- cryogenics
- all infrastructure
- optics
- injection

BCT – lifetime around 10h



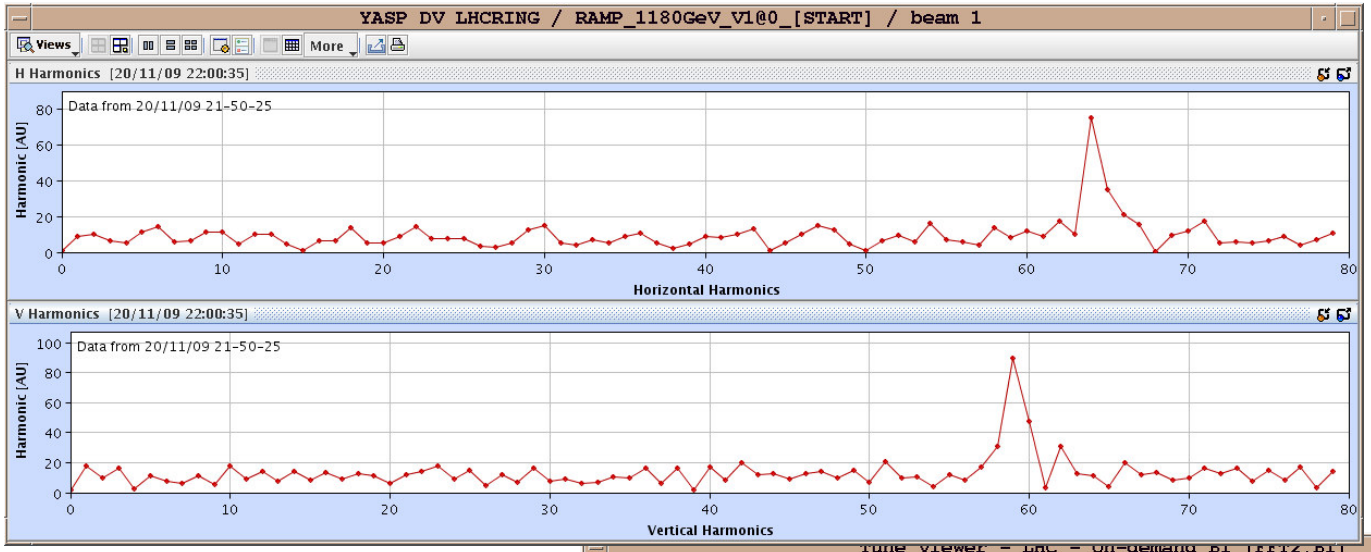
Dispersion B1



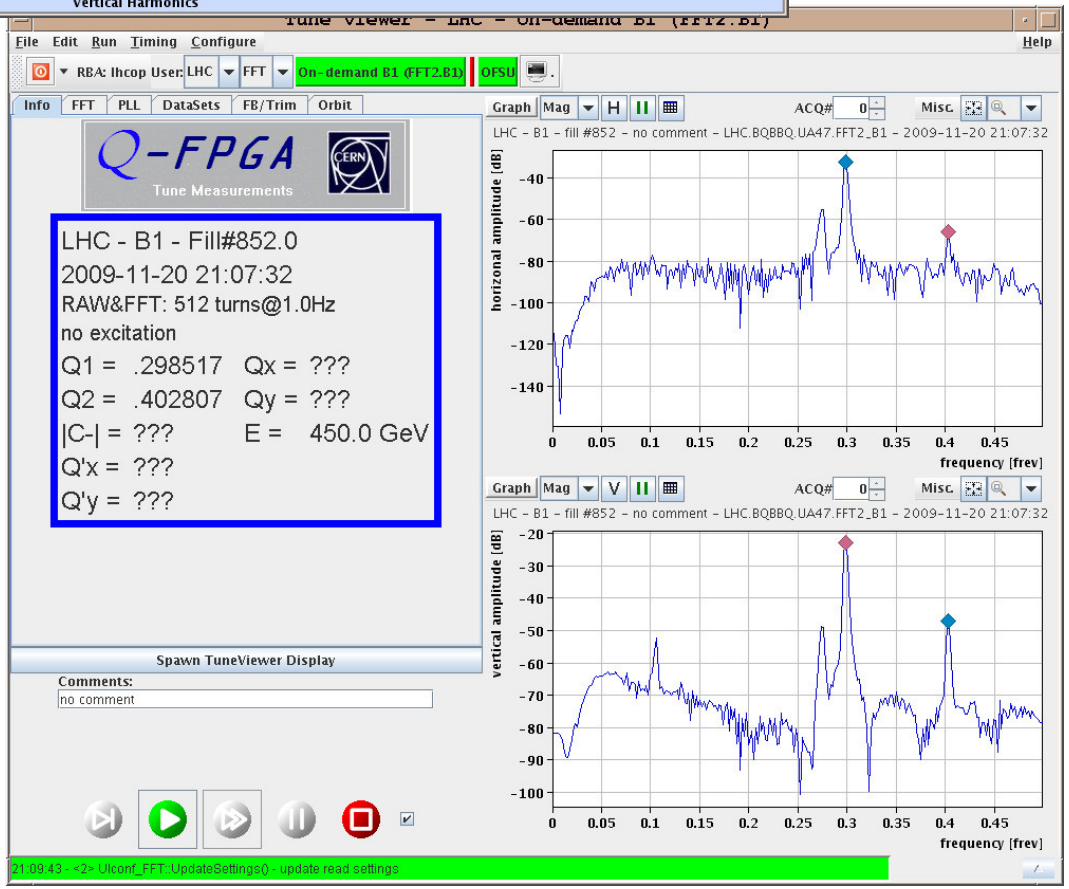
Green dots are measured: blue line calculated

Tunes

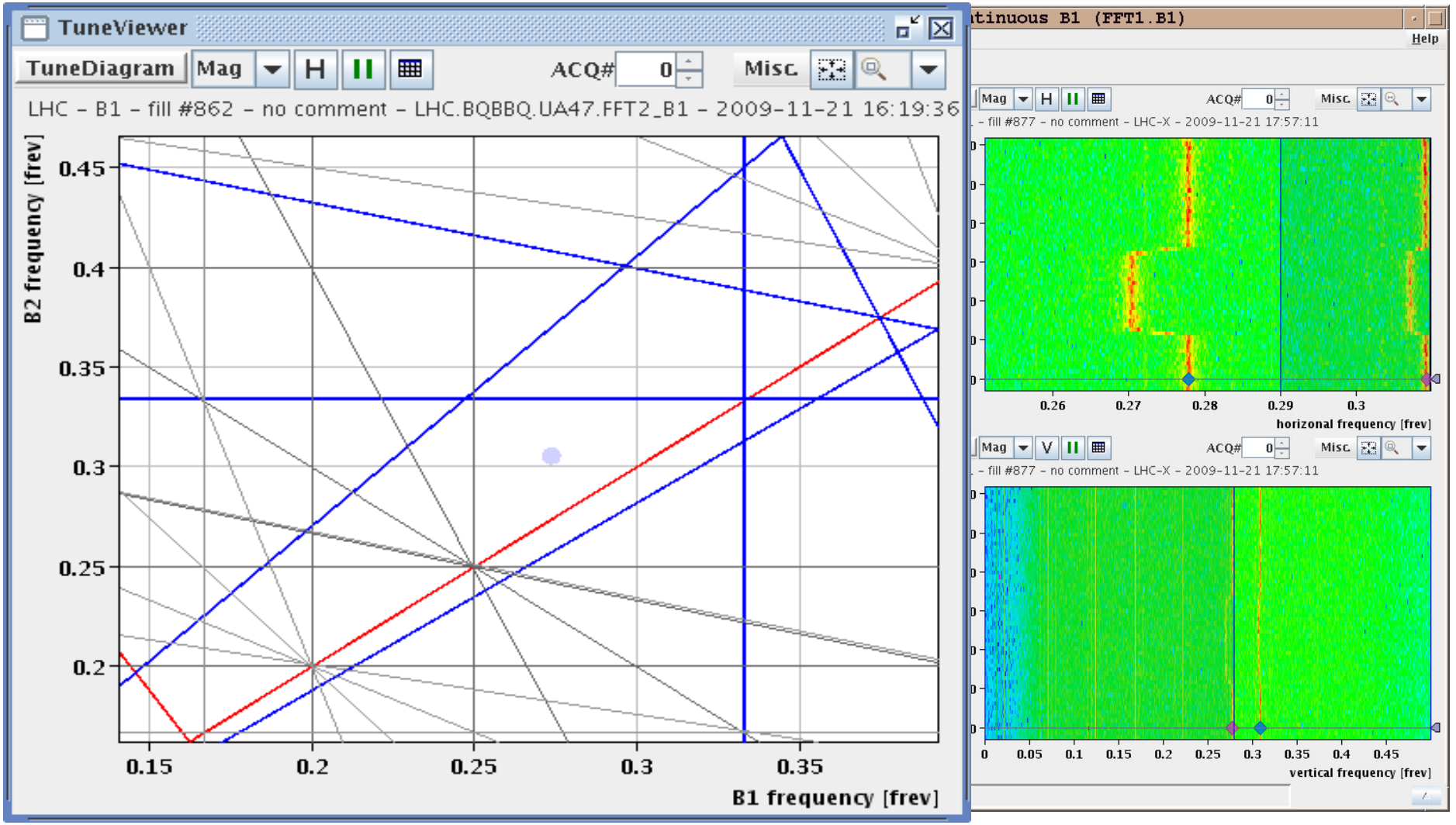
Integer



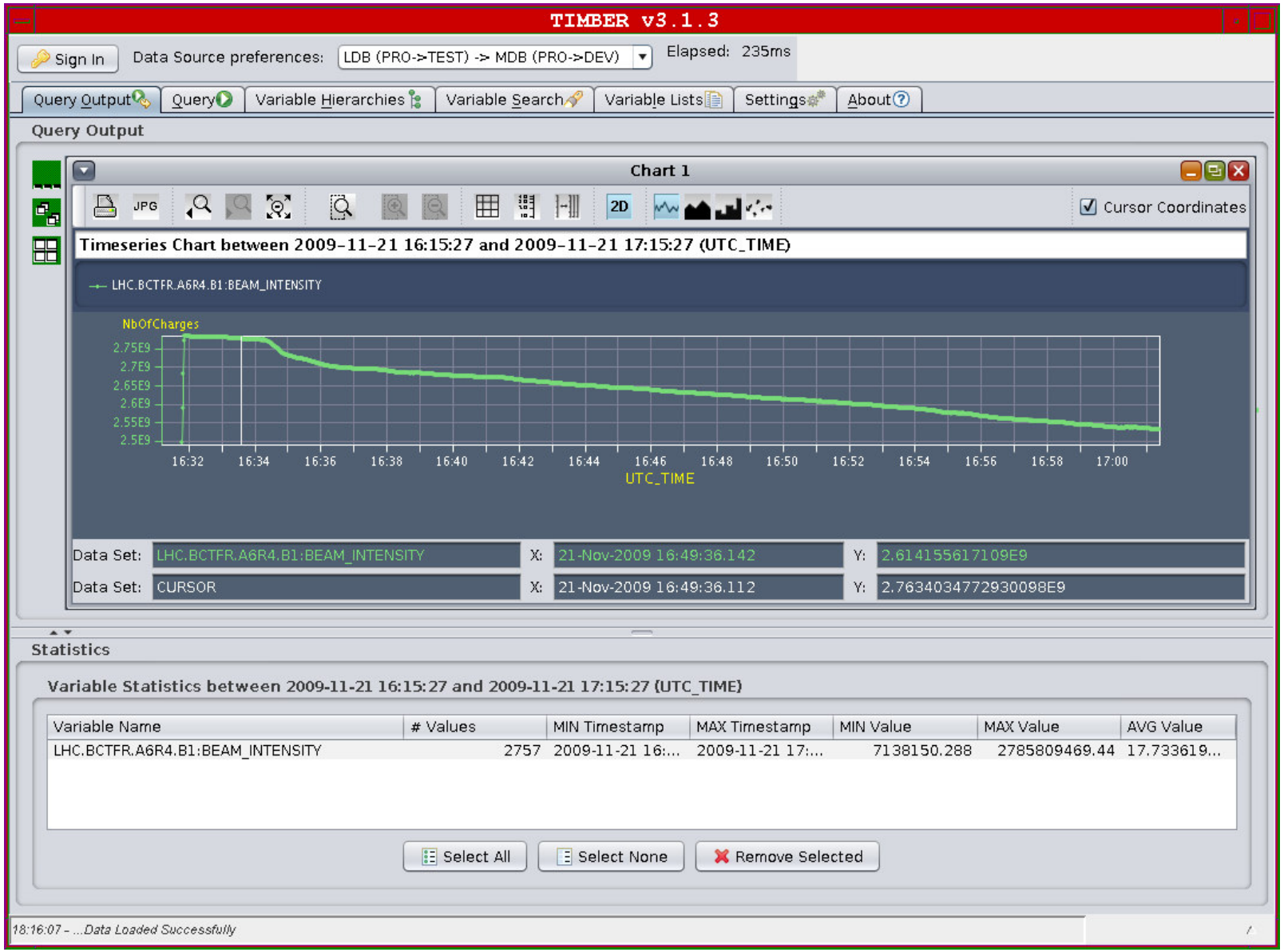
Non-Integer



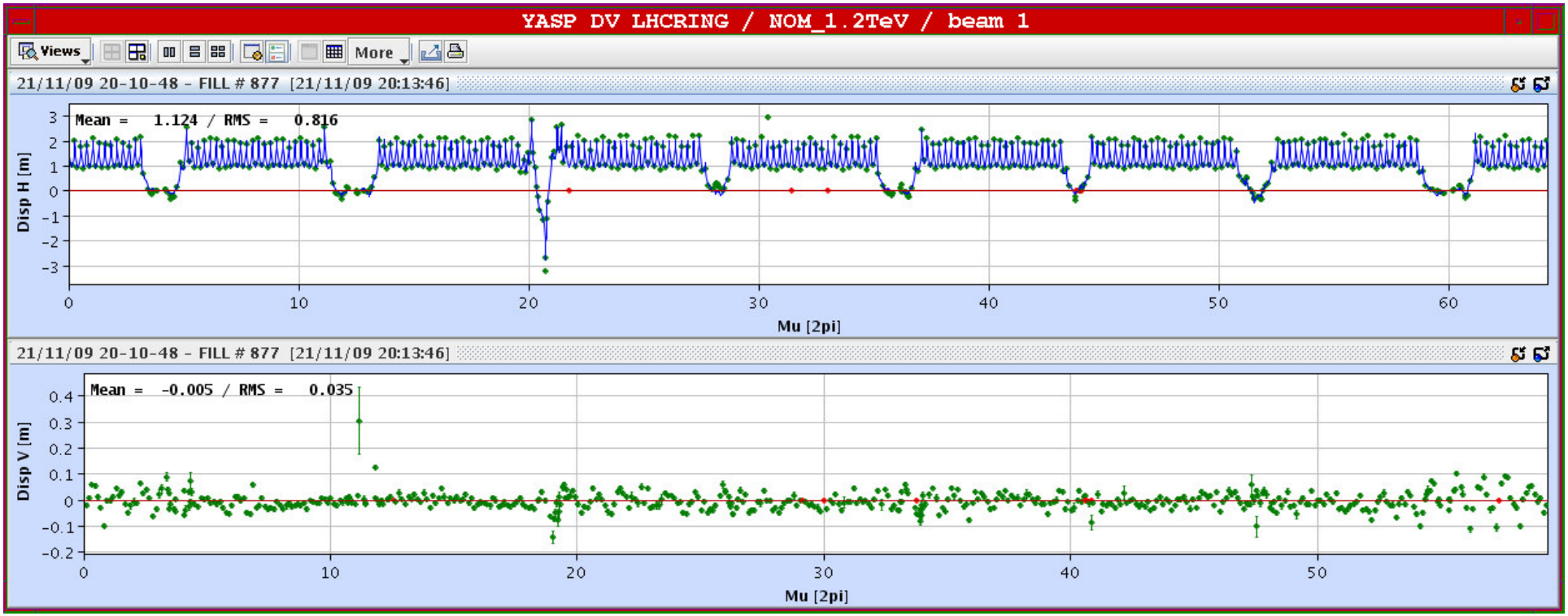
Tune measure and trim



BCT – lifetime around 10h



Dispersion B1



Green dots are measured: blue line calculated

Monday afternoon

- **Both beams circulating in LHC. Hands off by OP for half an hour.**
- Transverse Steering into collision using BPMs through 1 and 5.
- **Hands off by OP for half an hour**

- **Recorded collision events in ATLAS and CMS**

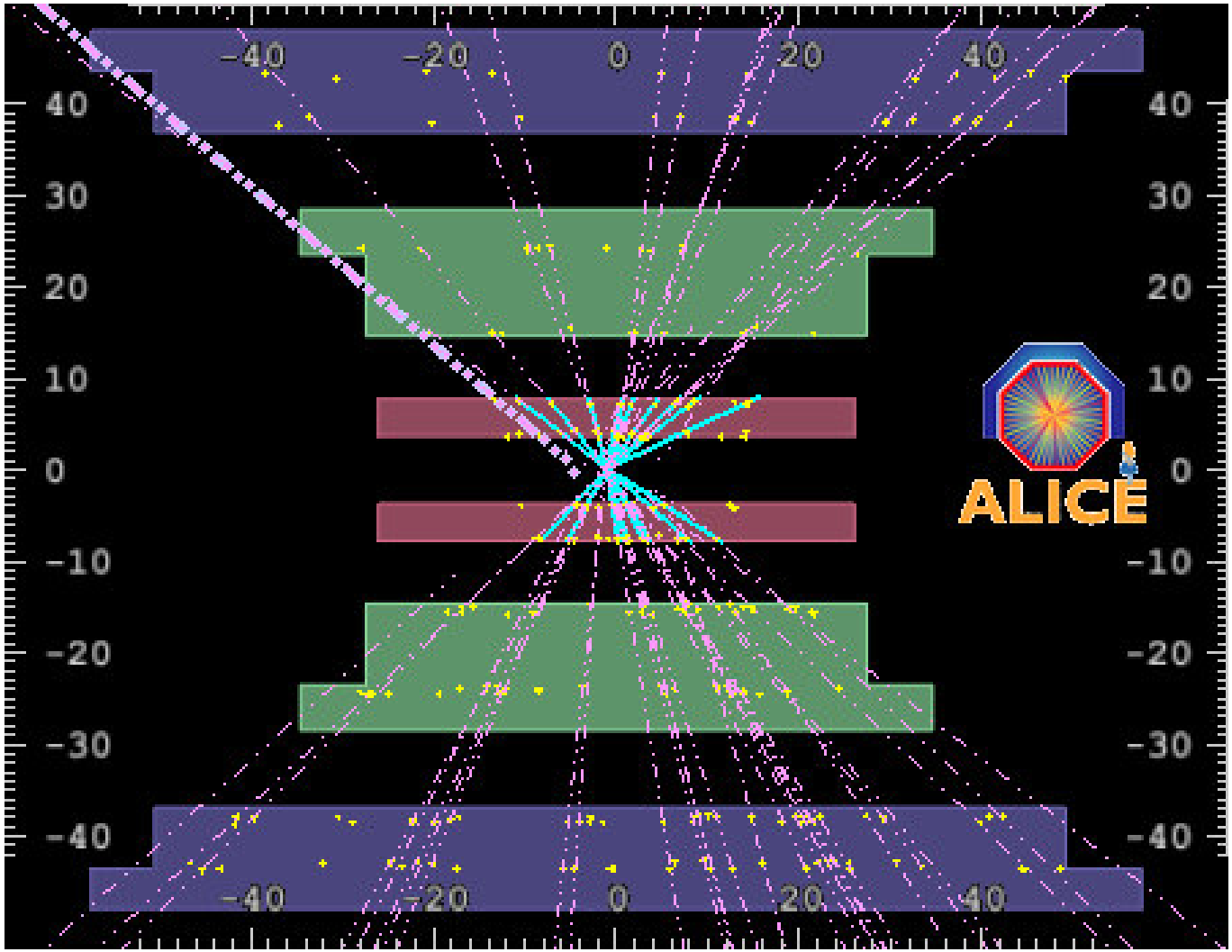
- From 16:00
  - Two beams in LHC at buckets 1 and 8911
  - **Quiet beams for ALICE**
  - Then 2 beams in LHC at buckets 1 and 26701
  - **Quiet beams for LHCb**

- **Recorded collision events in ALICE and LHCb**

- From 19.00
  - Beam 2 back in bucket 1
  - 2 beams in for collimation set up
  - Quickly steer IR5 (with new knob) and IR1
  - **Quiet beams for 15' for CMS and ATLAS**

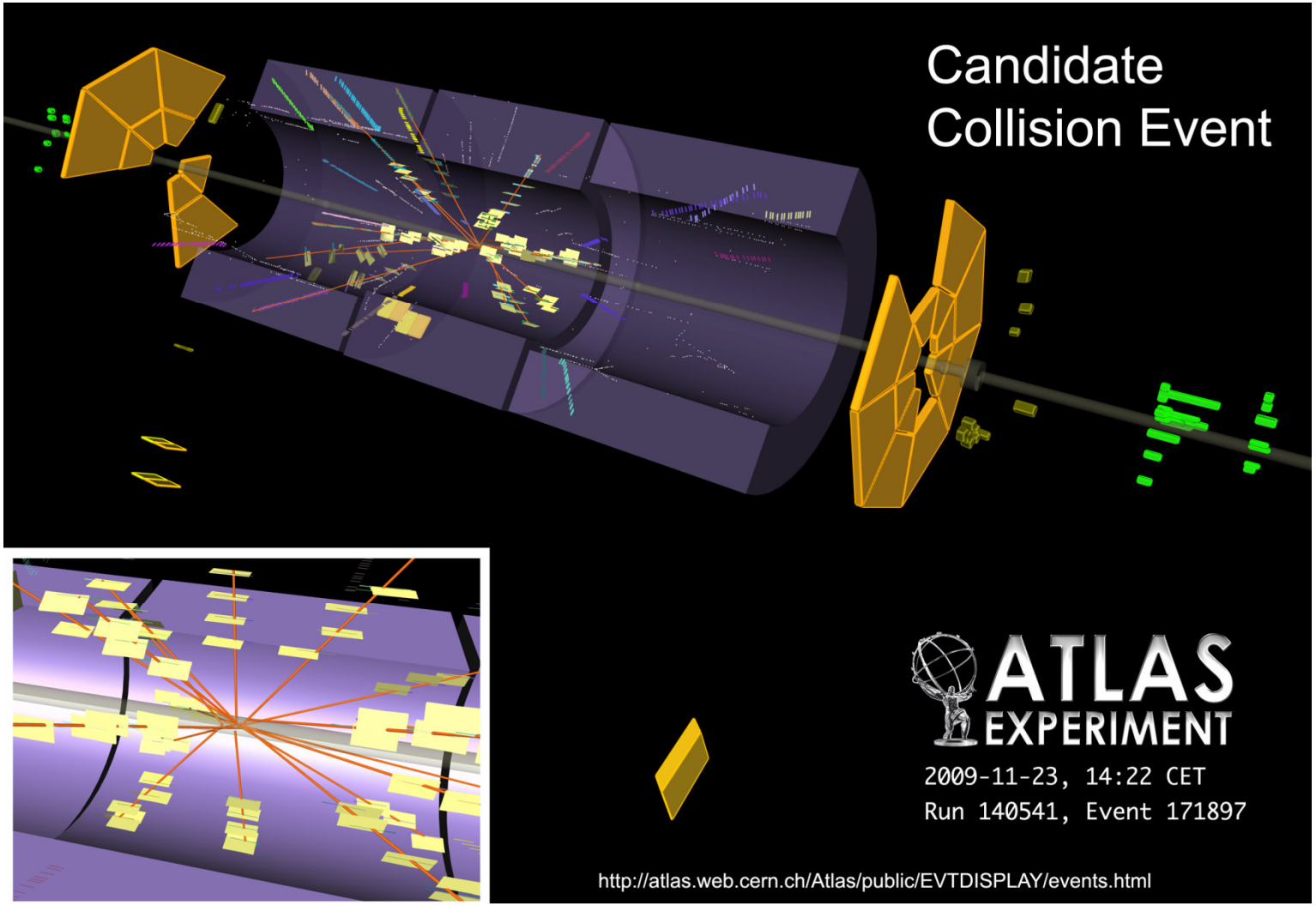
ALICE

Monday 23, Nov



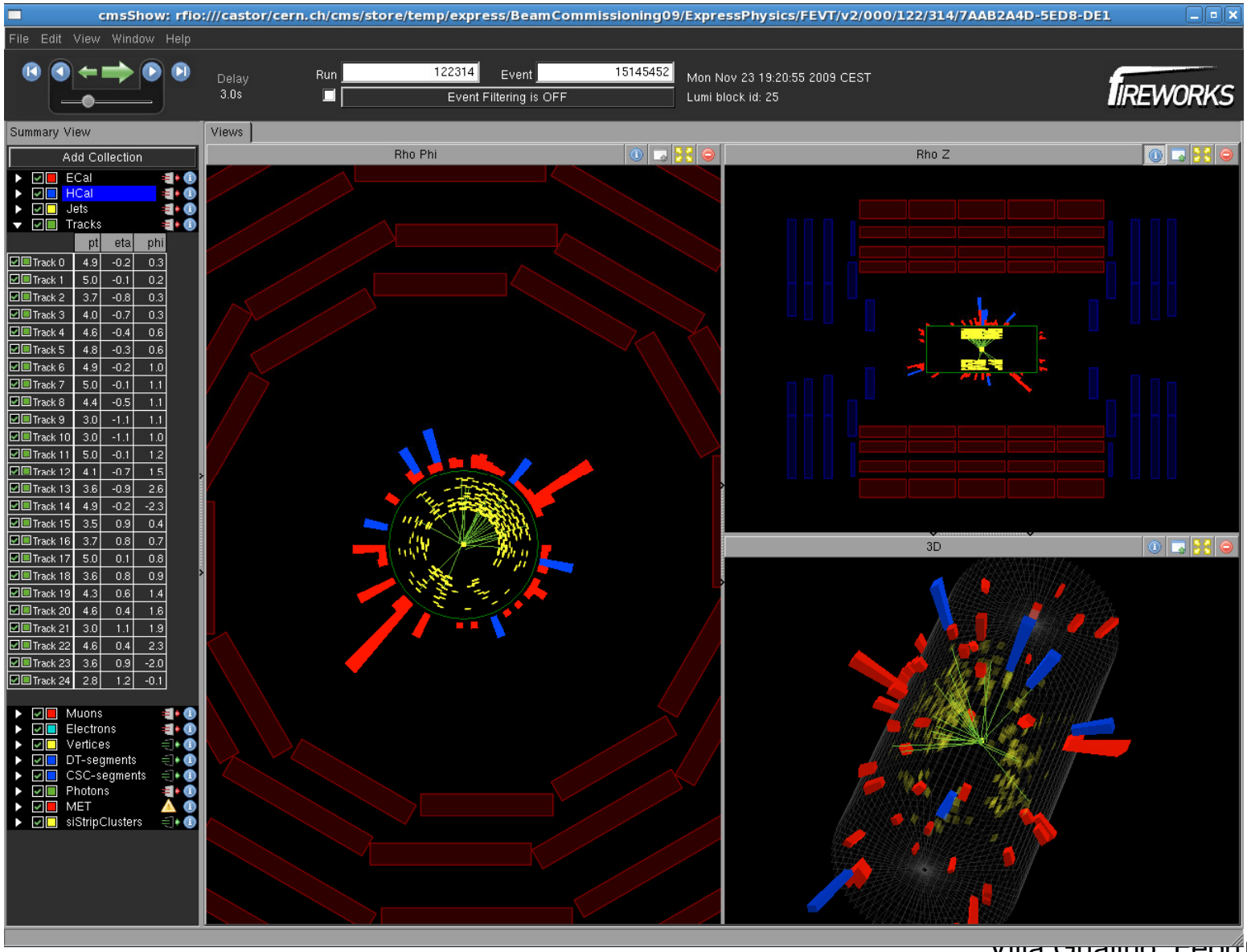
ATLAS

Monday 23, Nov



CMS

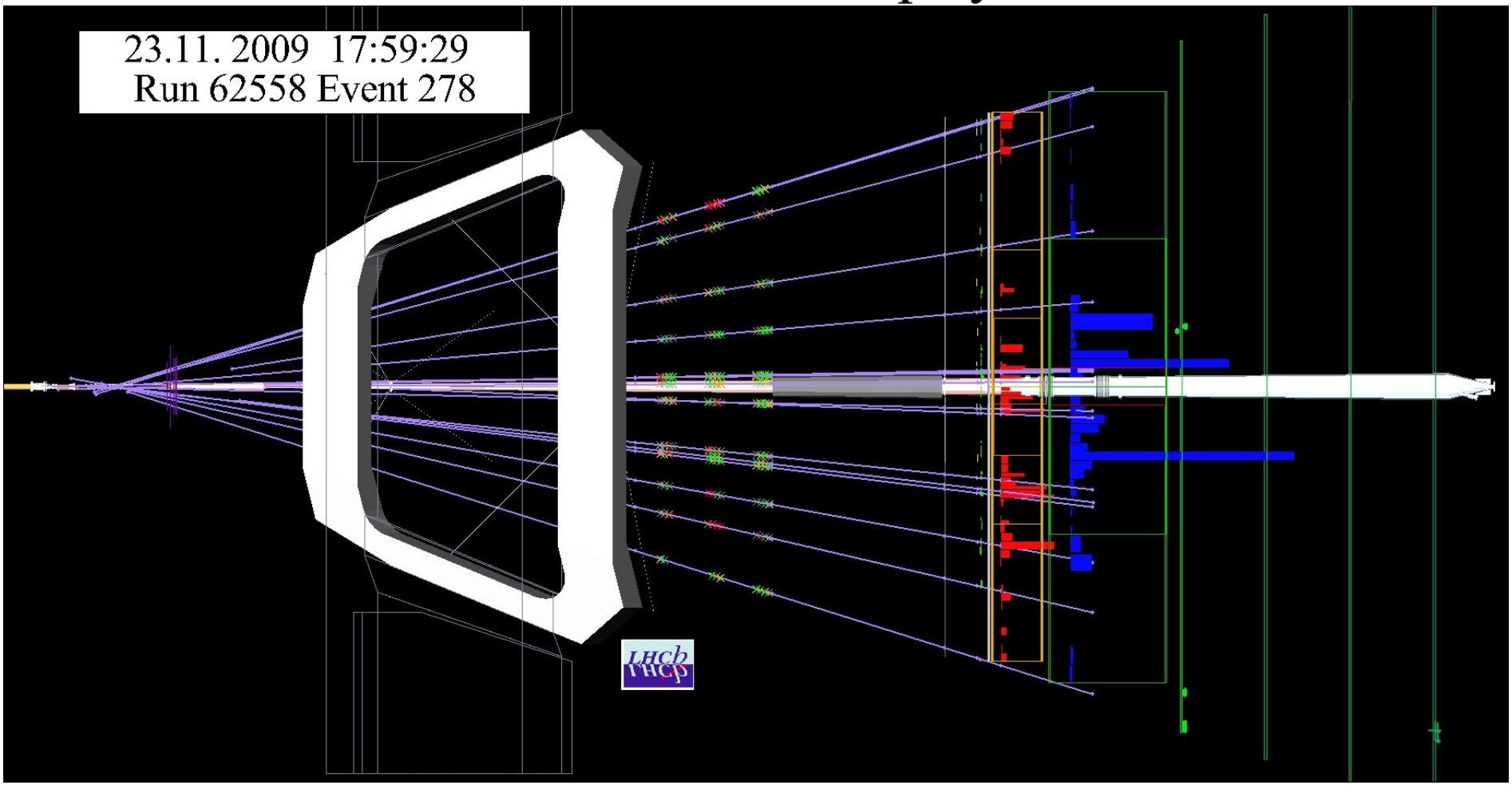
Monday 23, Nov



Monday 23, Nov

LHCb

LHCb Event Display



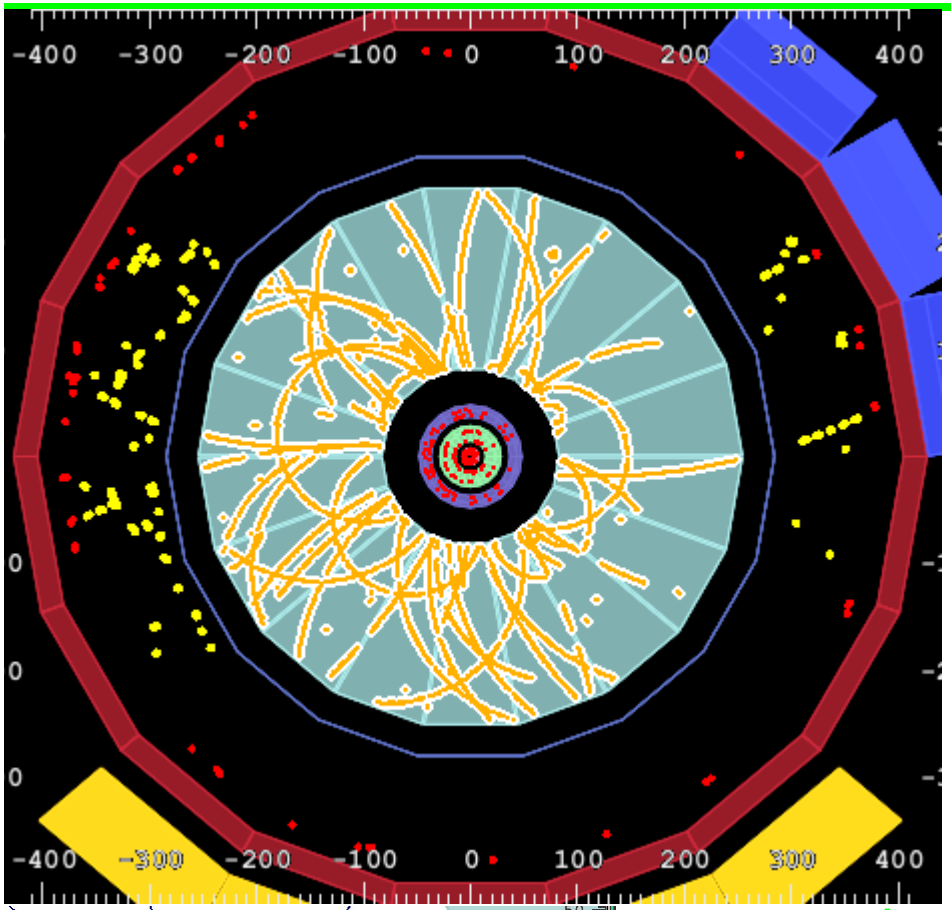
Monday November 30

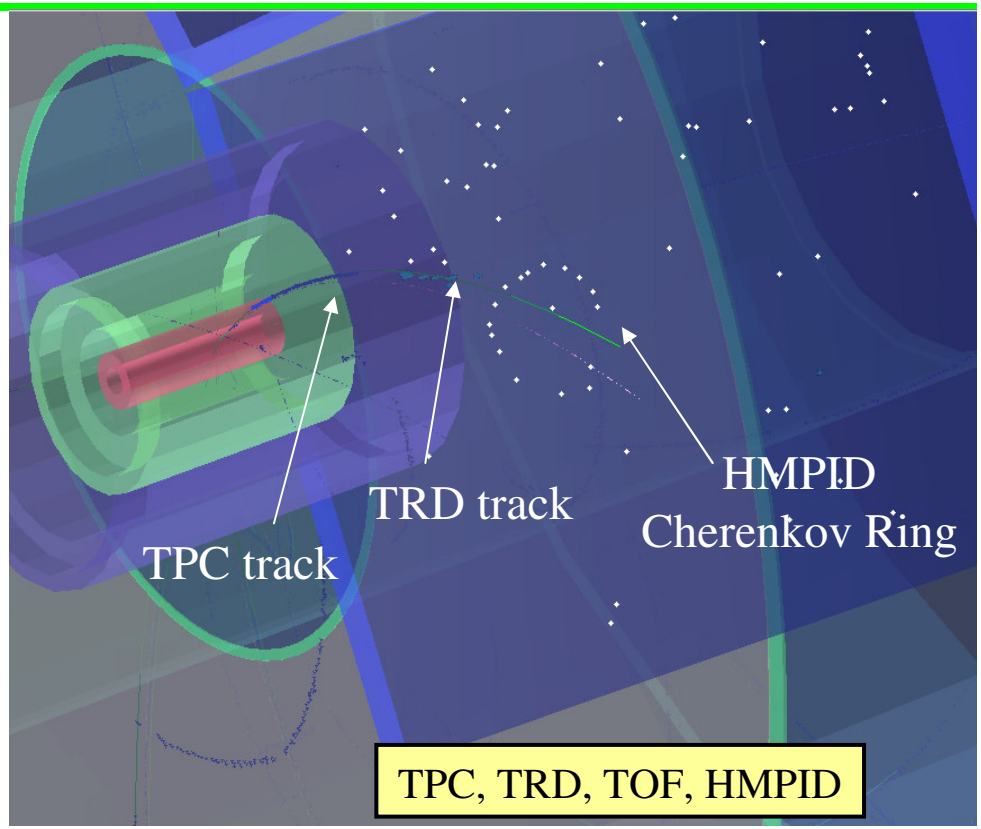
Both beams accelerated at 1.18 TeV!

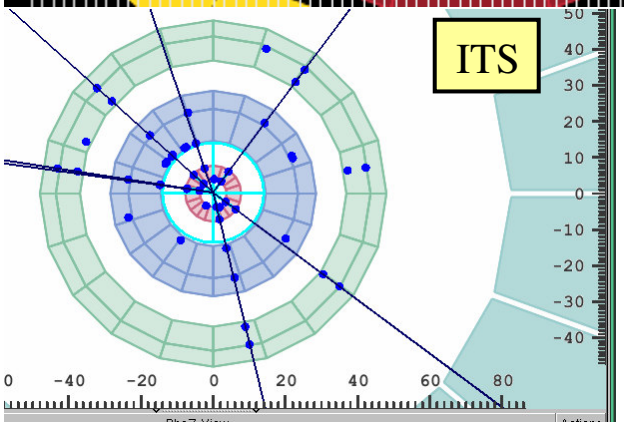
LHC experiments: a spectacular start as well!

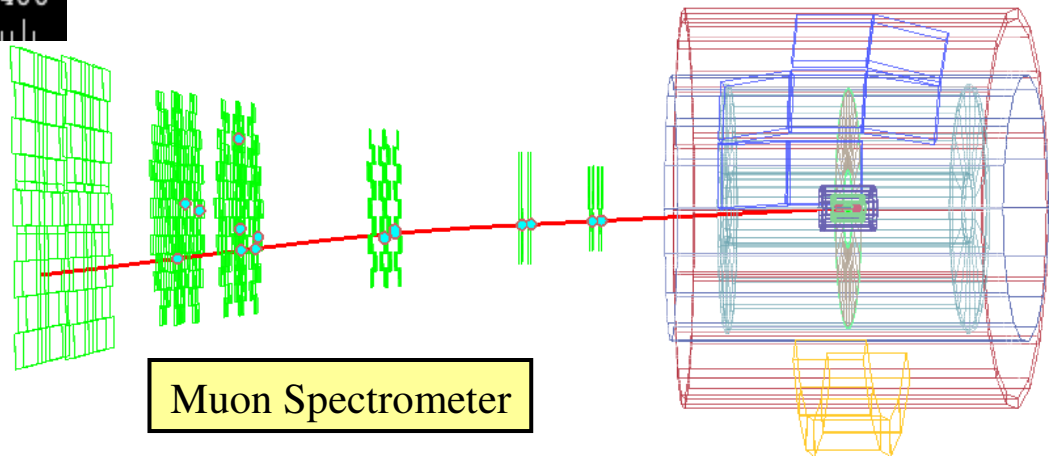
- Experiments showing their readiness
- Excellent experiment-machine interface
- Very encouraging news from the side of the backgrounds.
- Fast data turnaround times

Event Displays

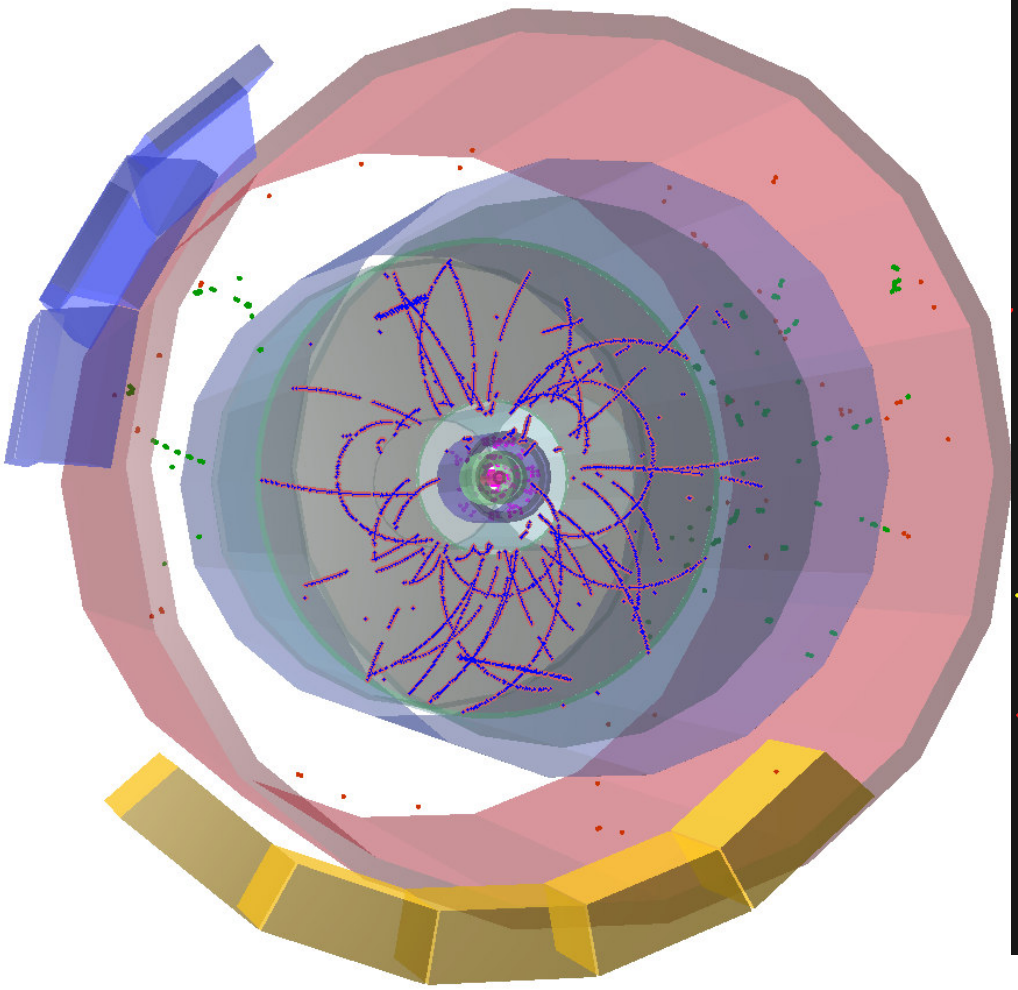


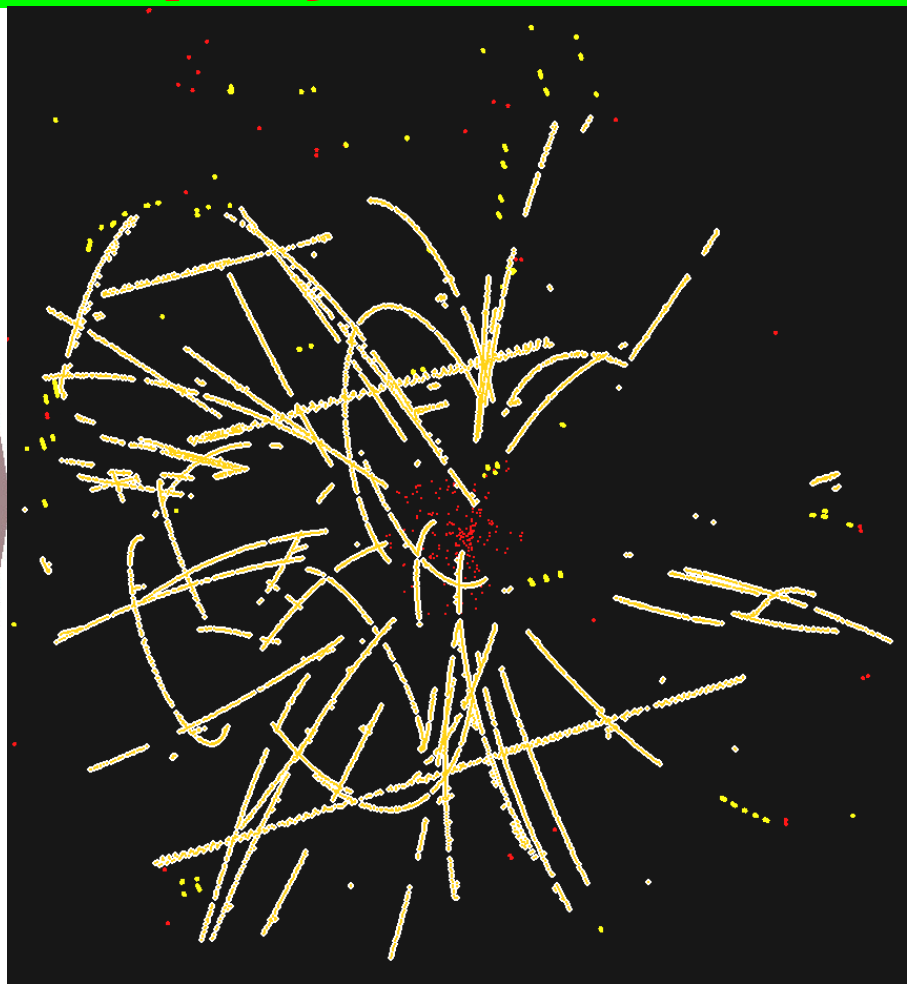




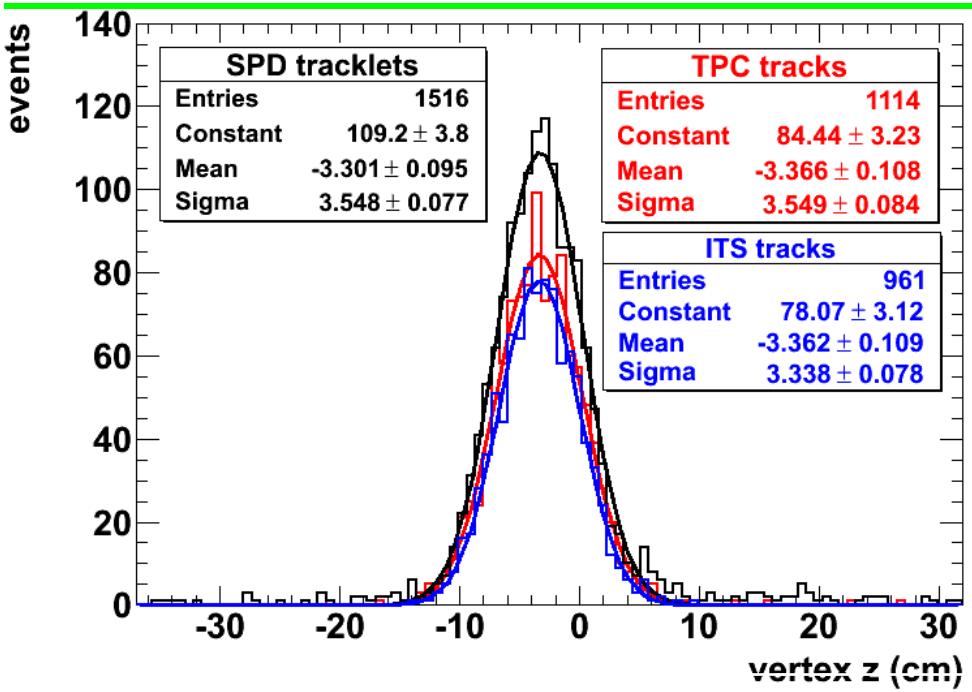


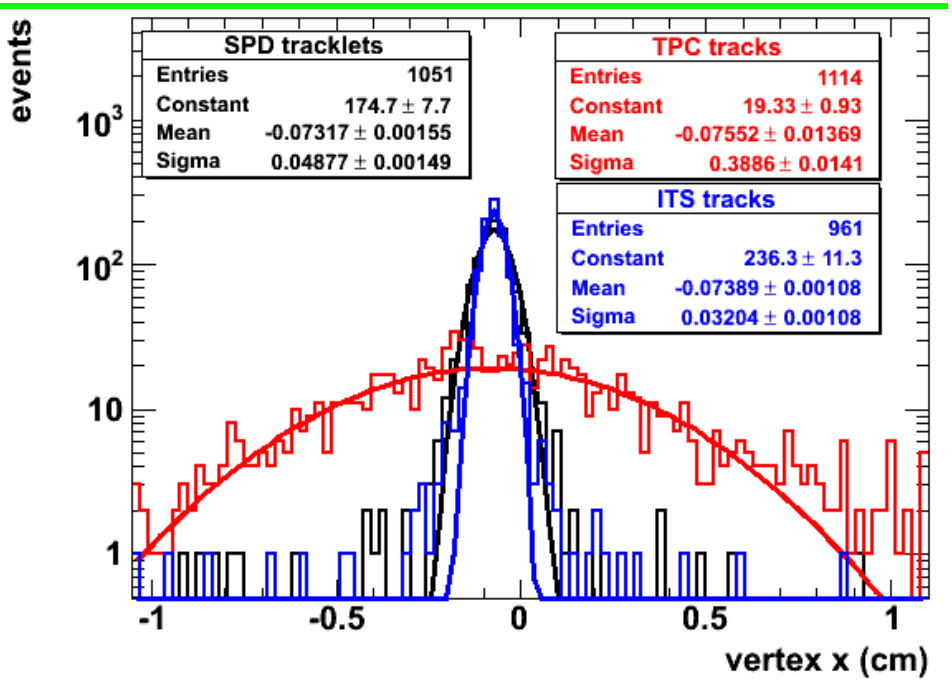
More Event Displays..



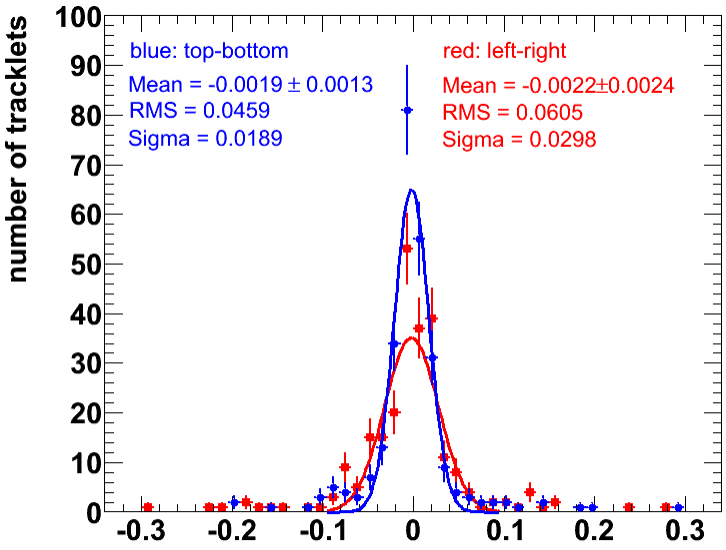


Vertex reconstruction



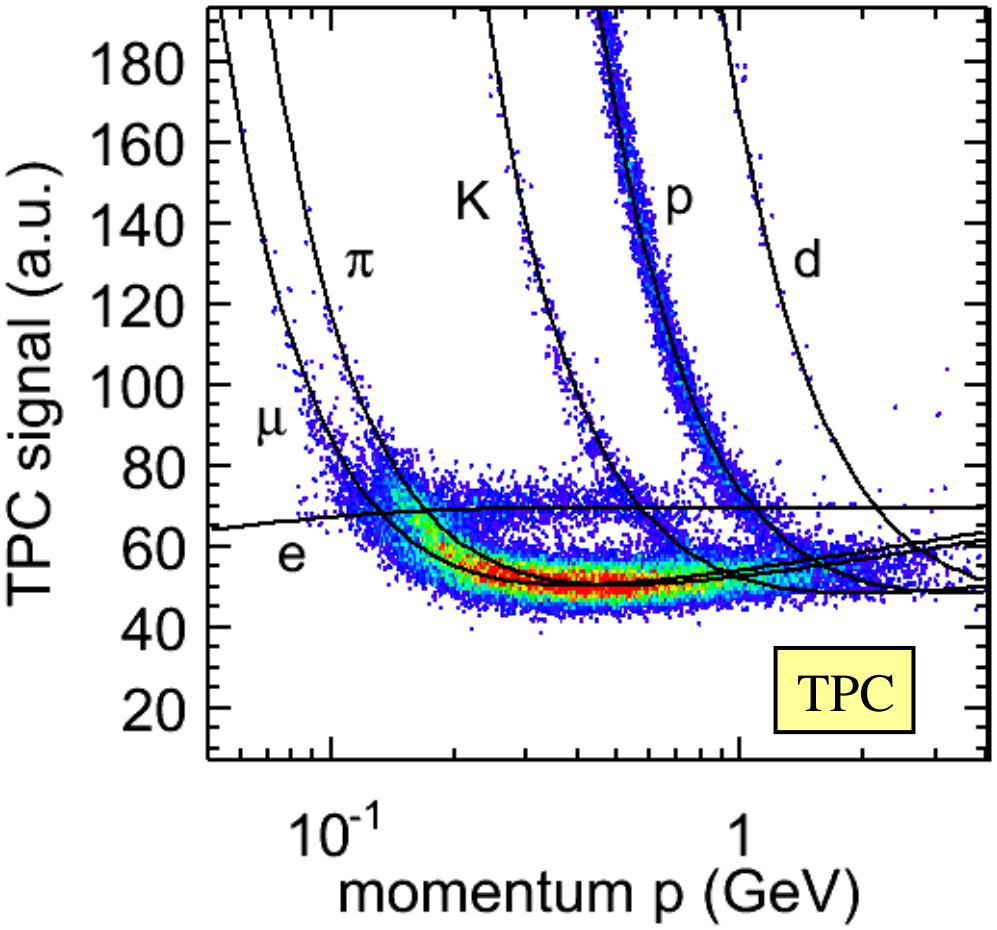


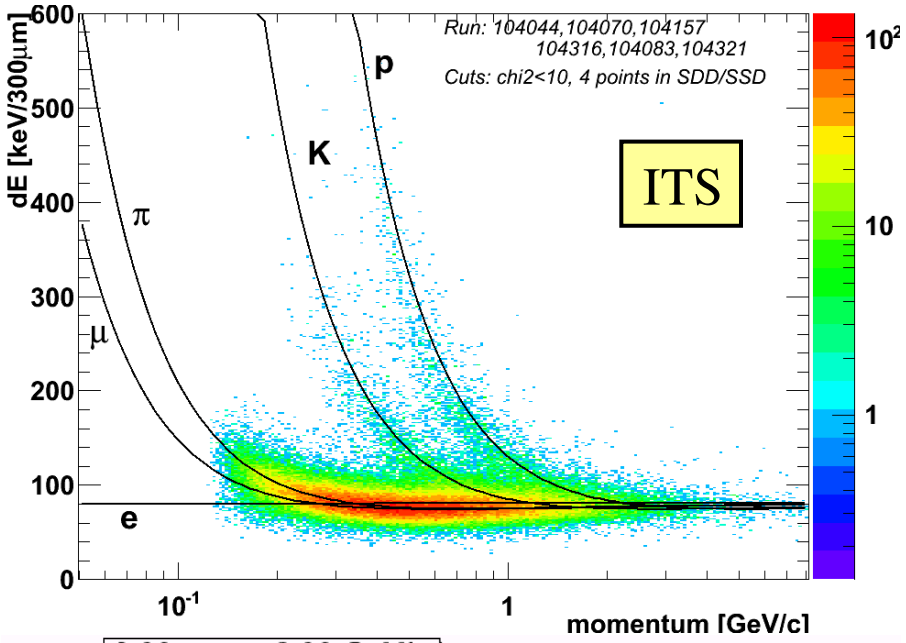
3 ways of reconstruction the vertex:
Pixels only; all ITS; TPC only.
TPC standalone resolution is of course much worse than the ITS,
but gives the same position; i.e. the relative alignment is ok.
The x resolution is for all momenta and track multiplicties; the
actual beamspot (after unfolding) is slightly less than 200 micron.

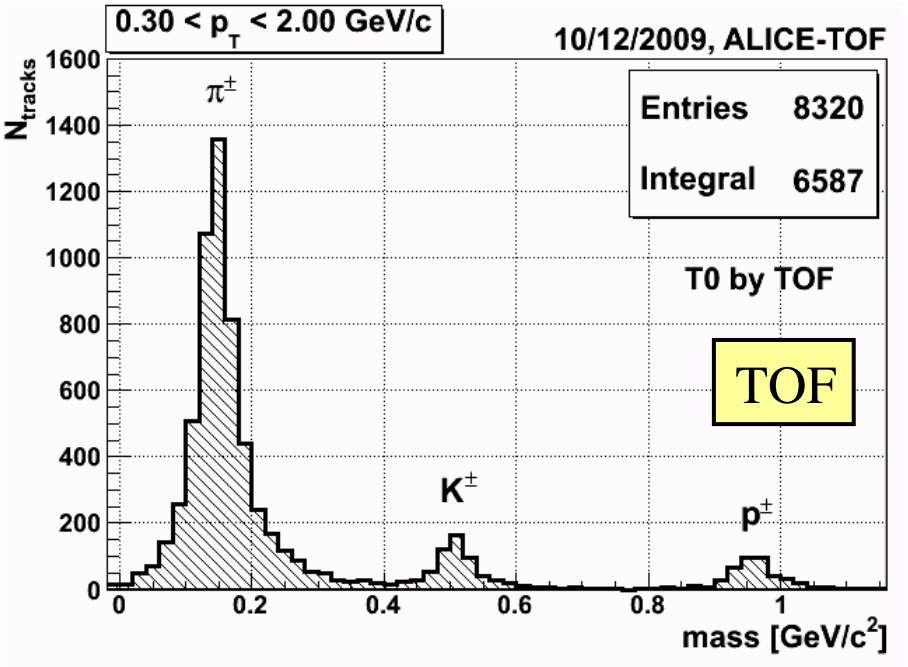


Impact parameter distribution (DCA) of SPD tracklets to the found vertex.
Sigma is about 190 micron for horizontal tracklets (all momenta and multipl.)
(alignment error contribution < 15 micron).
It is worse for vertical tracklets
(less statistics from cosmics available for alignment,
to be done with collission events)

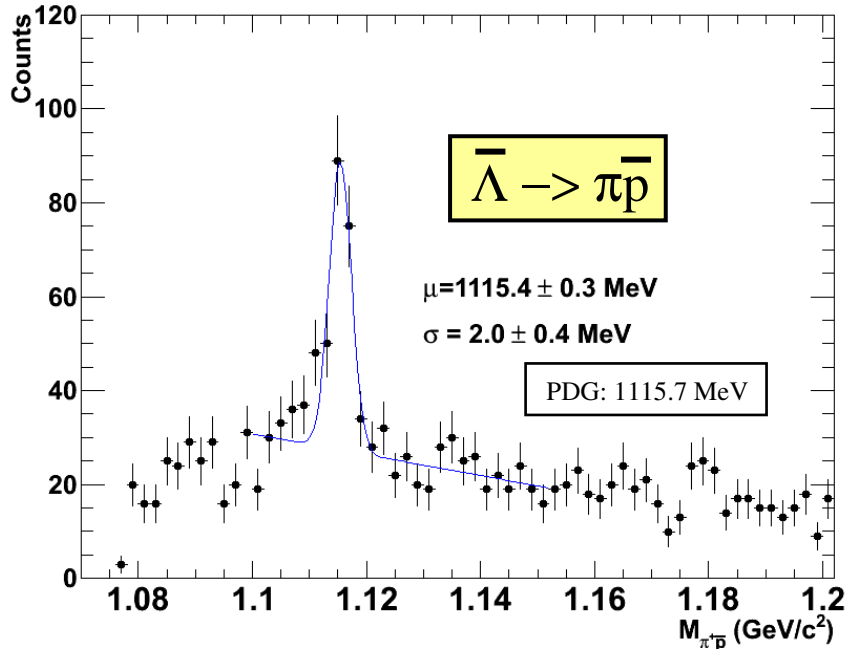
Particle Identification

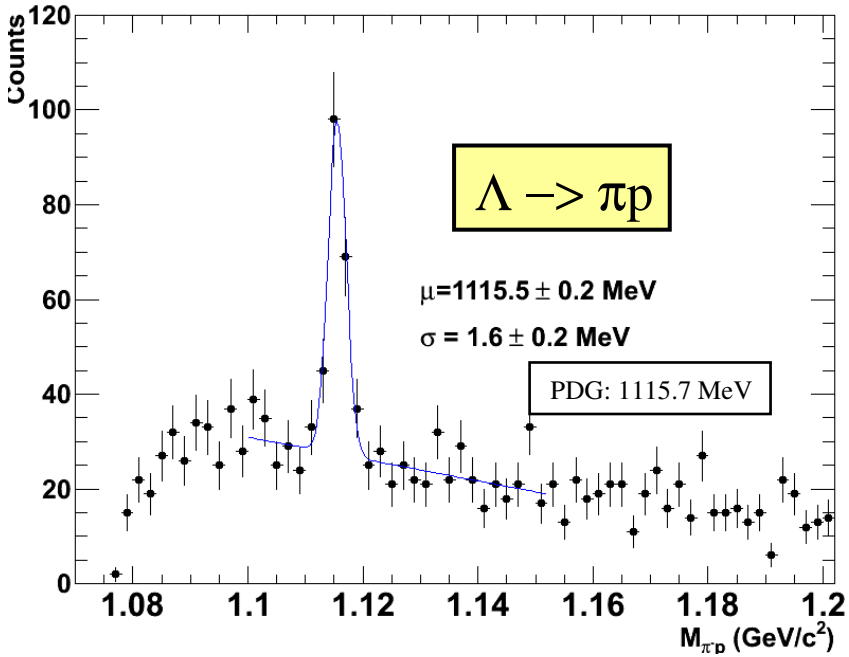


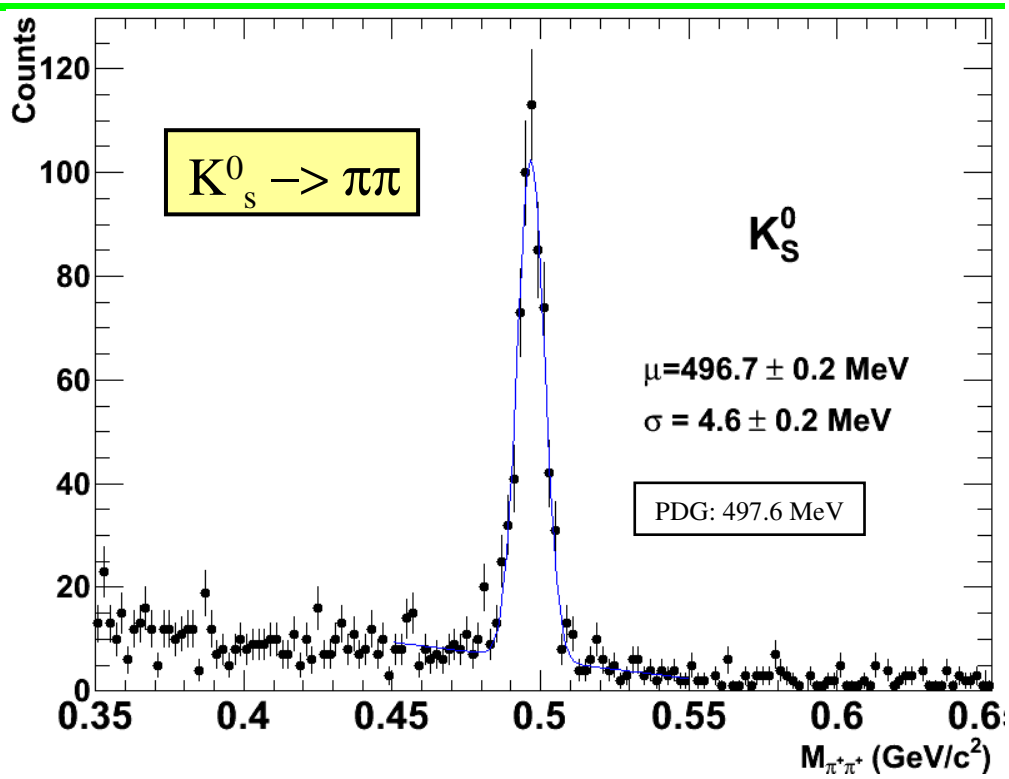


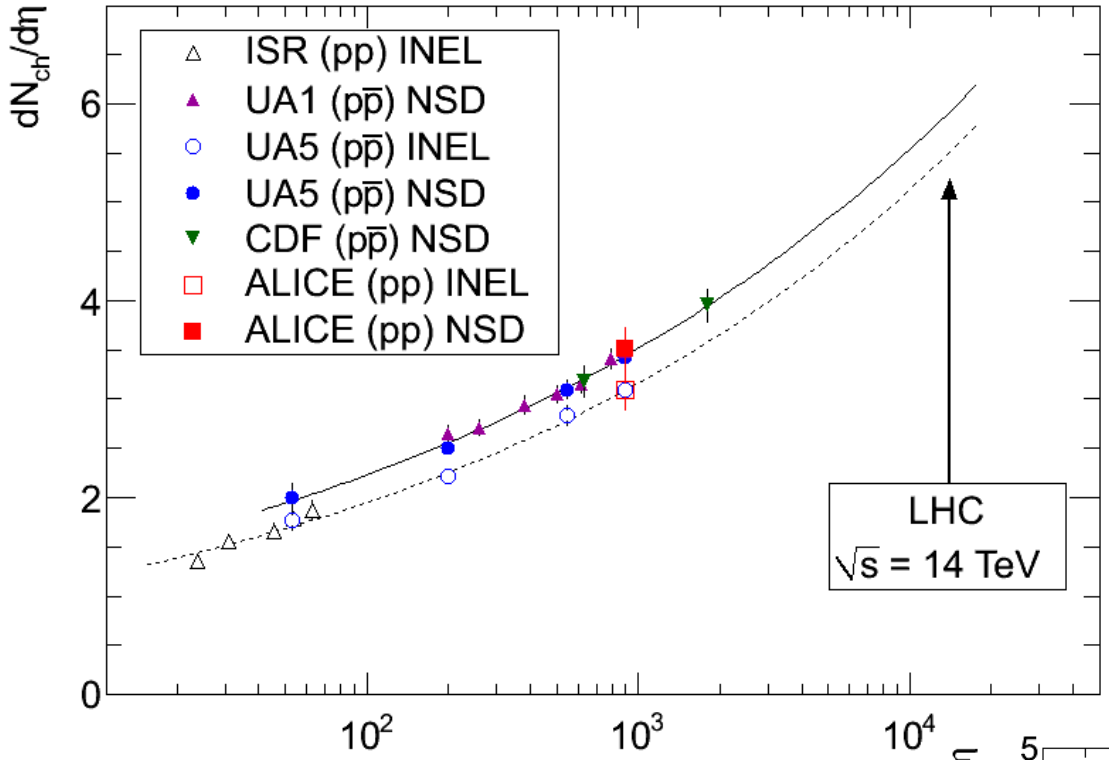


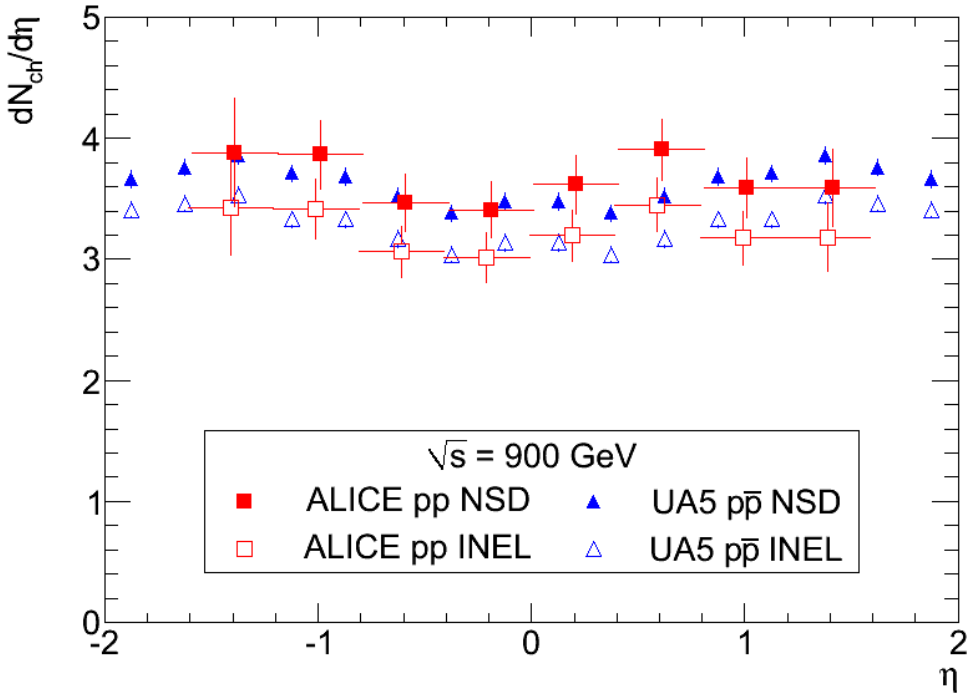
Decay Reconstruction

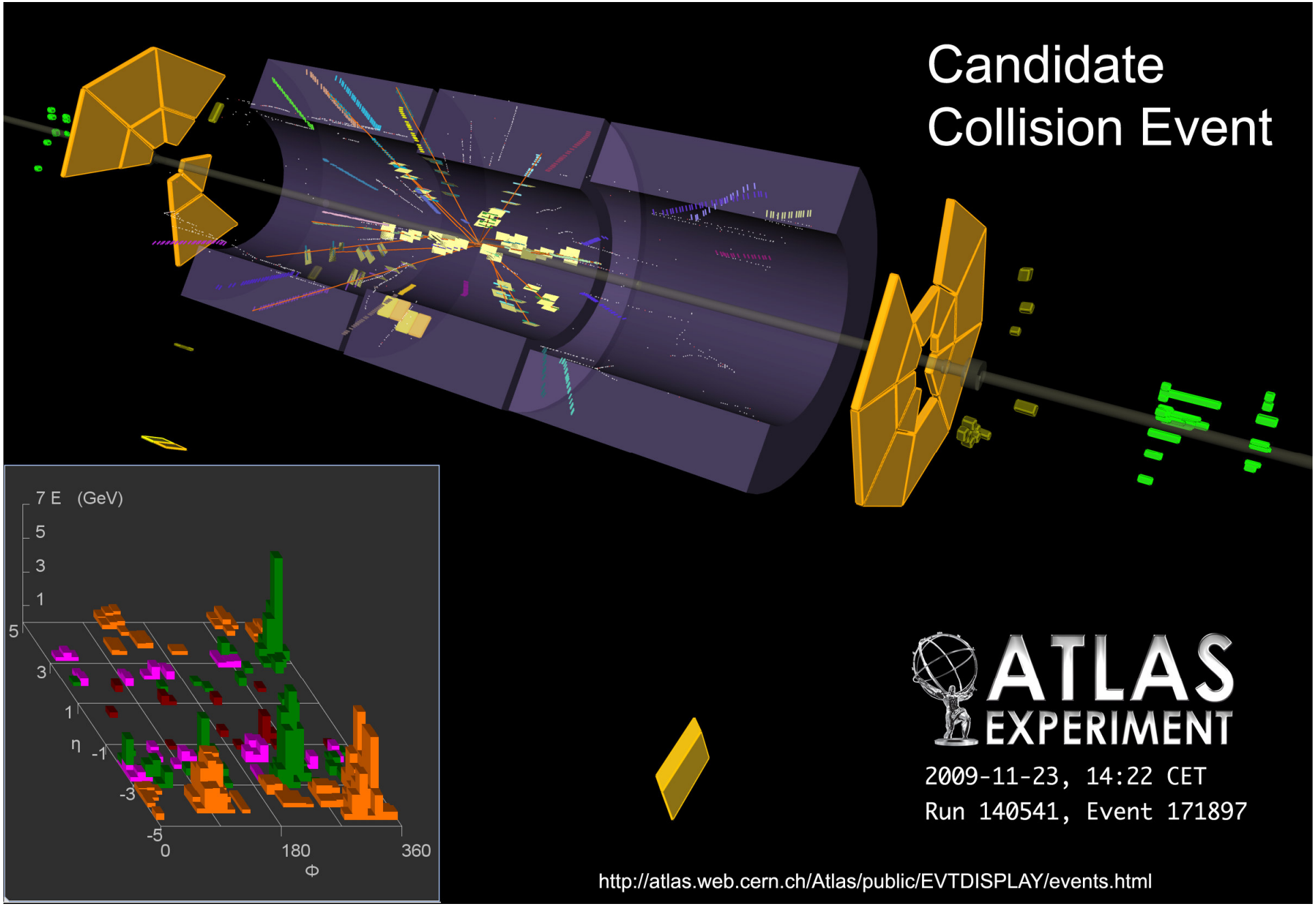




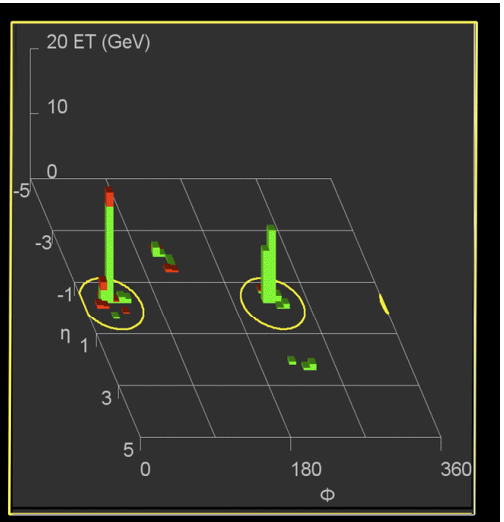



$dN_{ch}/d\eta$
ISR (pp) INEL
UA1 (p$\bar{p}$) NSD
UA5 (p$\bar{p}$) INEL
UA5 (p$\bar{p}$) NSD
CDF (p$\bar{p}$) NSD
ALICE (pp) INEL
ALICE (pp) NSD
LHC
$\sqrt{s}$ = 14 TeV
0
2
4
6
10^2
10^3
10^4


$dN_{ch}/d\eta$
$\sqrt{s}$ = 900 GeV
ALICE pp NSD
ALICE pp INEL
UA5 p$\bar{p}$ NSD
UA5 p$\bar{p}$ INEL
0
1
2
3
4
5
-2
-1
0
1
2
η


Candidate
Collision Event
7 E (GeV)
5
3
1
5
3
1
η
-1
-3
-5
0
180
360
Φ
ATLAS
EXPERIMENT
2009-11-23, 14:22 CET
Run 140541, Event 171897
http://atlas.web.cern.ch/Atlas/public/EVTDISPLAY/events.html

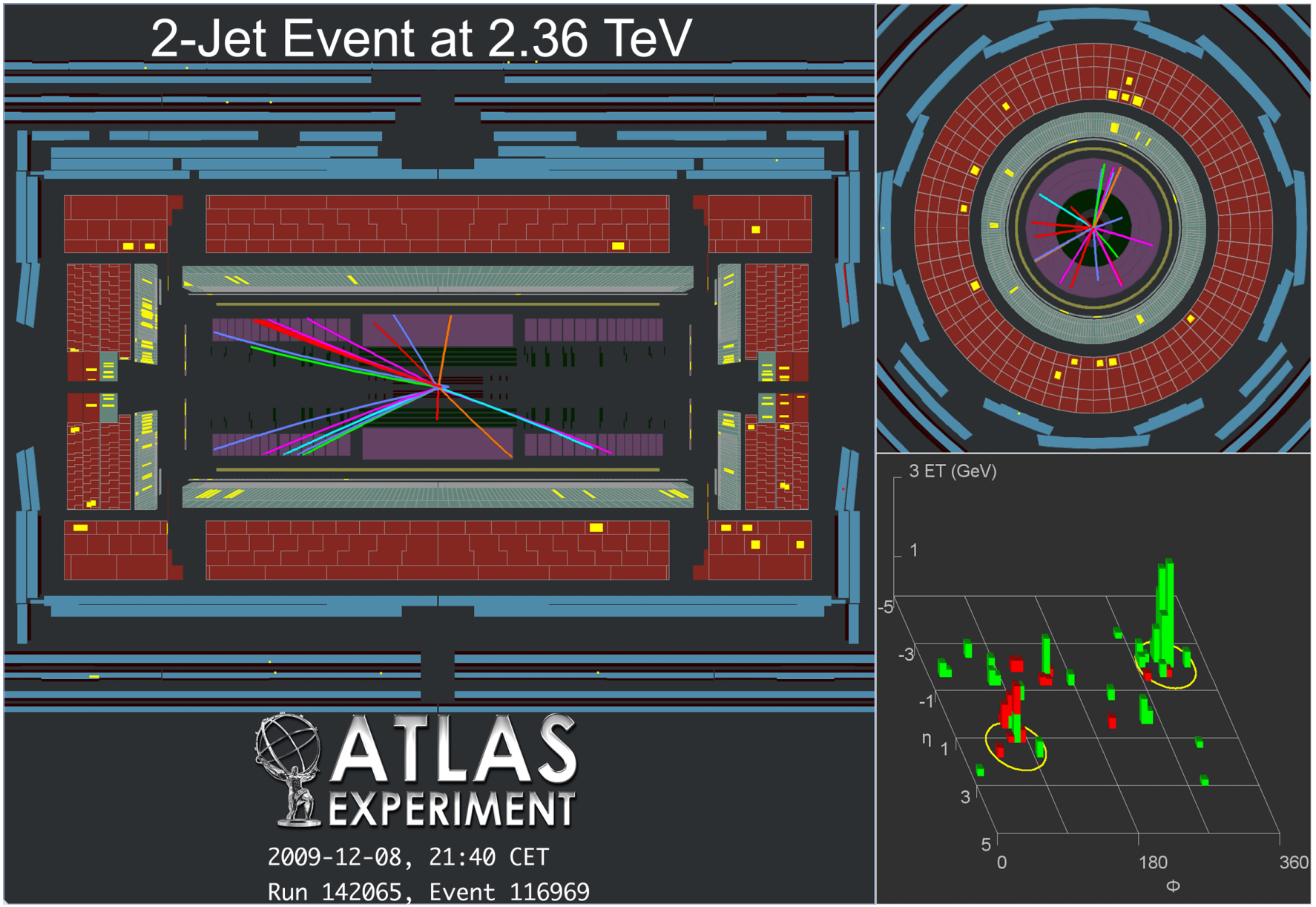
Collision Event with 2 Jets



ATLAS EXPERIMENT

2009-12-08, 03:45 CET
Run 141994, Event 566308

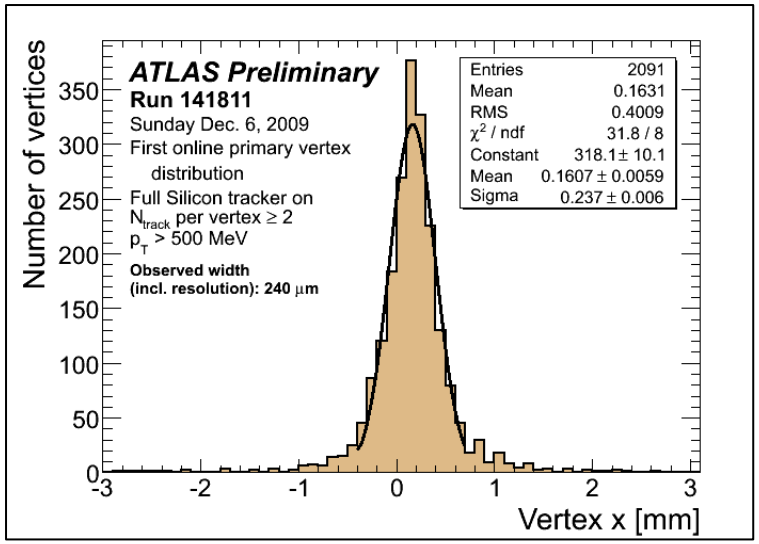
Uncalibrated E_T~55 GeV for both jets
Both jets at η = -0.2 ; ~ no missing E_T

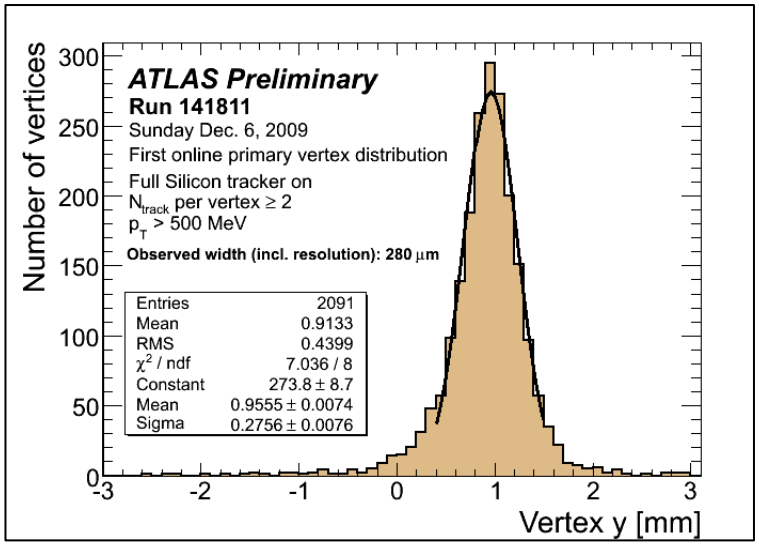


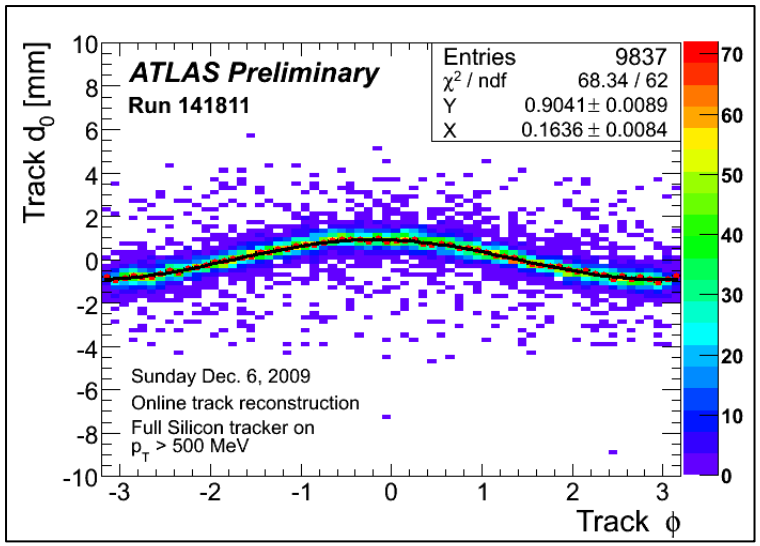
Jet1: uncalibrated E_T~22 GeV, η = -2.1
Jet2: uncalibrated E_T~11 GeV, η = 1.4

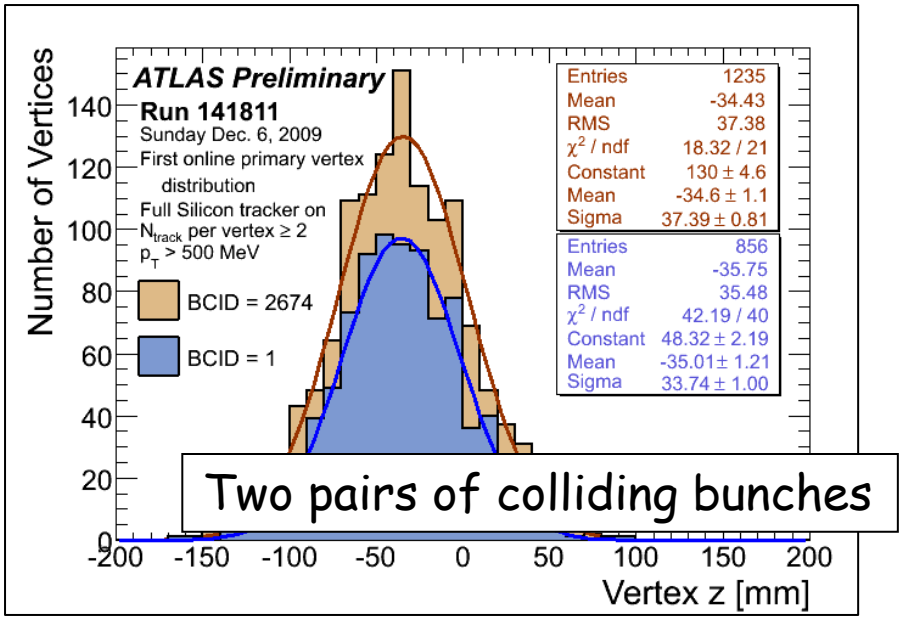
Online determination of the primary vertex and beam spot using the Level-2 trigger algorithms

High-Level Trigger running with > 150 chains







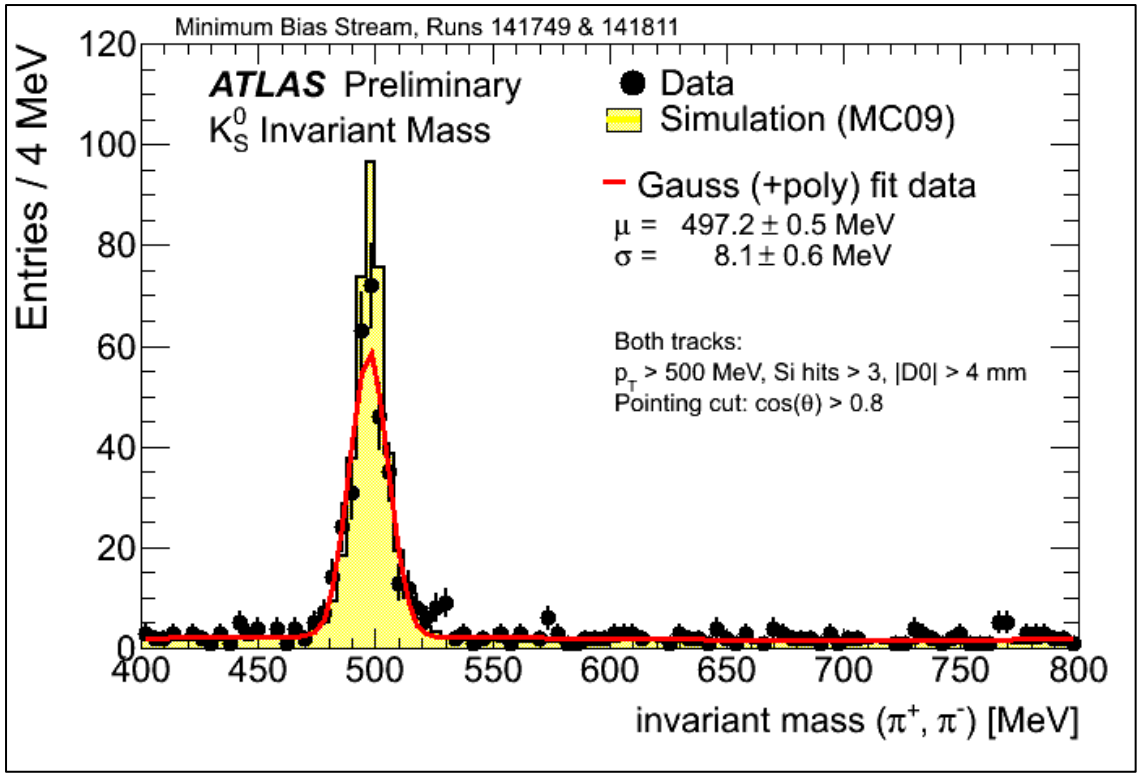


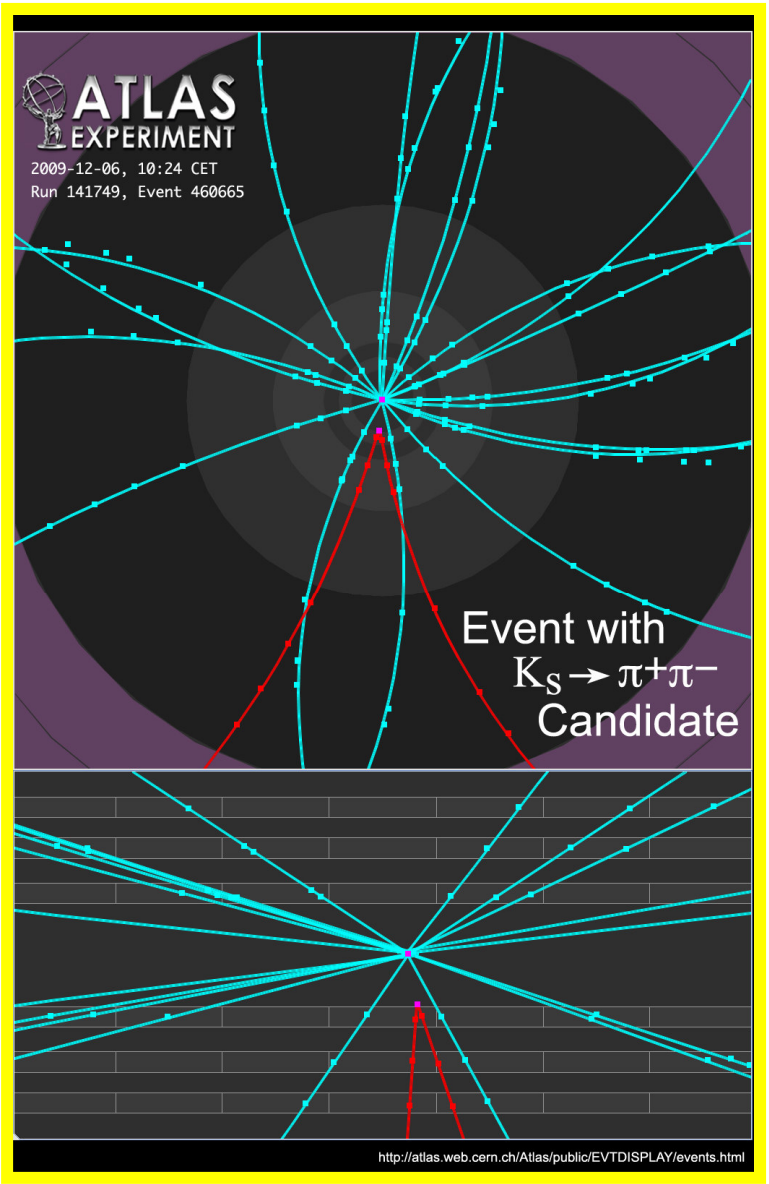
Two pairs of colliding bunches

$K^0_s \rightarrow \pi^+ \pi^-$

2 opposite-sign tracks:
- p_T >500 MeV
- originating from common vertex
- impact parameter d_0 > 4 mm
- momentum sum along flight direction

Data and MC normalized to the same area

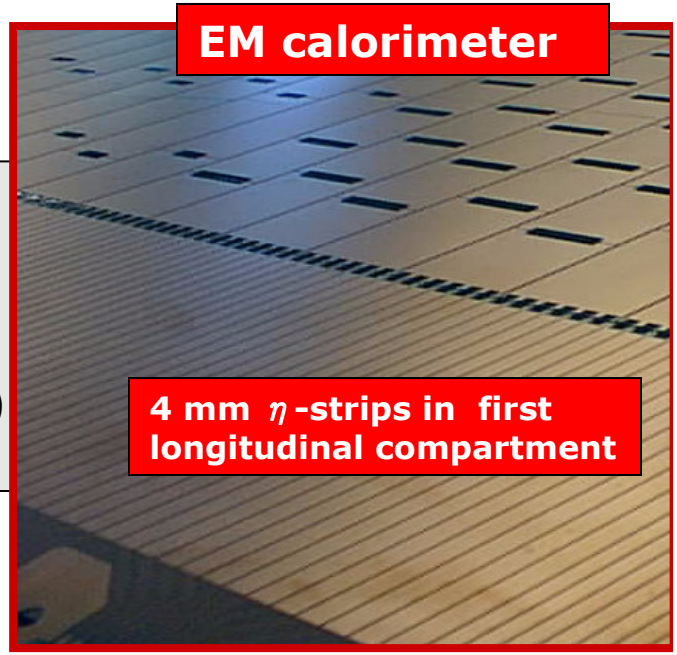


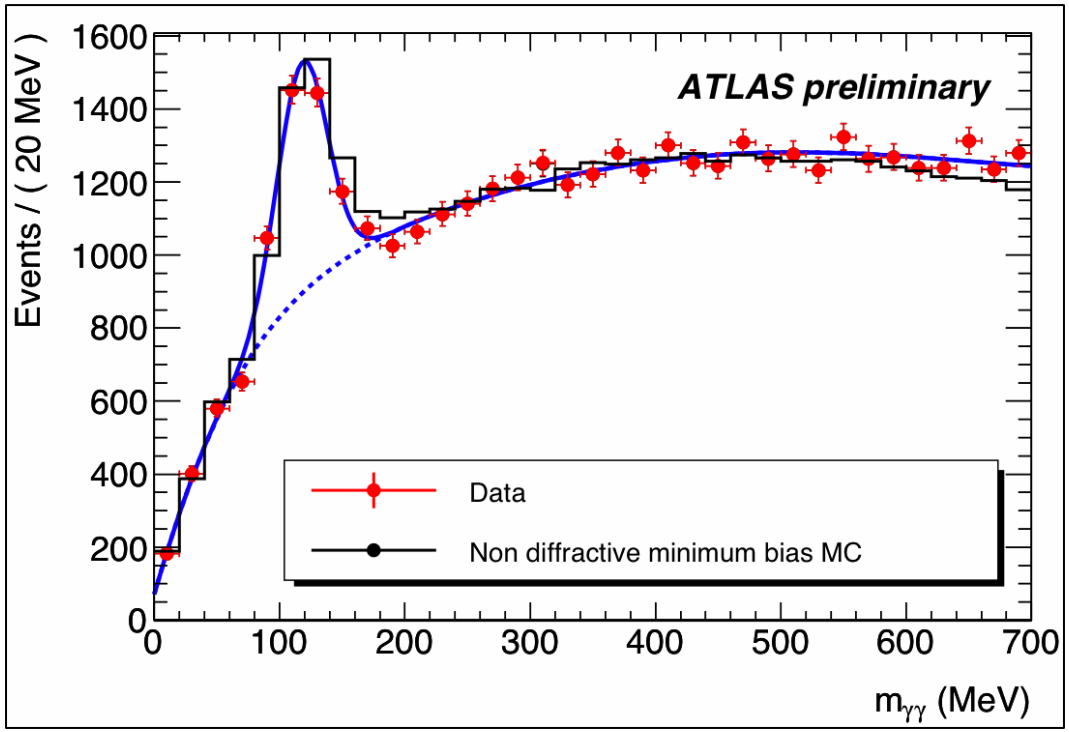


$\pi^0 \rightarrow \gamma\gamma$

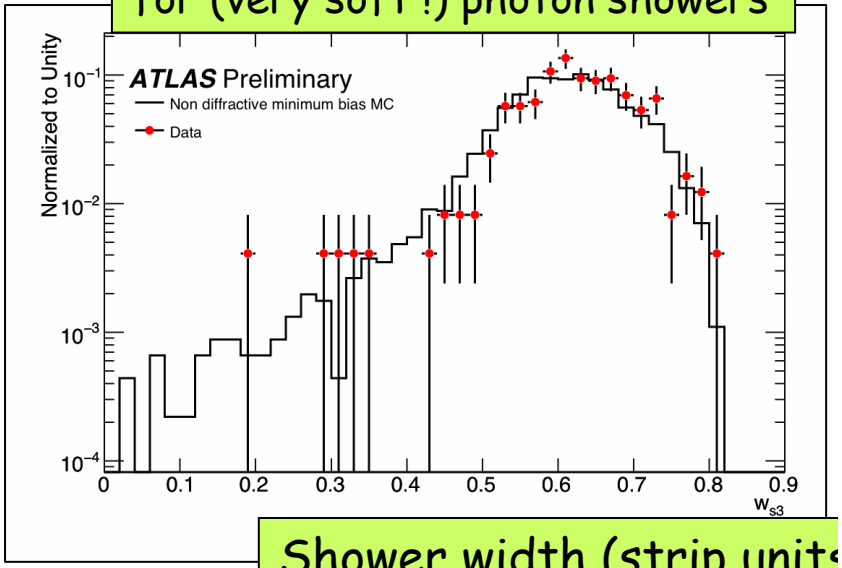
- 2 photons with $E_T(\gamma) > 300$ MeV
- $E_T(\gamma\gamma) > 900$ MeV
- shower shapes compatible with photons

All combinations plotted.
No correction for upstream dead material (~ 2.5 X_0 at $\eta = 0$)
Data and MC normalised to the same area



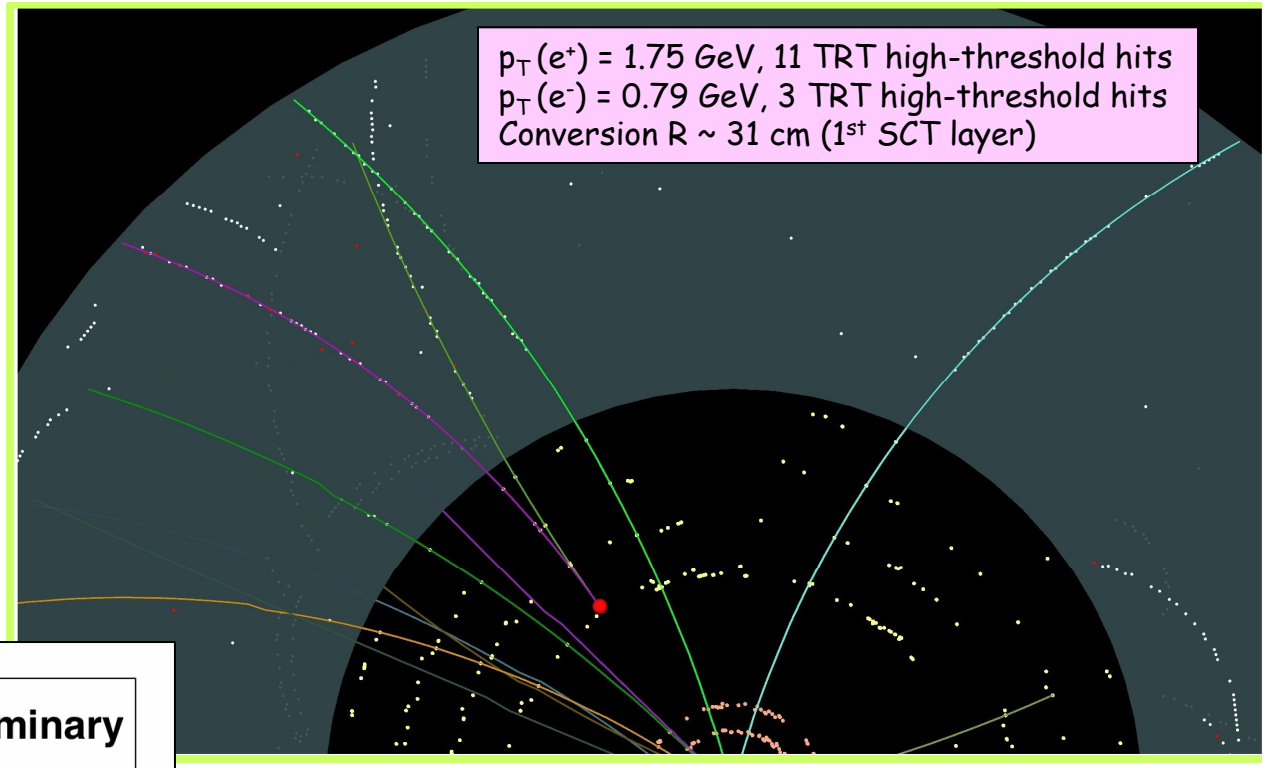


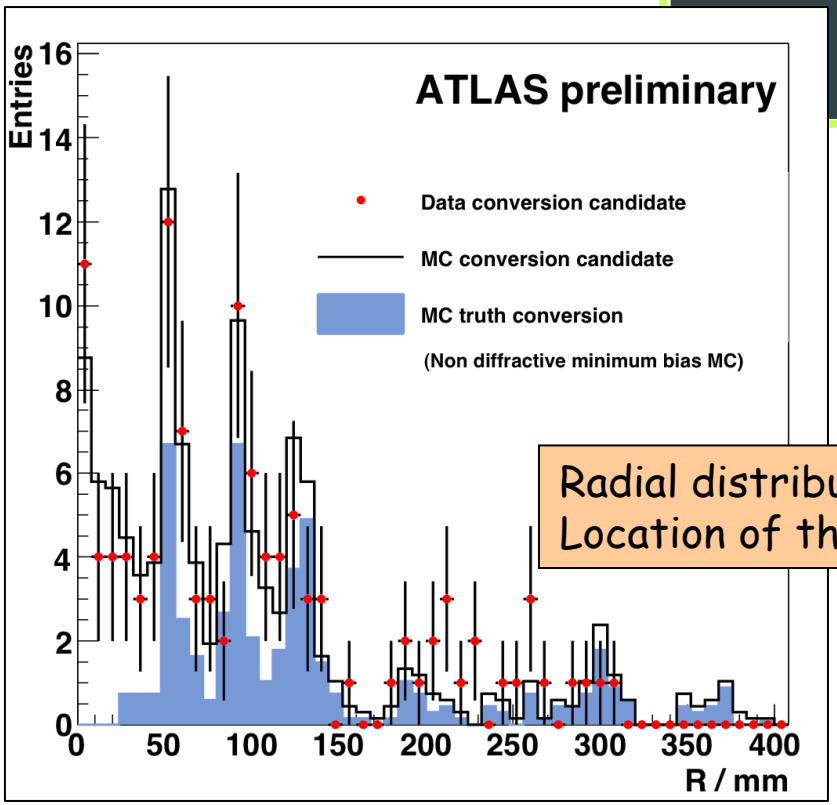
Very good data-MC agreement for (very soft !) photon showers



Shower width (strip units

$\gamma \rightarrow e^+e^-$ conversions

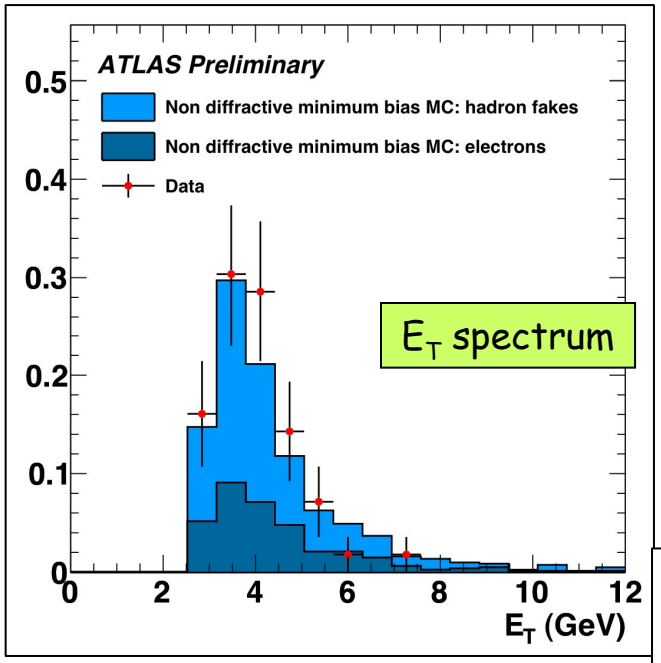




Radial distribution of conversions occurring in Si layers.
Location of the pixels layers at R=50, 90, 120 mm is clearly visible

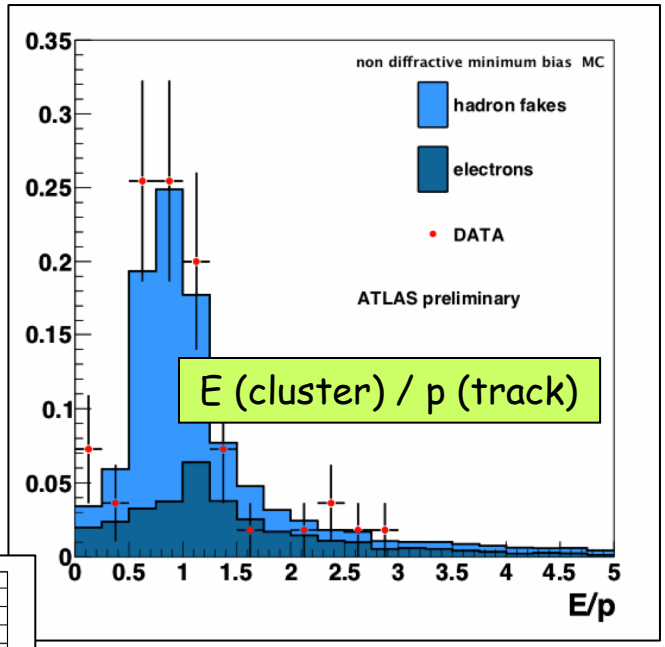
Electron candidates

EM clusters E_T > 2.5 GeV matched to a track
→ 47 candidates in 20000 minimum-bias events
Data and MC normalised to the same area



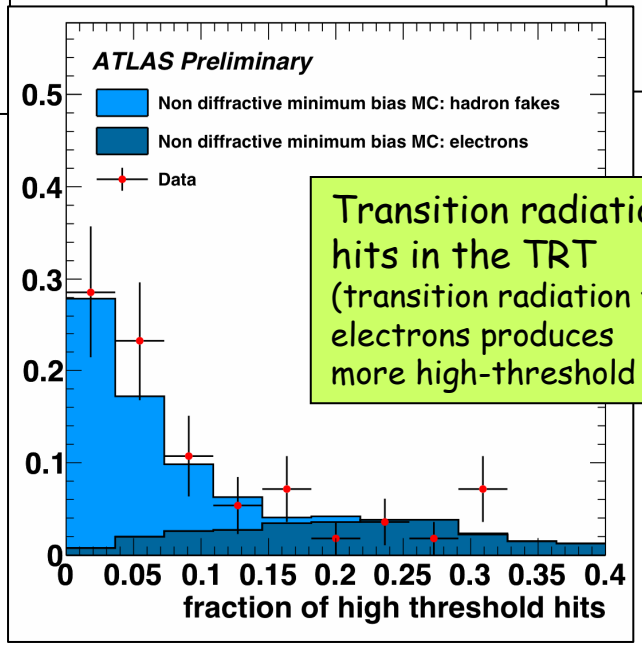
E_T spectrum

According to MC:
- Sample dominated by hadron fakes
- Most electrons from γ-conversions

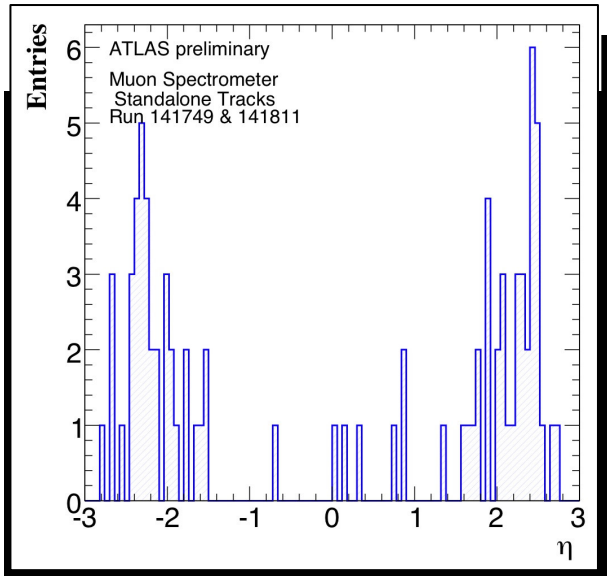


E (cluster) / p (track)

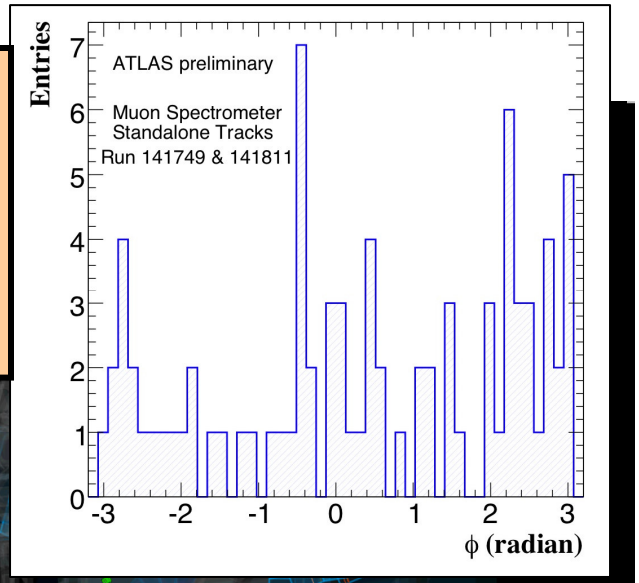
Very good data-MC agreement for (soft !) electrons and hadrons

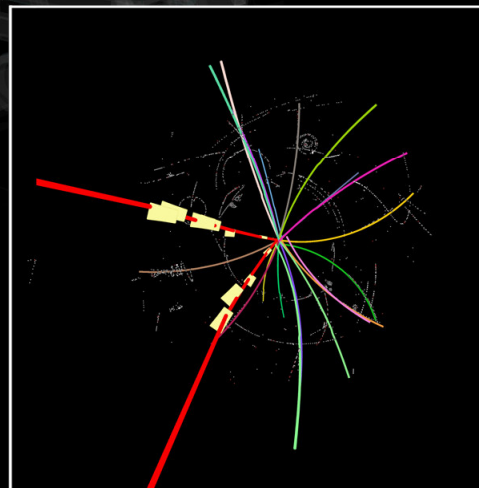


Transition radiation hits in the TRT
(transition radiation from electrons produces more high-threshold hits)



η and ϕ distributions of (very low momentum p ~ 3 GeV) muon candidates are compatible with particles produced in the collisions (mainly coming from K/π decays)



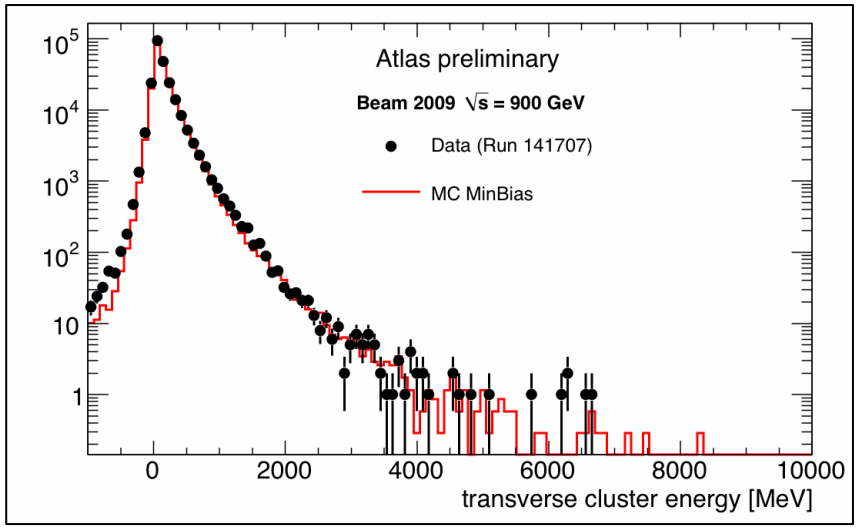


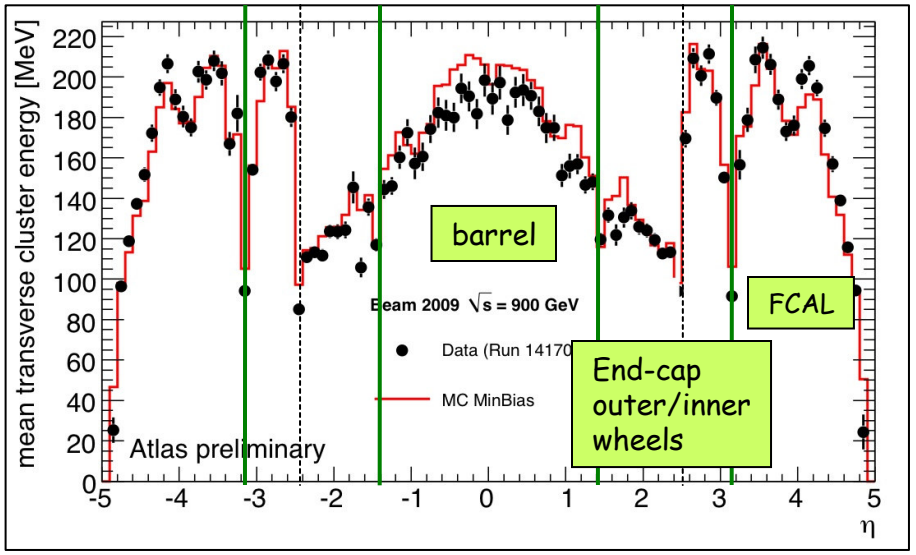
Collision Event with 2 Muon Candidates

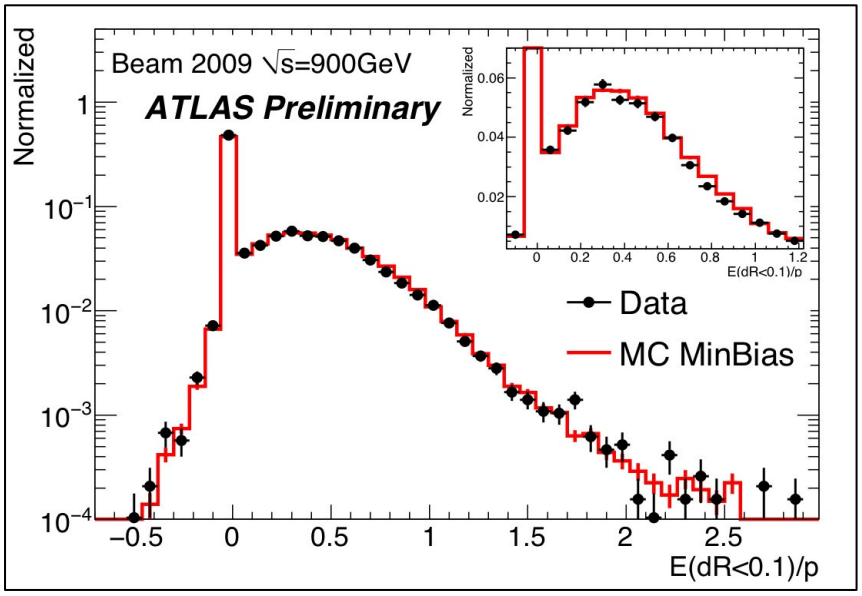
http://atlas.web.cern.ch/Atlas/public/EVTDISPLAY/events.html

Energy flow in calorimeters …

Uncalibrated clusters
(topological clusters with noise suppression)





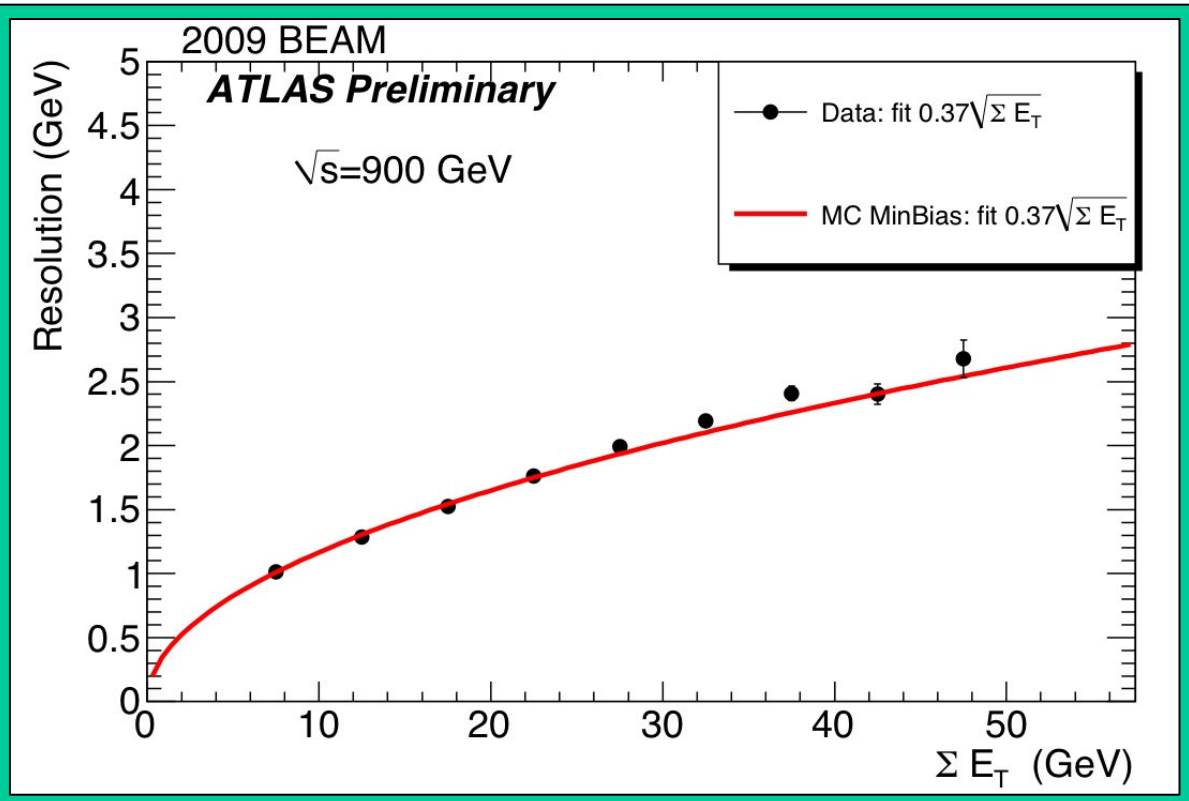


$$\frac{E(\text{calorimeter})}{p(\text{tracker})}$$

for isolated tracks with $|\eta| < 0.8$
and $0.5 < p_T < 10$ GeV (average ~ 0.8 GeV)
Cluster energy at EM scale

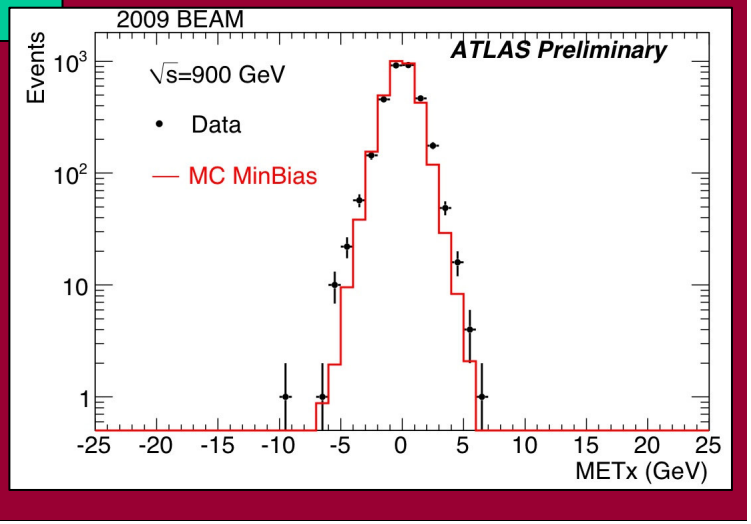
Excellent agreement data-MC at such low energies indicates very good description of material in simulation and G4 shower modeling

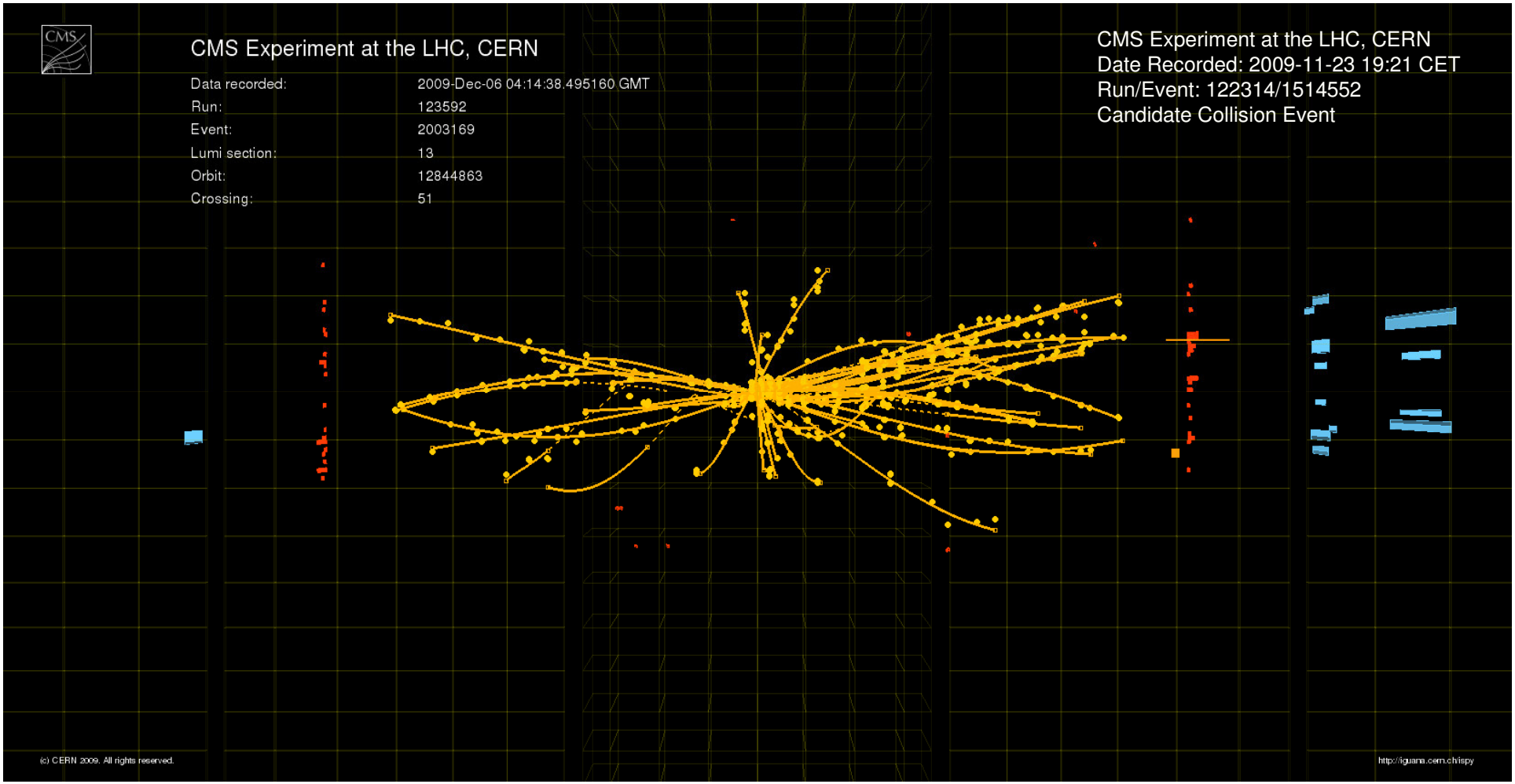
… and missing transverse energy resolution



Energy resolution of the two components (METx, METy) of the missing E_T vector vs the total transverse energy in the calorimeters

- Measurement over full calorimeter coverage, $|\eta| < 5$, ~ 200000 cells
- Calculated using clusters at EM-scale
- Noise contribution (from random triggers): 0.5 GeV



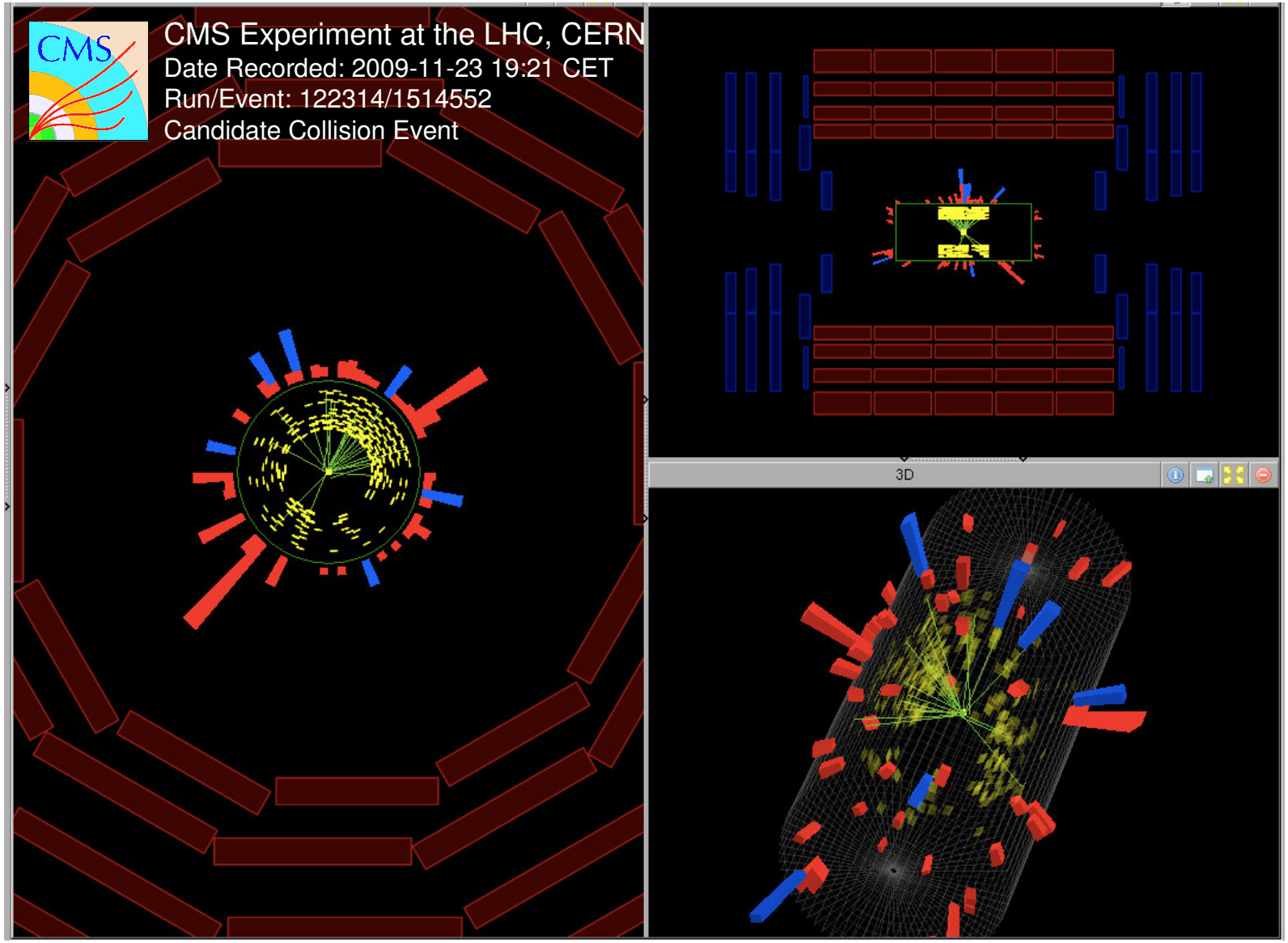


CMS

Compact Muon Solenoid

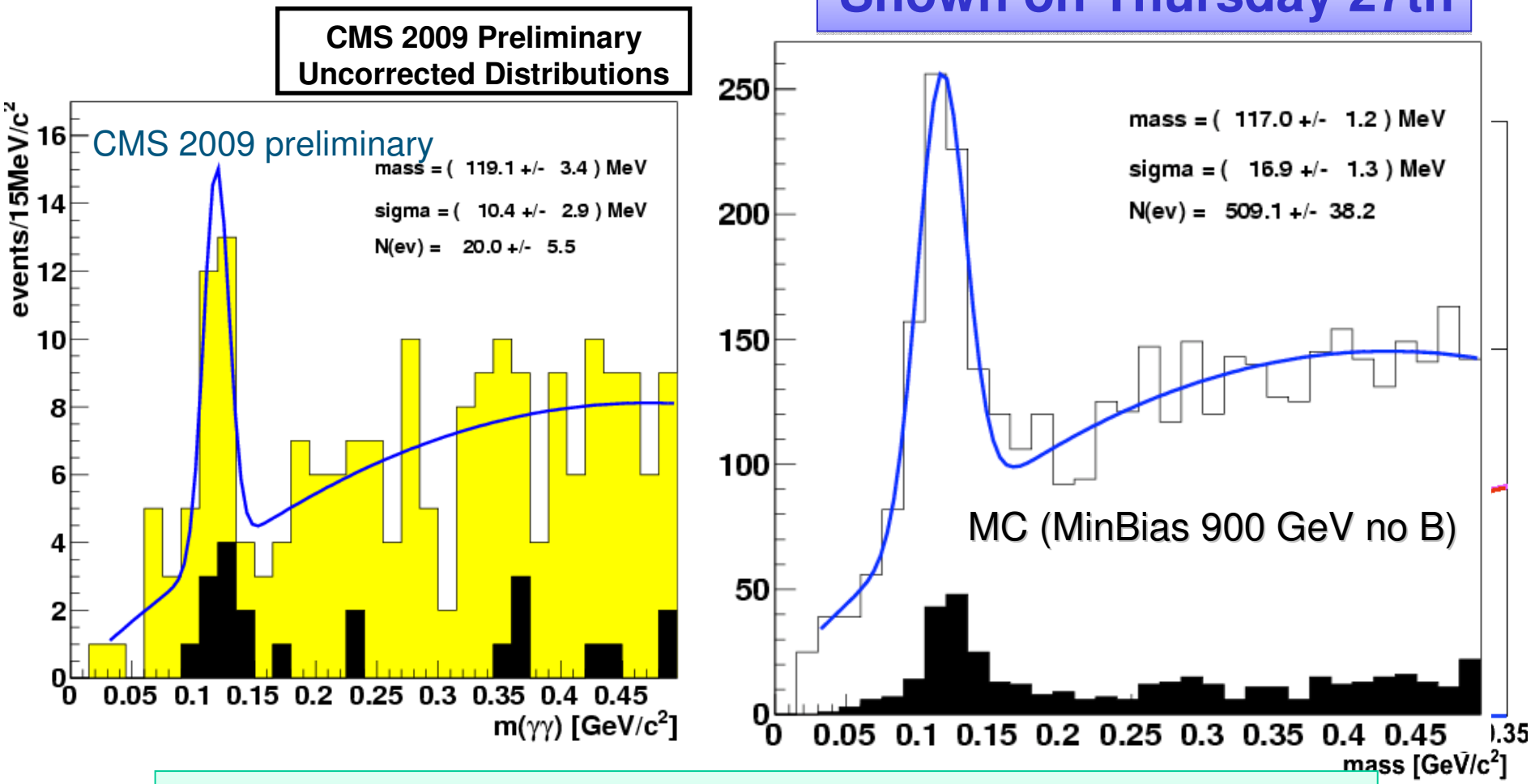
Dec09 SPC

Monday 23rd November



First Di-photon Distribution in CMS

Shown on Thursday 27th



- M(π^0) is low in both data and MC
- Mostly due to the readout threshold (100 MeV/Crystal).
- Conversions: part of the energy is deposited upstream of ECAL.
- Event timing is consistent

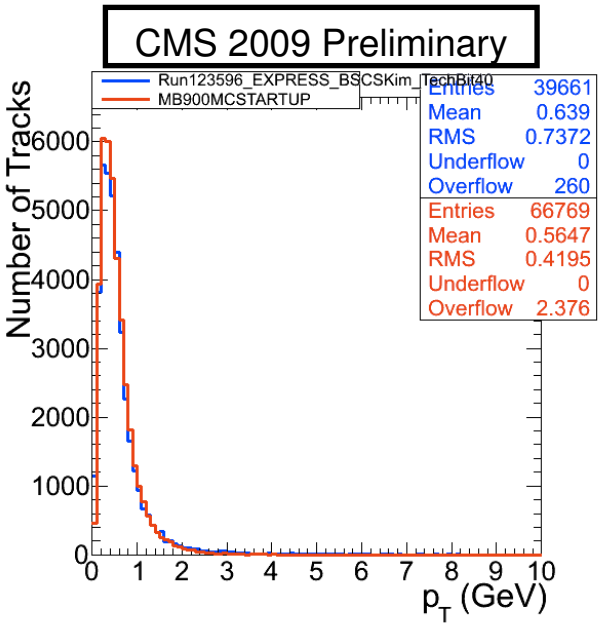
Machinery in Place for Rapid Analysis

Sunday 6th Early Morning First: "Physics" Fill

4x4 bunches, Σ ~ e10 protons Stable Beam Flag set for the first time

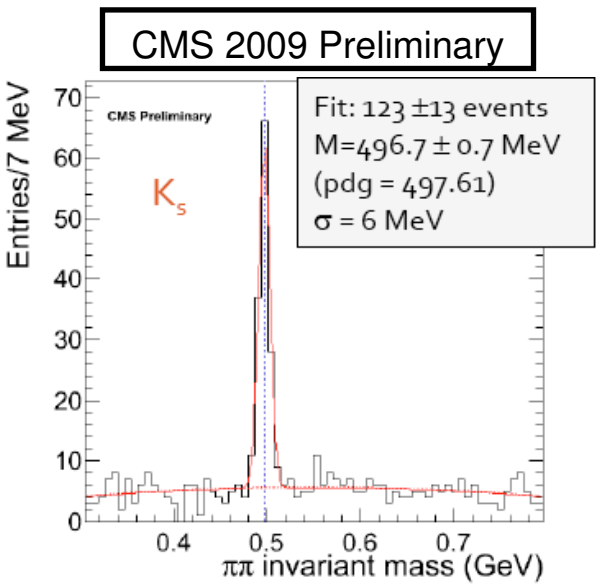
All CMS ON

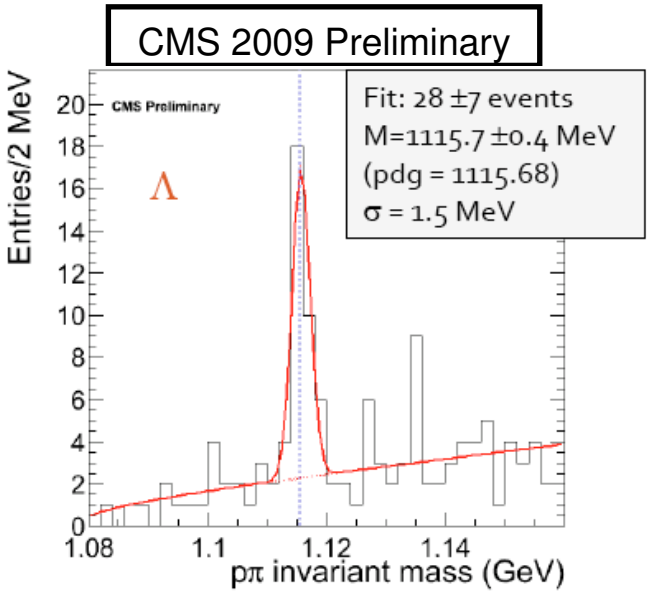
Sunday 6th : 9am



Charged particle p_T spectrum produced a few hours after the first fill and compared with MC.

Monday 7th : 9am

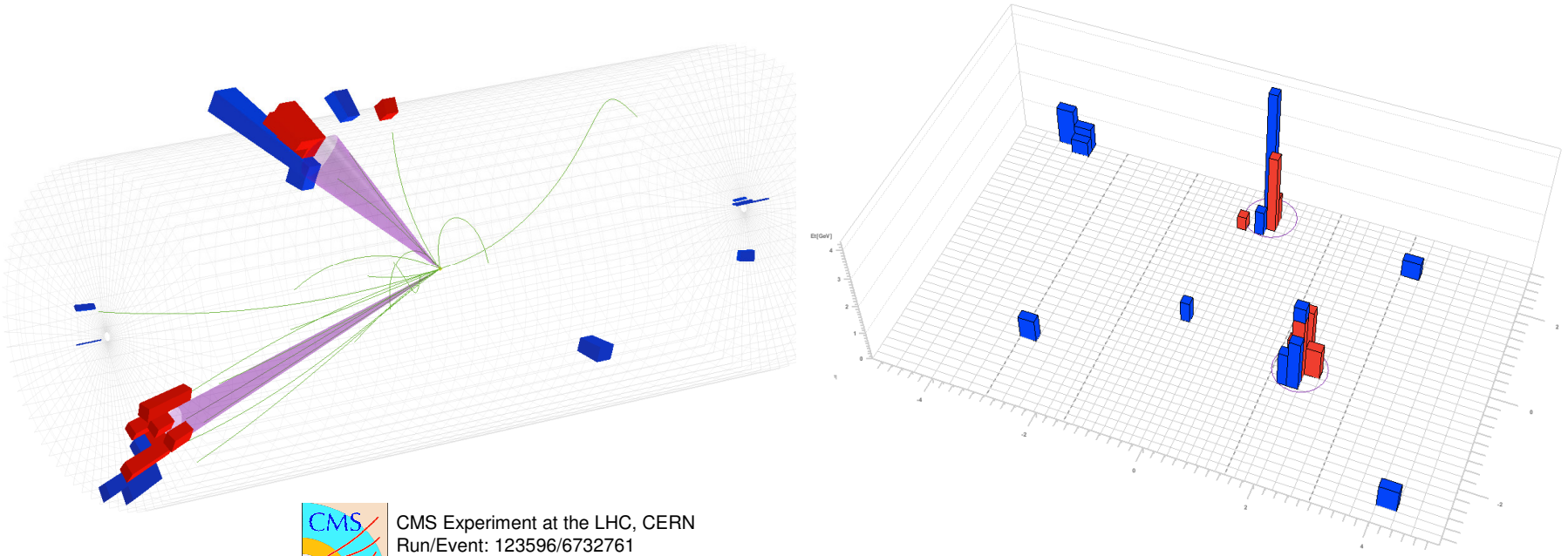




K^0 and Λ (η and φ have also been observed)

Secondary vertex and track reconstruction in good shape,
p/K hypotheses checked with Si dE/dx,
magnetic field map is good

Jets



CMS Experiment at the LHC, CERN
Run/Event: 123596/6732761
Candidate Di-Jet Event

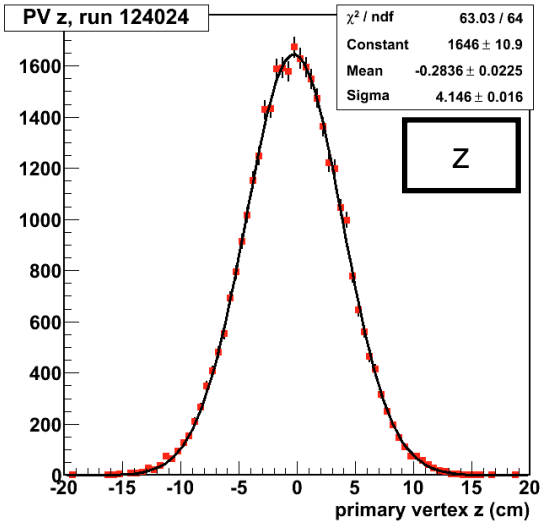
Anti-K_T algorithm with cone size R=0.7

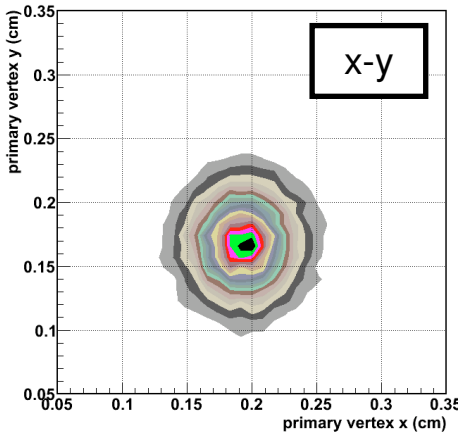
	Jet 1	Jet 2
Corrected p_T (GeV)	24	26
η	0.3	2.0
ϕ	2.5	-0.7
EM Energy Fraction	0.5	0.6

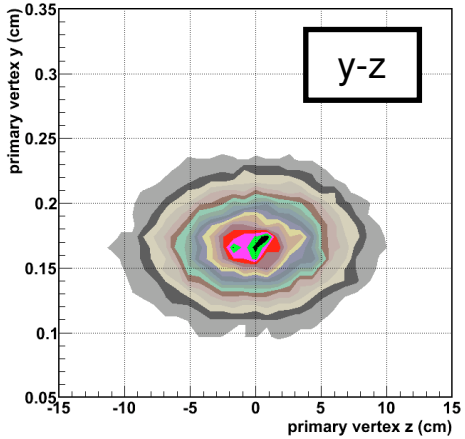
Calibration and Monitoring: Examples

Saturday 12th : "Physics" Fills (250k minbias events)

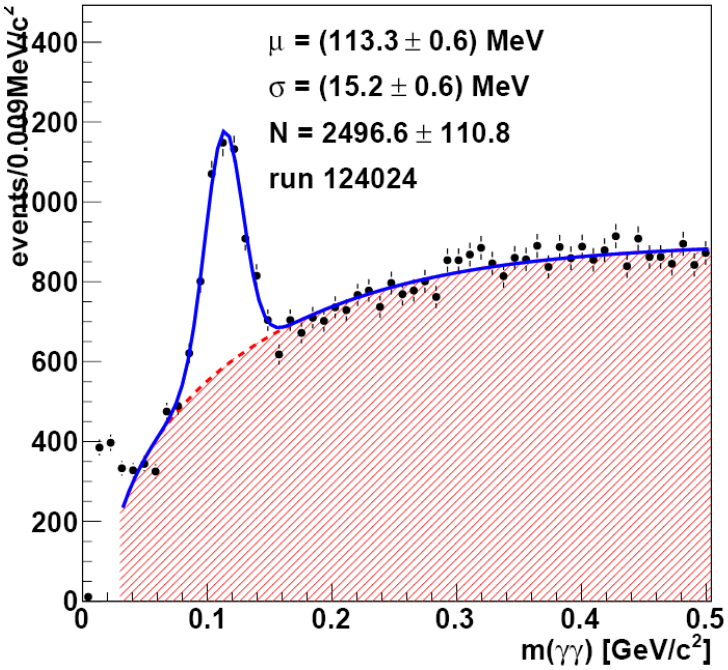
Reconstructed Primary Vertex Distributions
Beam scan yielded a factor 3 increase in rate at CMS!







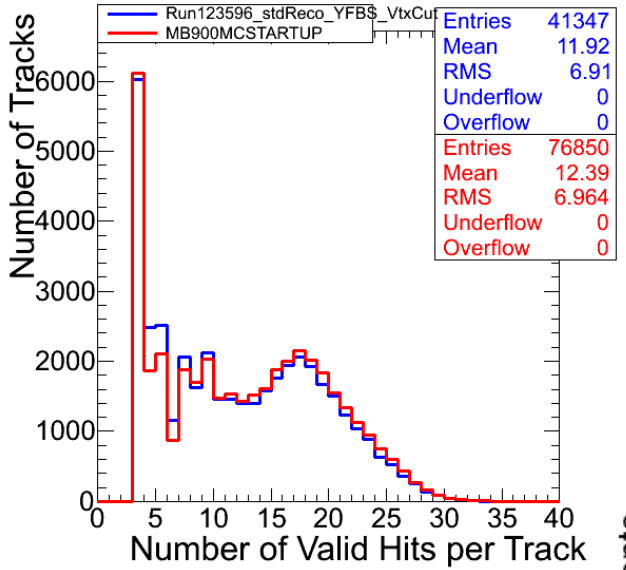
CMS 2009 Preliminary

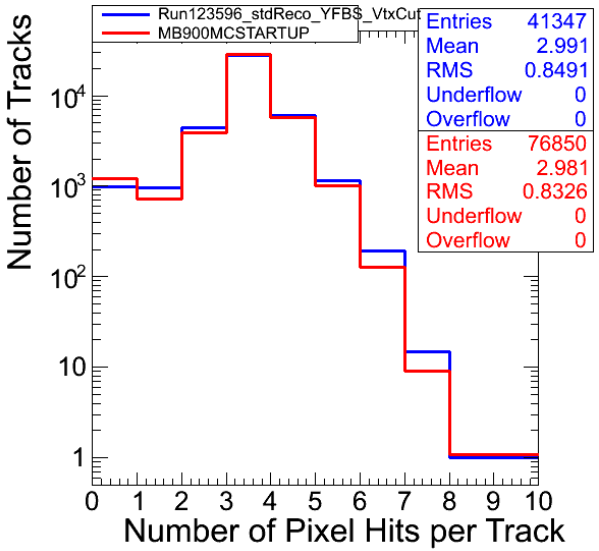


Run 124024
Taken on Sat 12th 14:57-17:06
Workflow for ECAL calibration
Plot produced after a few hours

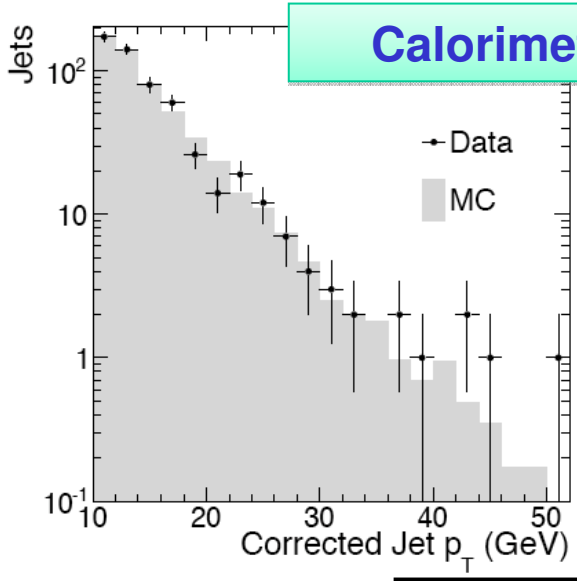
Performance of CMS
Good agreement with MC Expectation

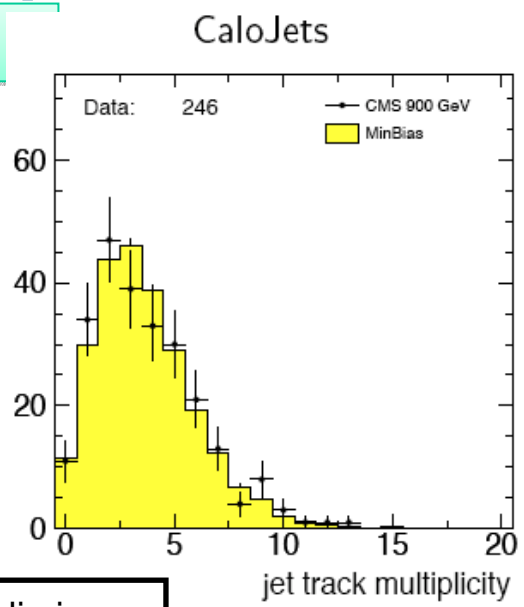
Tracking



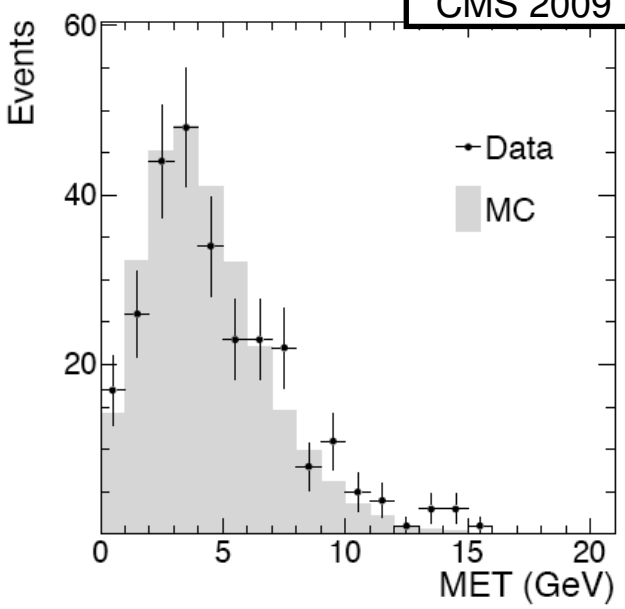


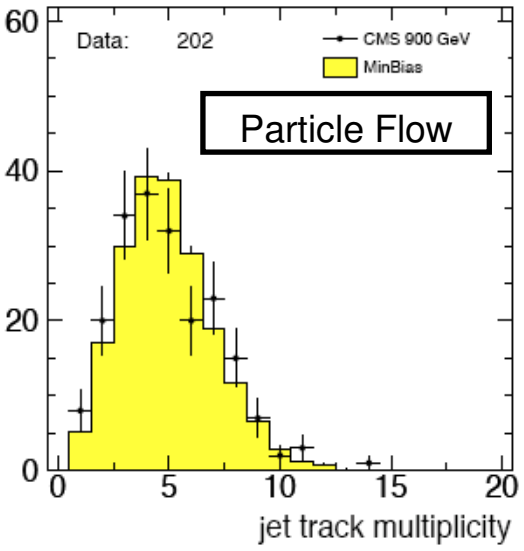
Calorimetry



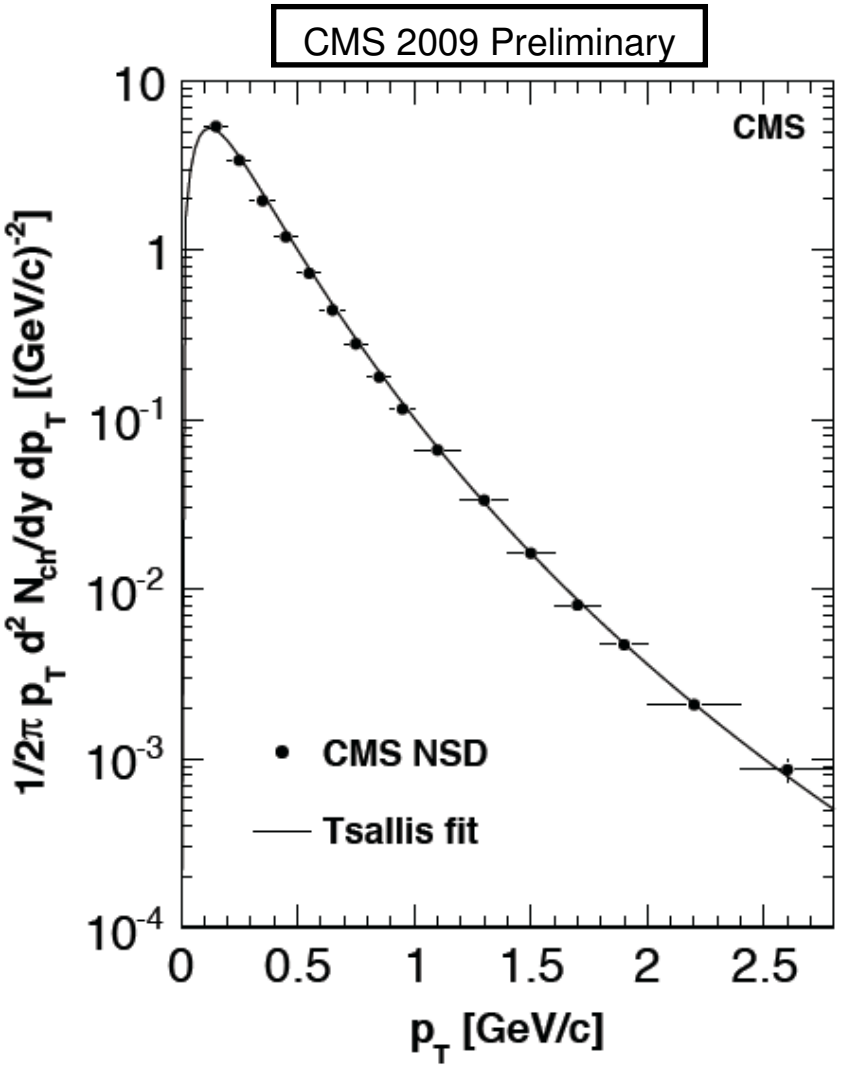


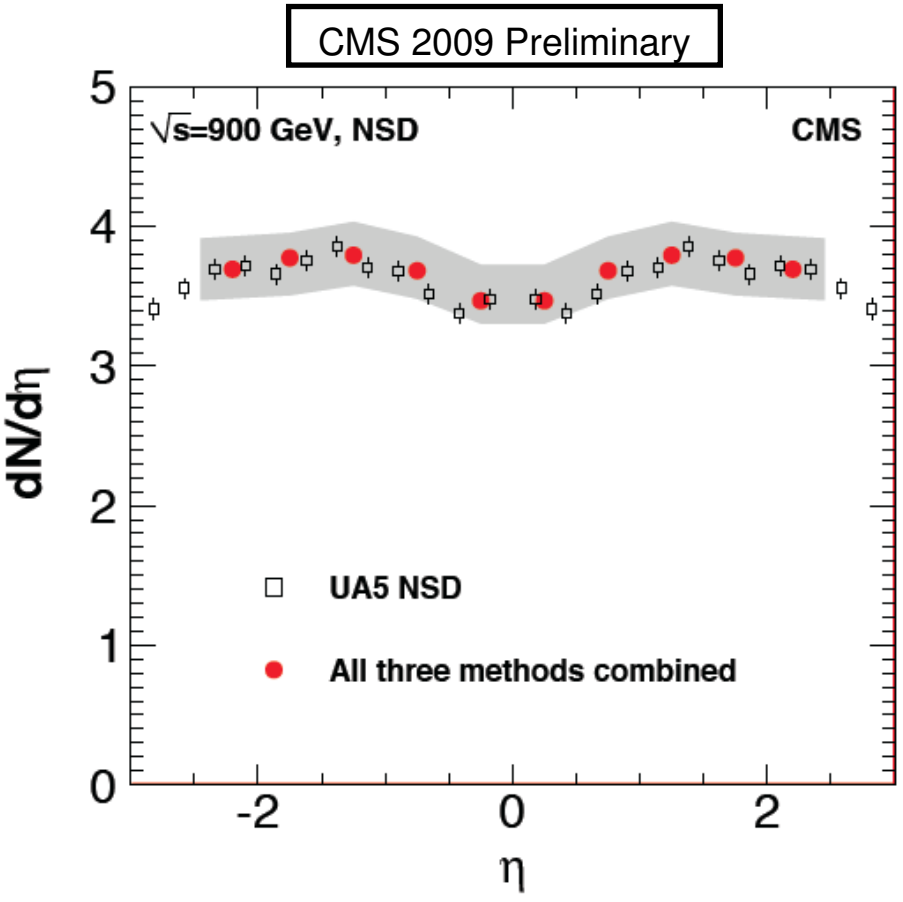
CMS 2009 Preliminary



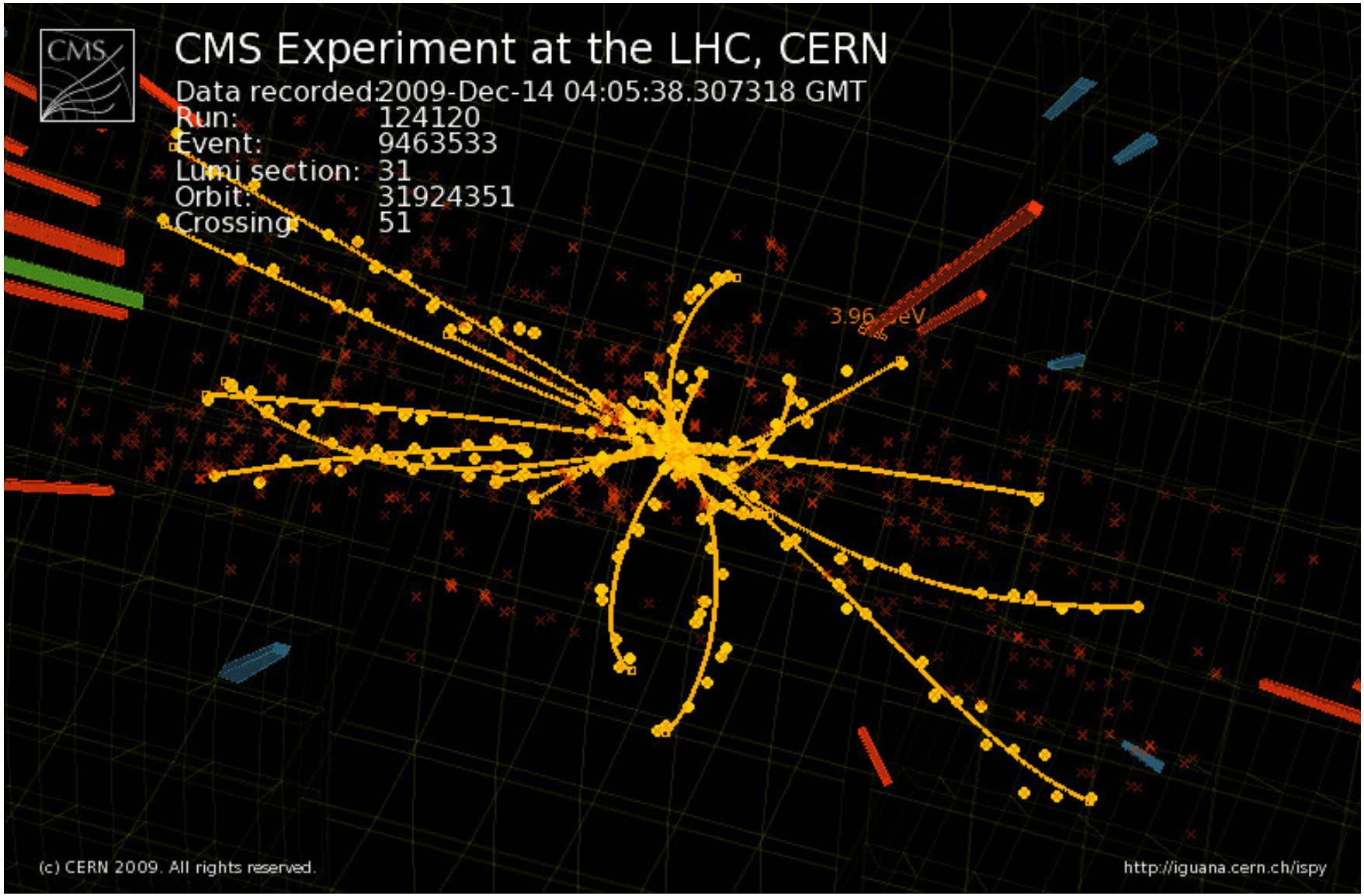


First Physics Distributions



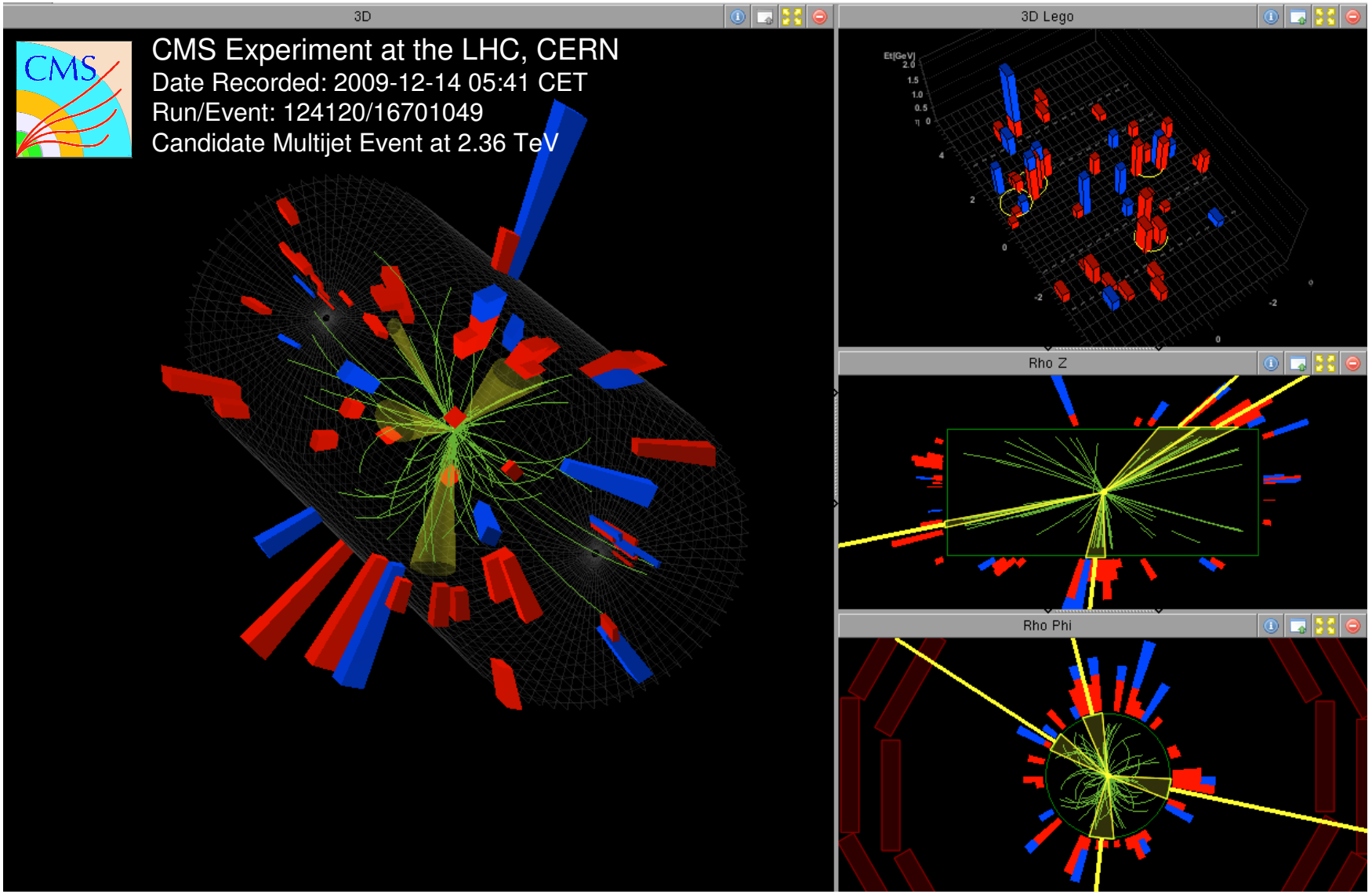


Sunday 14th December @ 2.36 TeV



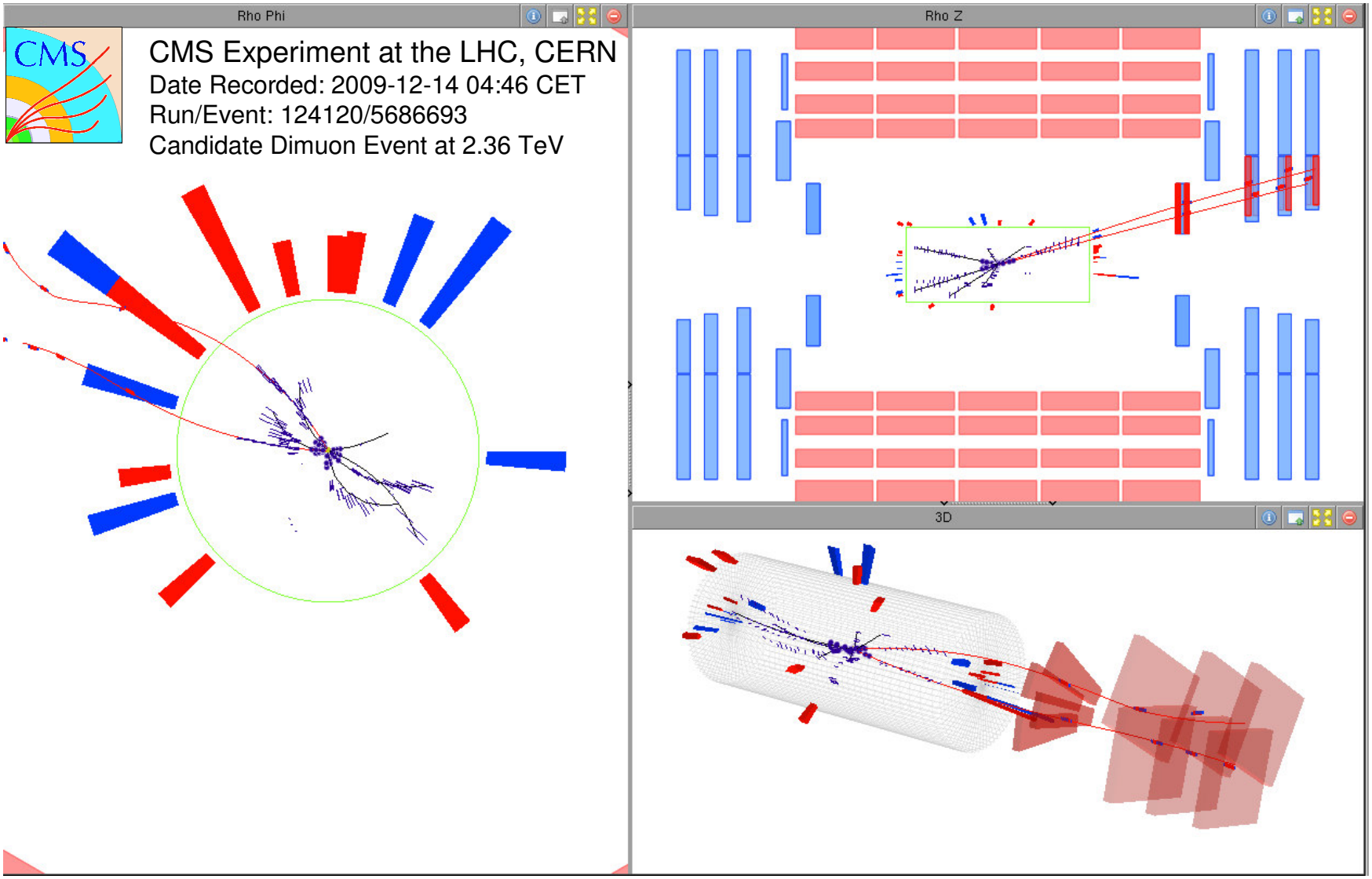
Ran from 4:17 to 5:49: Around 15k events taken

MultiJet Event at 2.36 TeV

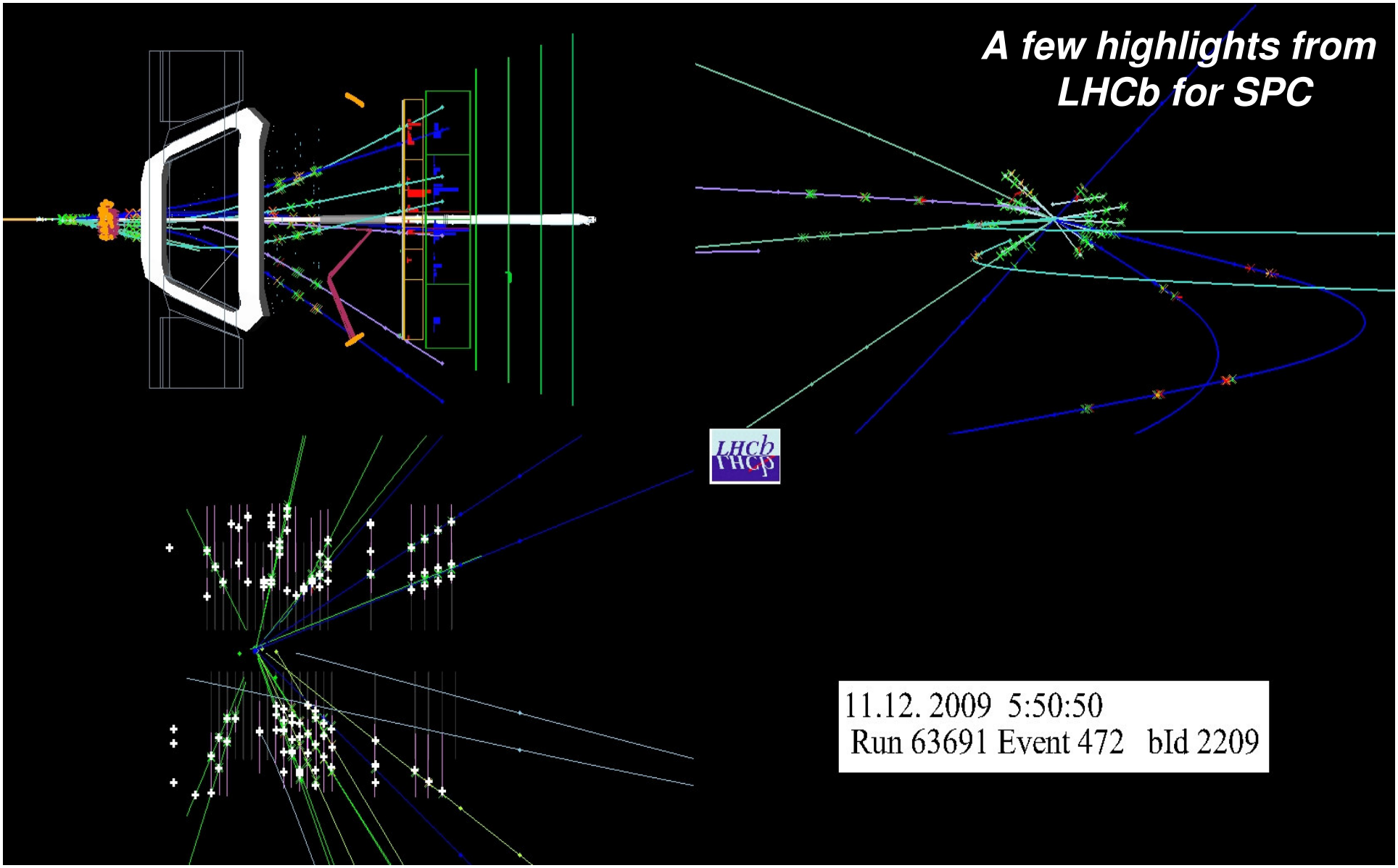


4 PFlow Jets E_T> 7 GeV, p_T cut on tracks displayed > 0.4 GeV

Dimuon Event at 2.36 TeV



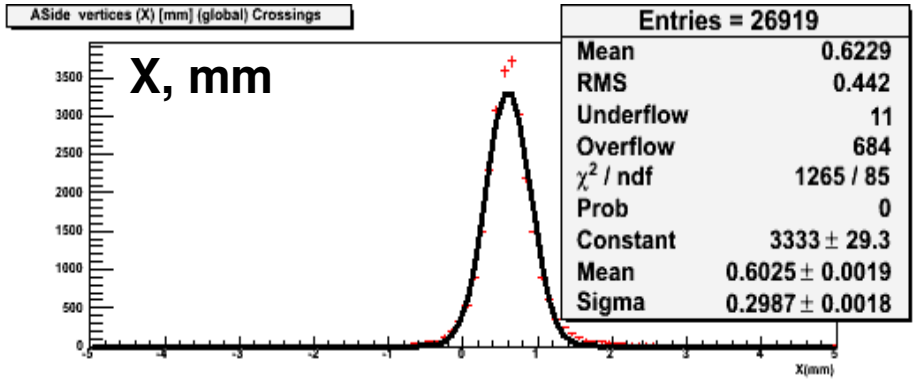
$p_T(\mu_1)$ = 3.6 GeV, $p_T(\mu_2)$ = 2.6 GeV, m($\mu\mu$)= 3.04 GeV

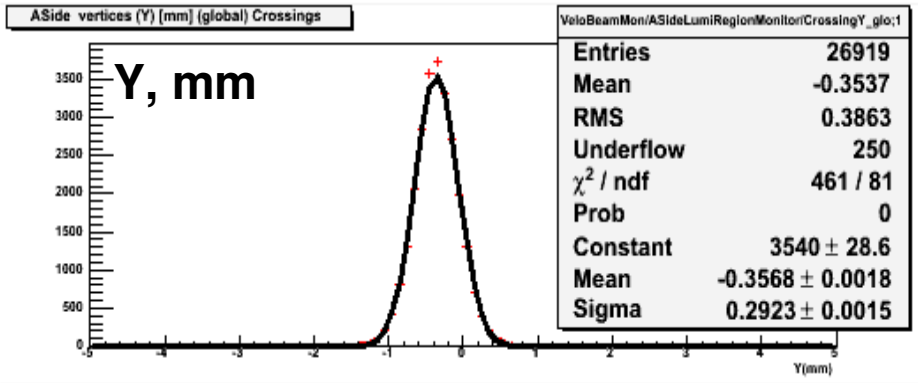

A few highlights from
LHCb for SPC
LHCb
11.12. 2009 5:50:50
Run 63691 Event 472 bId 2209

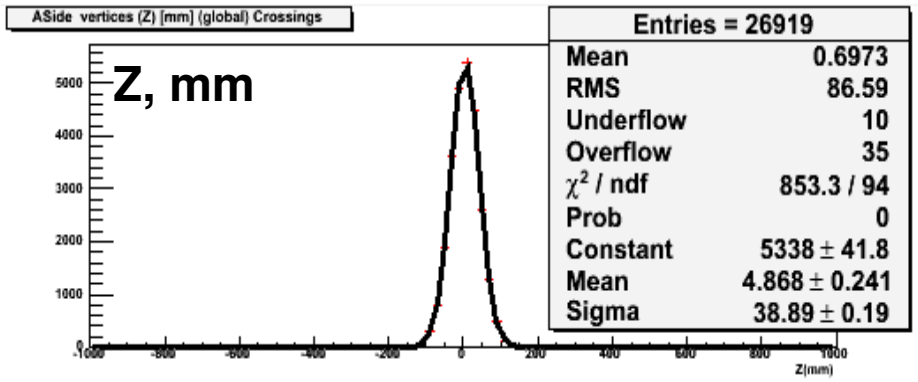
pp interaction vertex as seen by VELO

(VELO is halfway to nominal operation position: each side is 15 mm away from the nominal position)

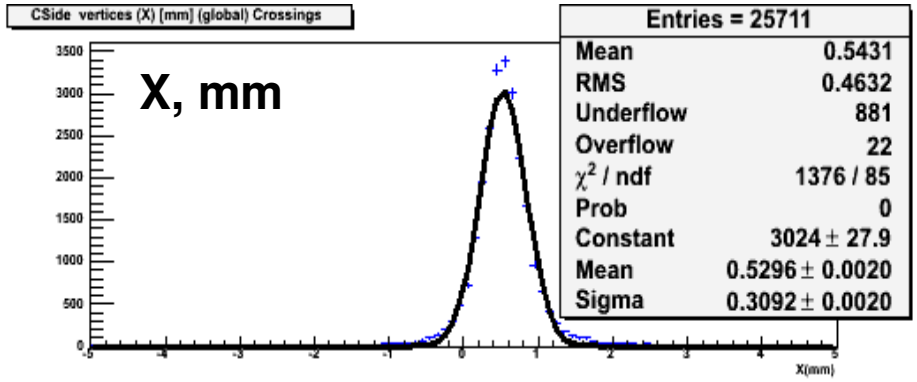
A-side

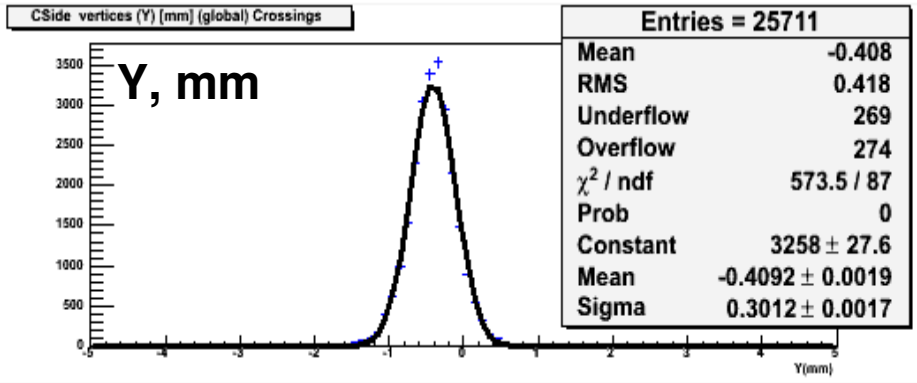


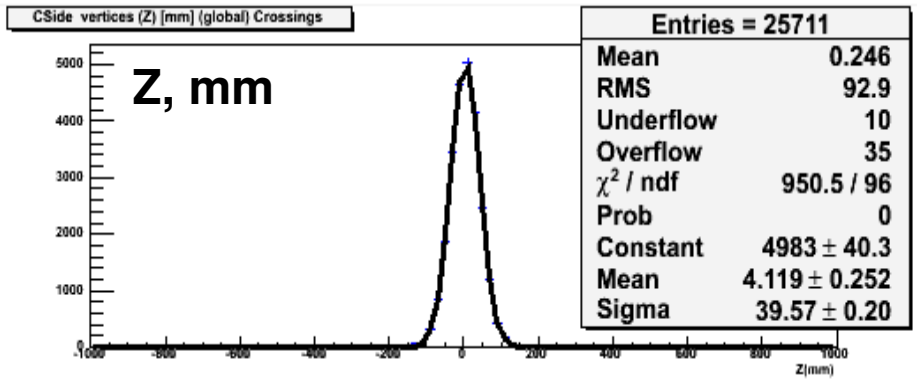




C-side

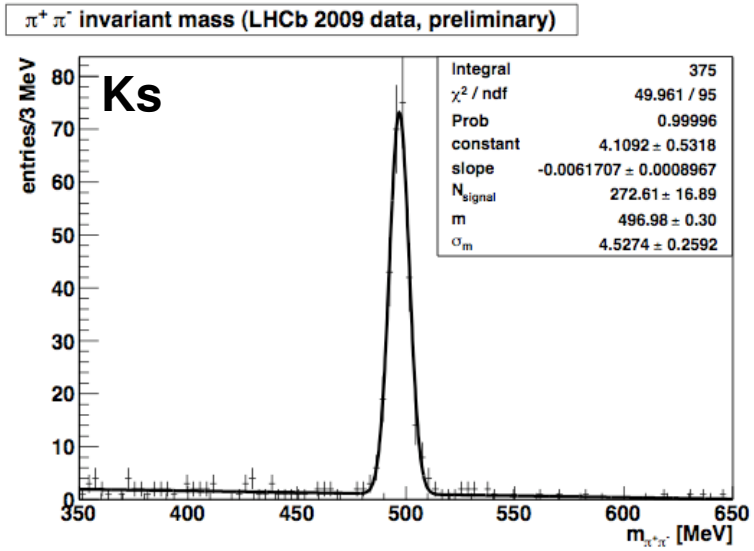


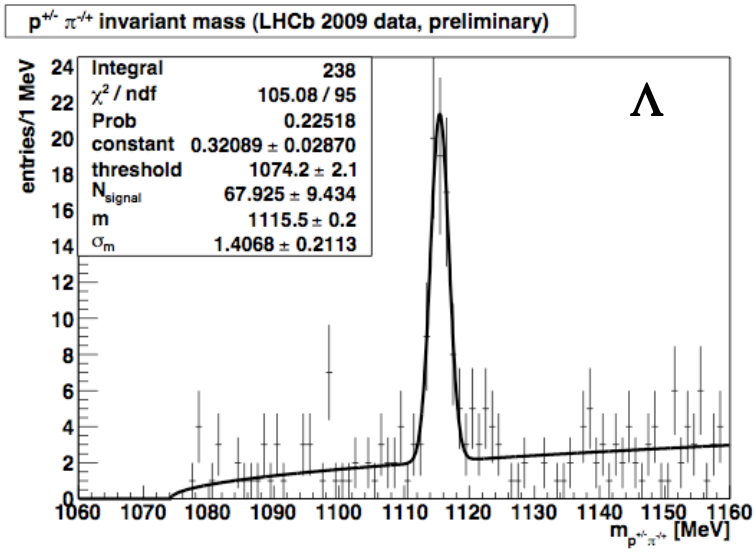




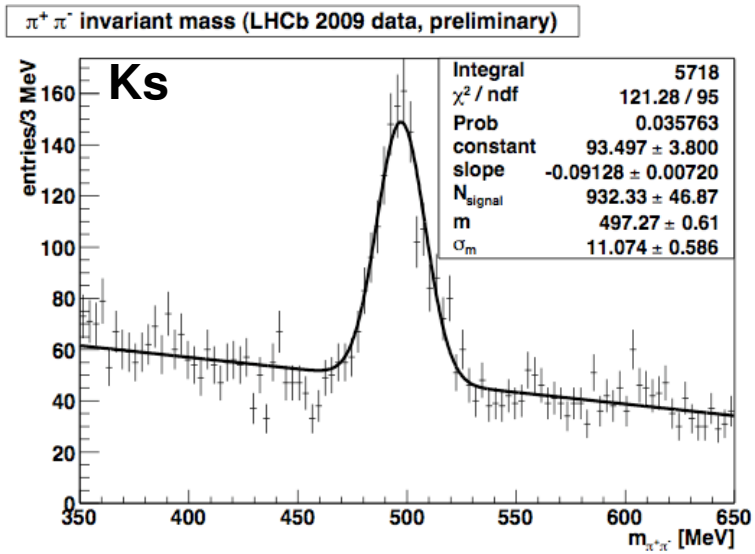
VELO + Outer Tracker + Silicon Tracker see K_S and Λ

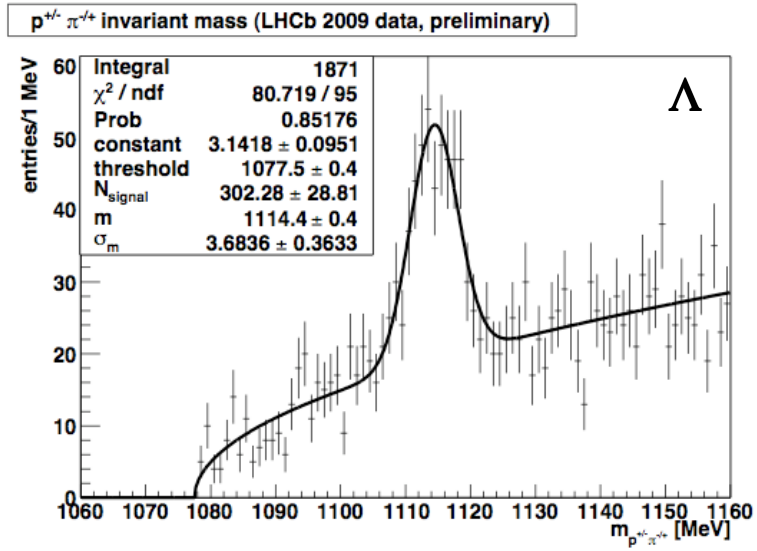
Using all tracking power, especially VELO !!!



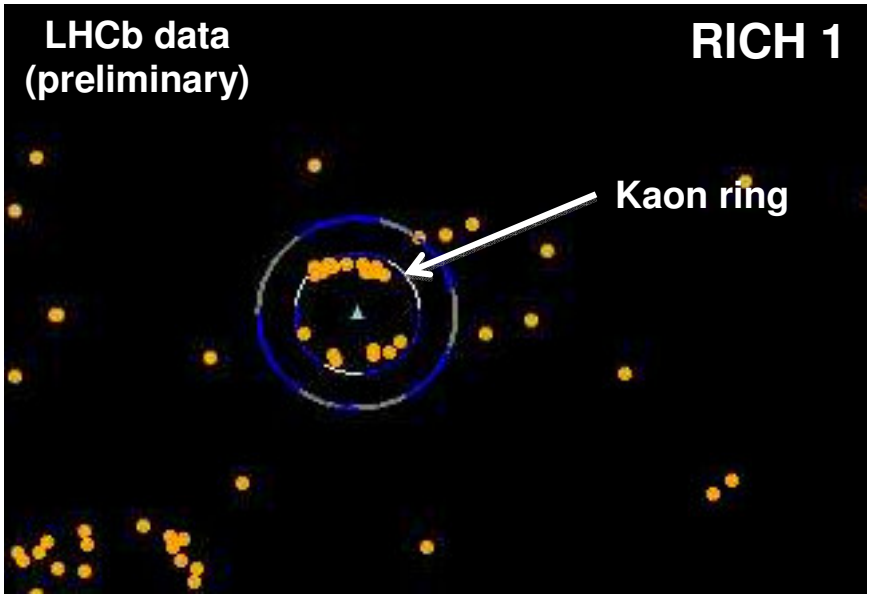


Tracking without VELO

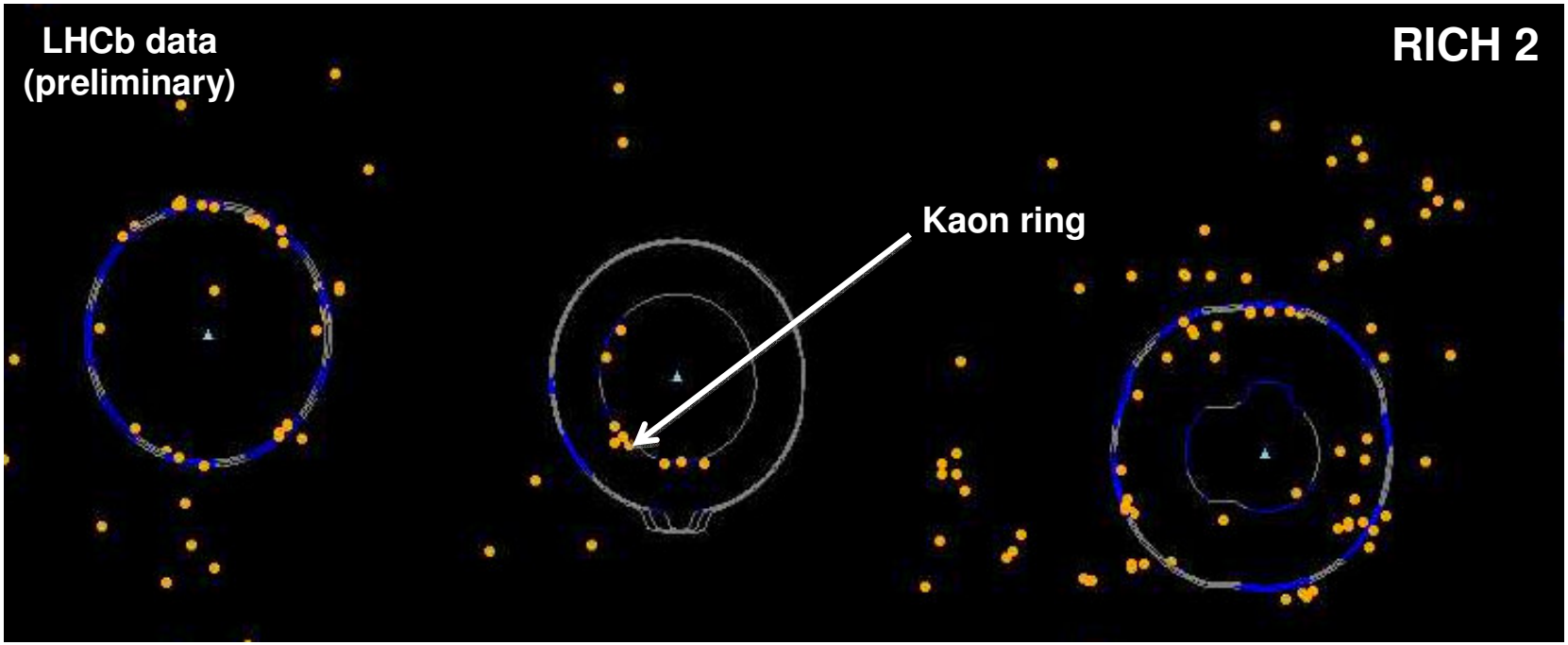




RICH identifies kaons



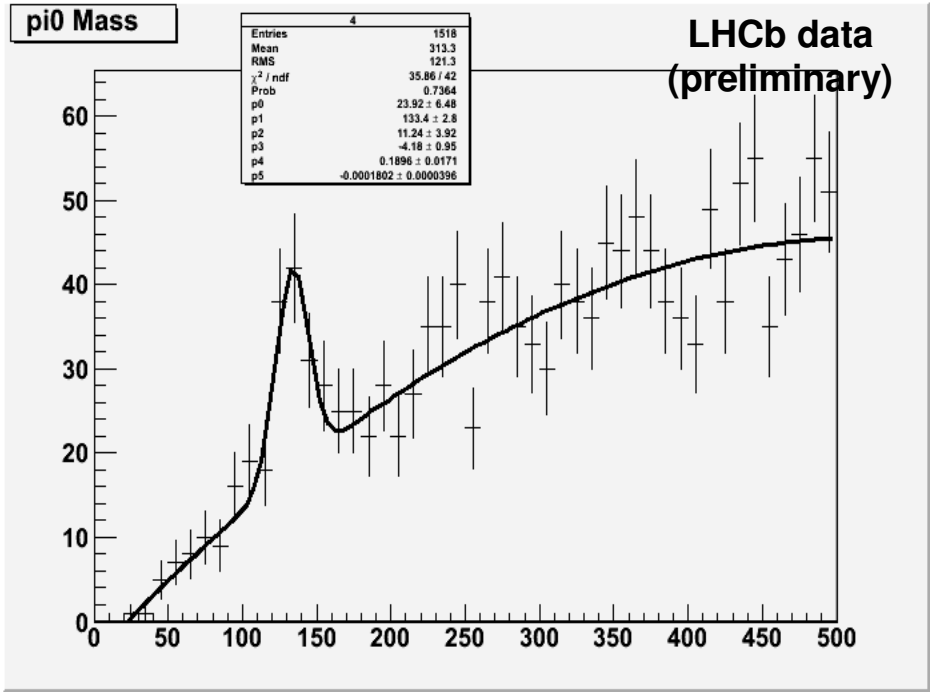
Orange points – photon hits
Continuous lines – expected distribution for each particle hypothesis (proton below threshold)



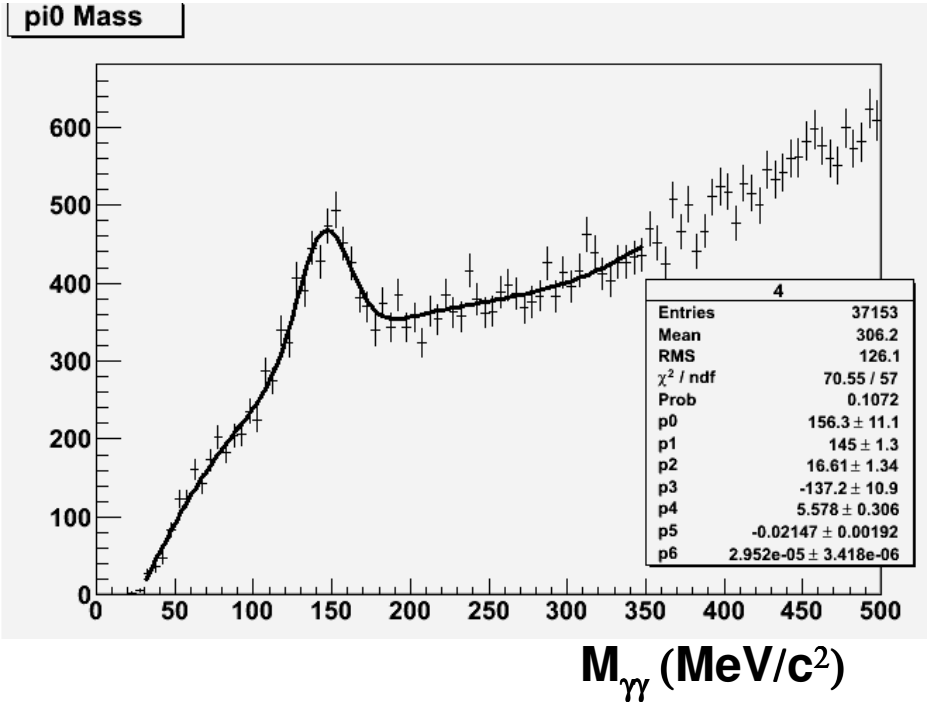
ECAL reconstructs π^0 signal

First data : 23 November 2009, No B-field

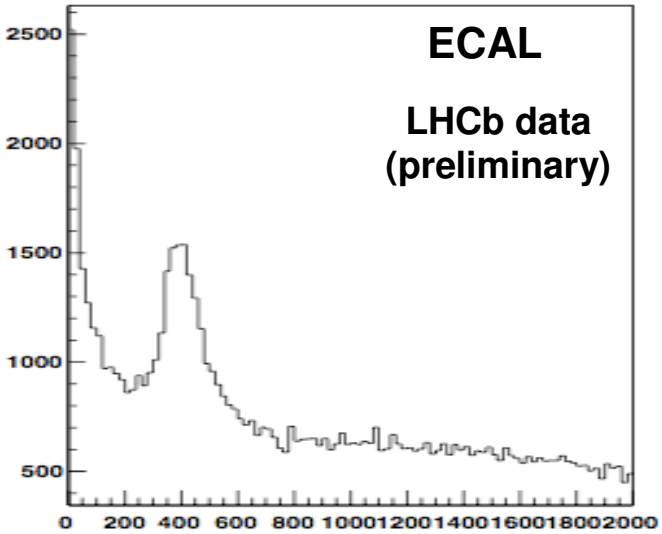
$\langle m \rangle = (133 \pm 3)$ MeV/c^2
$\sigma = (11 \pm 4)$ MeV/c^2

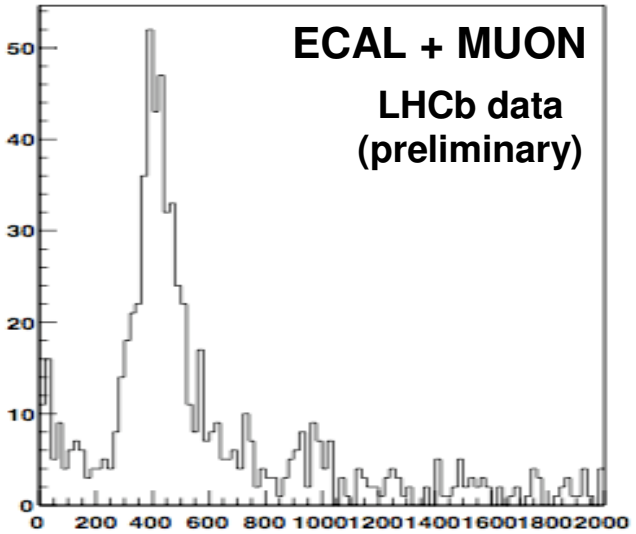


Now π^0 peak can be routinely monitored on-line:

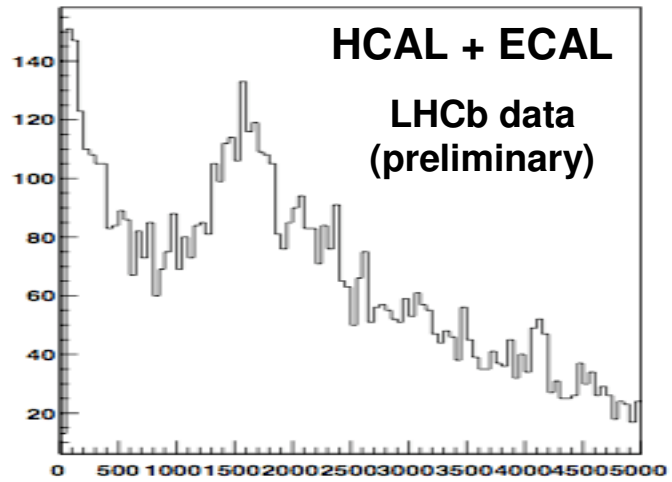


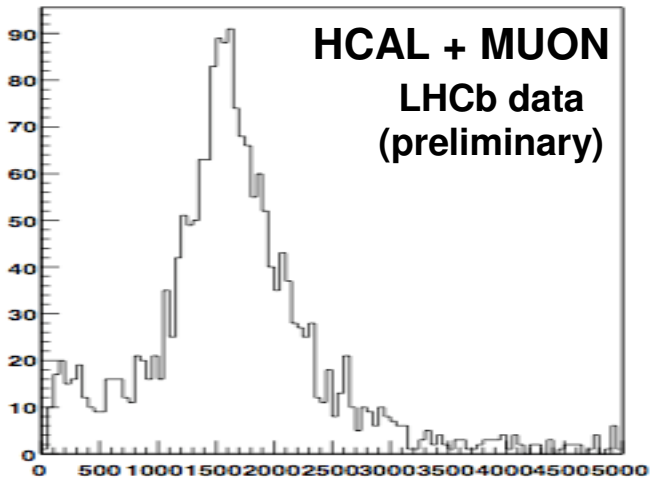
MIP identification using ECAL, HCAL & Muon





E_{ECAL} *(MeV)*

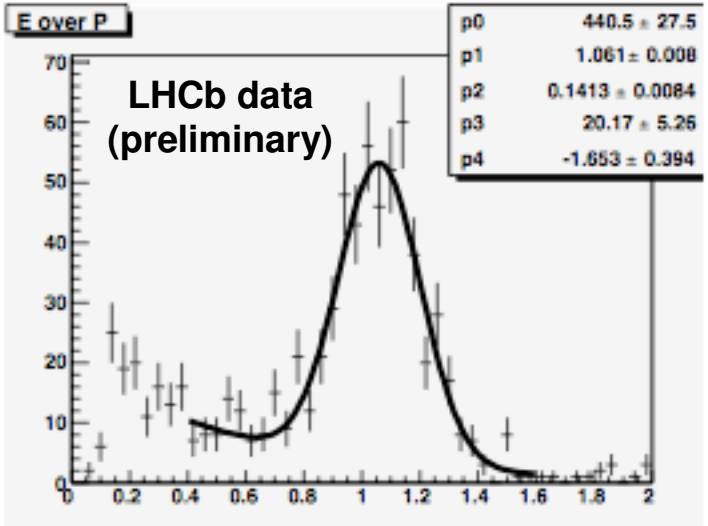




E_{HCAL} *(MeV)*

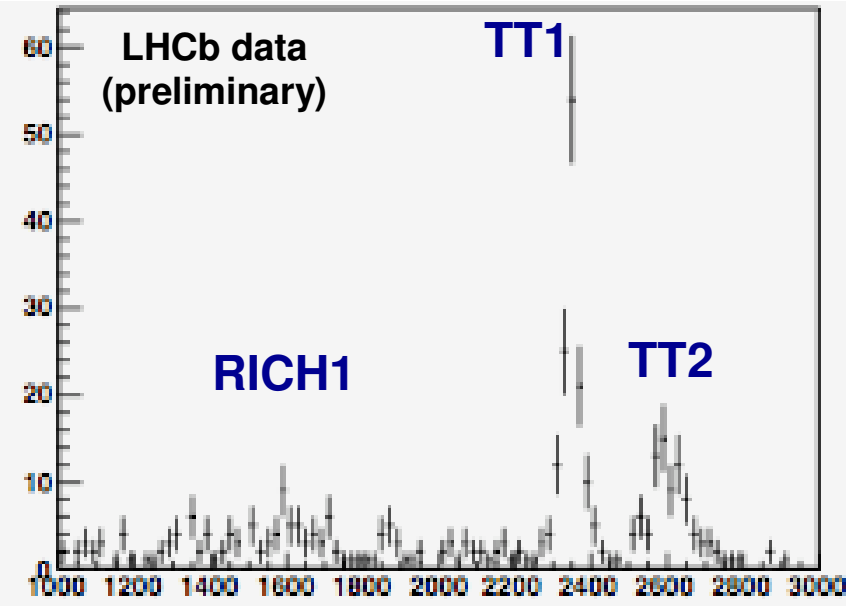
First glance at the material distribution using γ conversions upstream the magnet: Tracker system and ECAL

$M(e^+e^-) < 200$ MeV/c^2 for any pair of the oppositely charged tracks



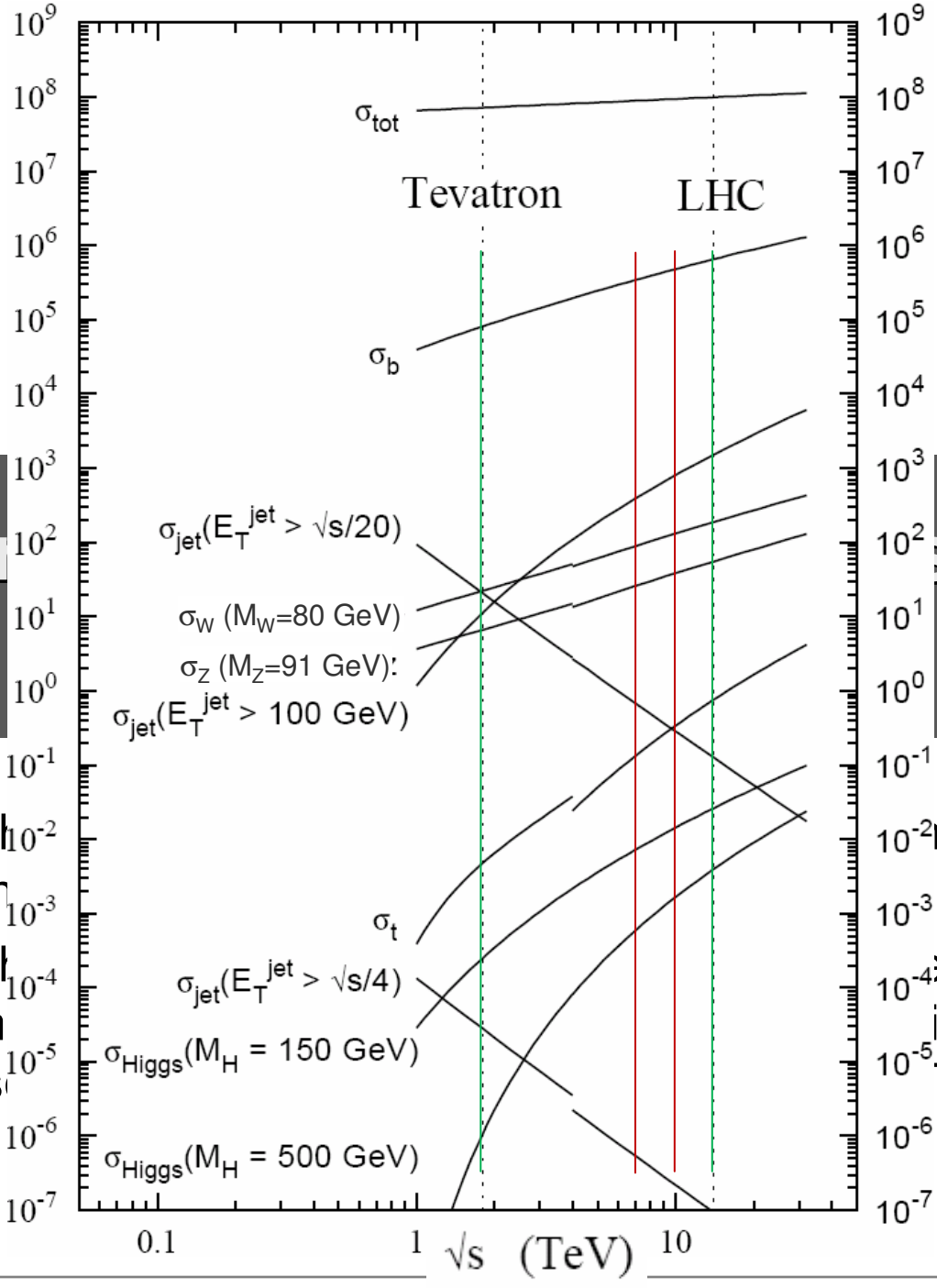
E / P

Z positions of the vertices reconstructed from 2 tracks with $M(ee) < 200$ MeV & $E/p > 0.7$ strongly peak at the location of the 2 stations of the Trigger Tracker: TT1 & TT2



Z, cm

Integr section



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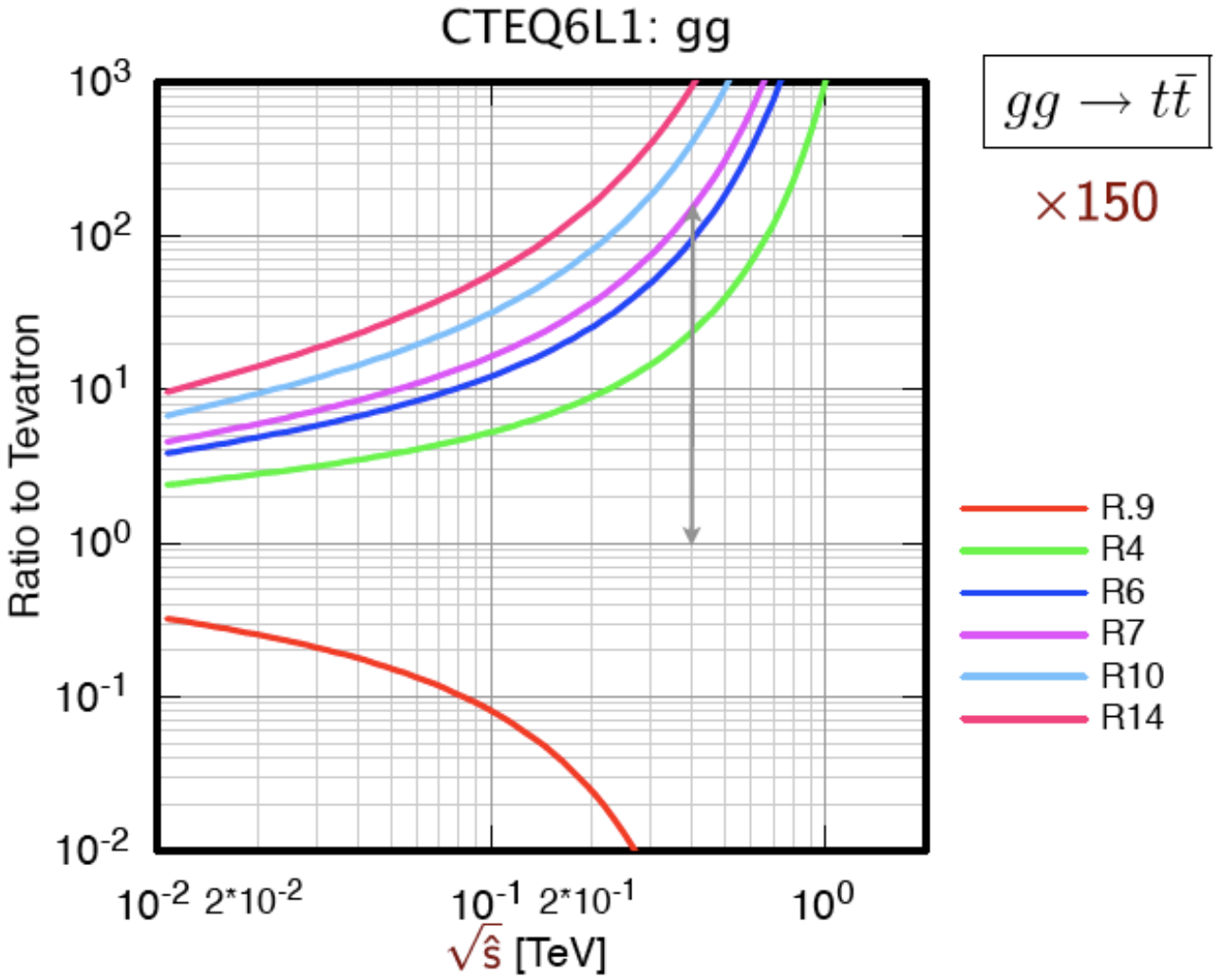
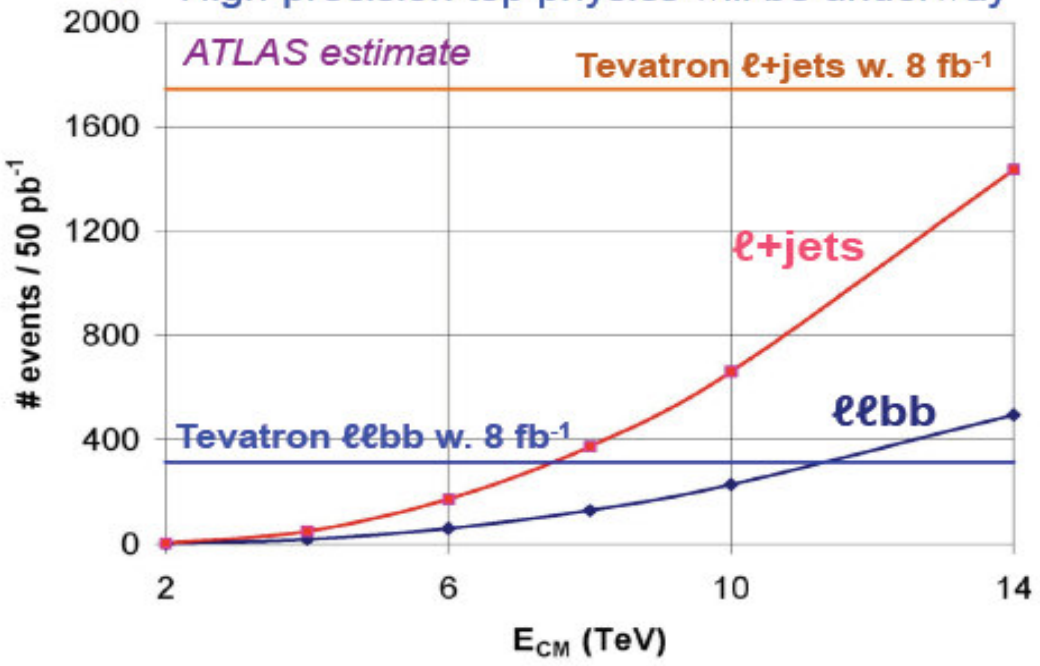
Luminosity Ratios



Top quark

- Background to new physics searches – must measure cross-section & properties in data
- Expected Tevatron statistics provide a benchmark:
  - Cross-section statistical precision will then be comparable to other uncertainties
  - High-precision top physics will be underway



~50 pb^{-1}@14 TeV would match full Tevatron sample

- lose ~factor 2 in cross-section dropping to 10 TeV
- lose ~another factor 2 dropping to 8 TeV

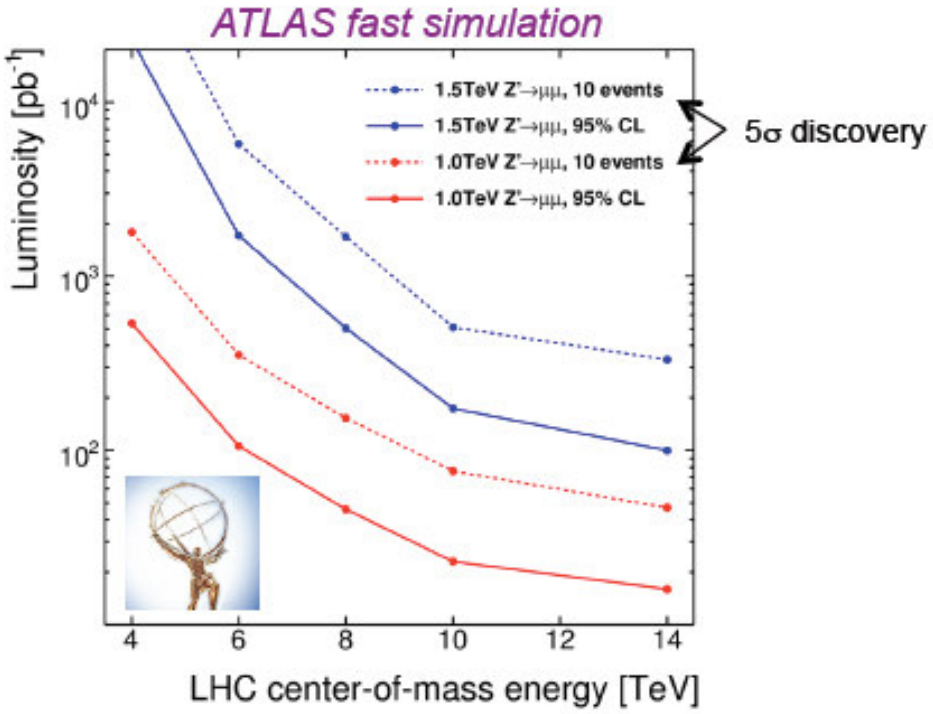
Below 8 TeV samples will be rather small, with a few tens of pb^{-1}

Catch up with Tevatron with $s^{1/2}$ = **8-10 TeV** and ~**200-100 pb^{-1} g.d.**

Z'

Z': Heavy partner of the Z (SSM)

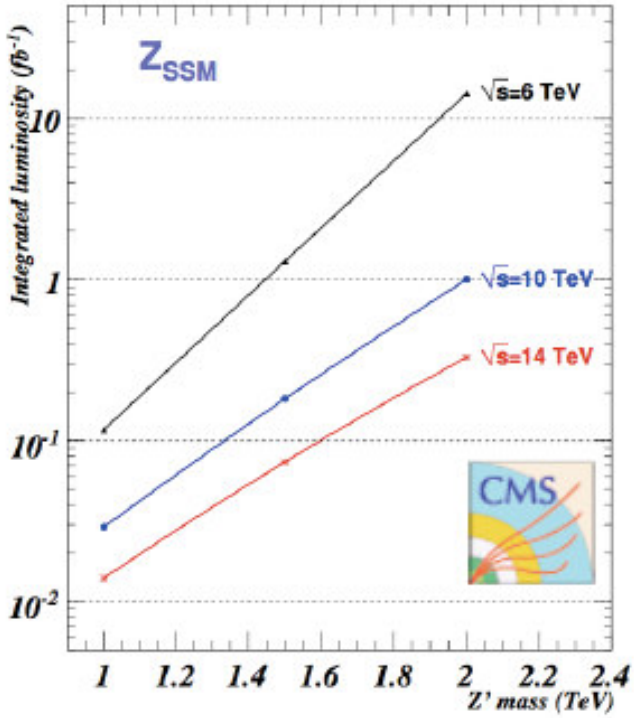
- Very clean experimental signal: $Z' \rightarrow \ell\ell$
- Tevatron 95% CL limit at $m_{Z'}$ =1 TeV



Needed luminosity for 95%CL exclusion at $m_{Z'}$ = 1 TeV :

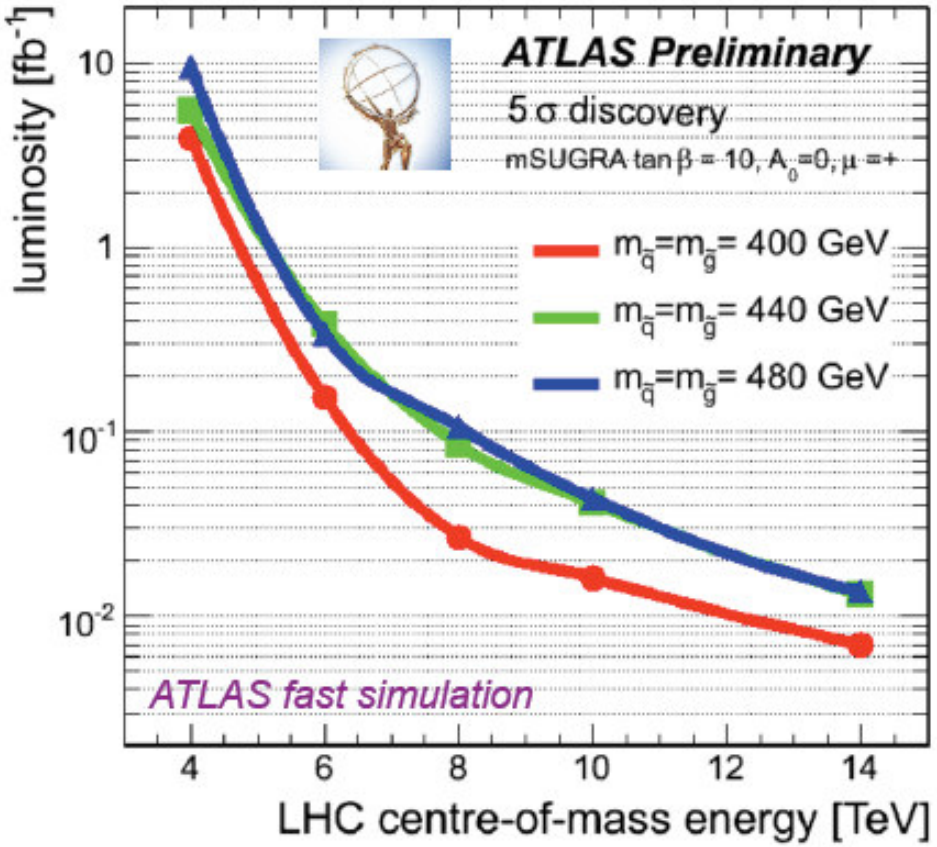
$s^{1/2}$: 14 → 10 → 6 TeV

Lumi: 13 → 30 → 110 pb^{-1}



SUSY, an example

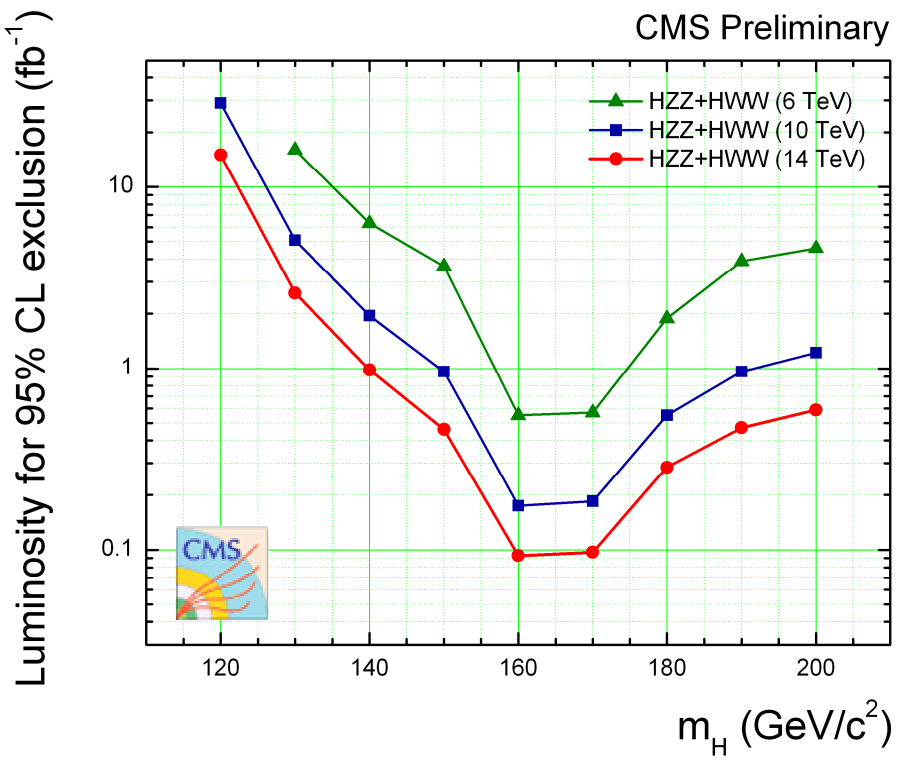
- ℓ+jets+missing-E_T channel
  - Not most sensitive, but will be usable before inclusive jets +missing-E_T analysis
- Tevatron limit currently is 380 GeV in this model ($m_{\tilde{q}} = m_{\tilde{g}}$)
  - plot shows 3 masses above this
- We will be sensitive to a region overlapping with ultimate Tevatron reach
- Below $E_{cm} \approx 8$ TeV, the sensitivity collapses



5σ discovery beyond current Tevatron limits is possible with
$s^{1/2}$ = 8-10 TeV and **~30-15 pb^{-1} g.d.**

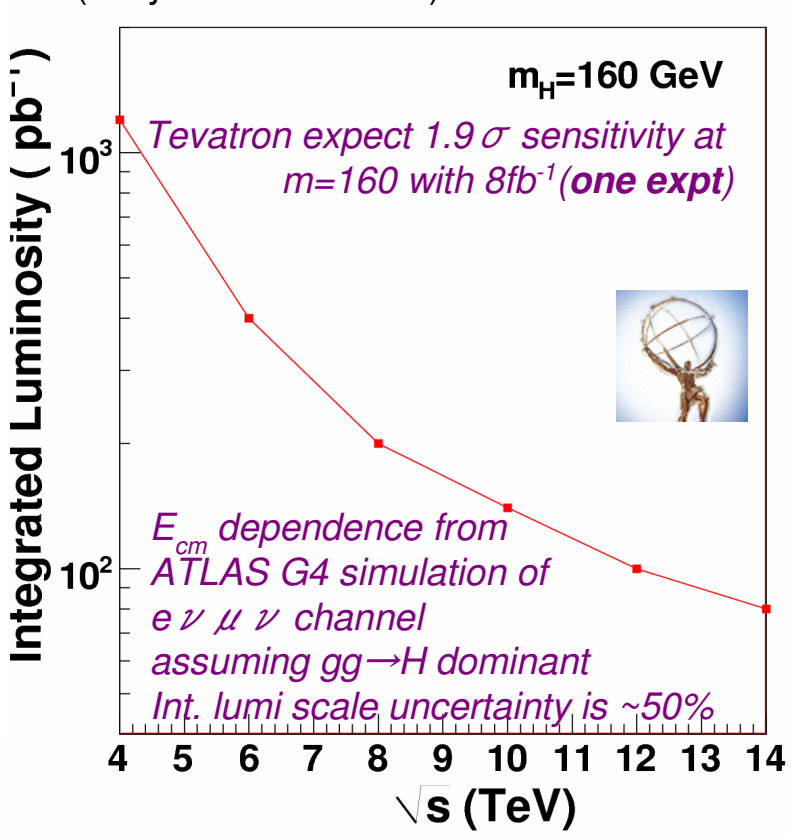
Higgs 95% CL at LHC GPD , H→ weak bosons, indicative

Combined H→WW + H→ZZ: lumi for 95% CL



- Energy $s^{1/2}$ 14 → 10 → 6 TeV
- Lumi needed 0.1 → 0.2 → 0.6 fb^{-1}

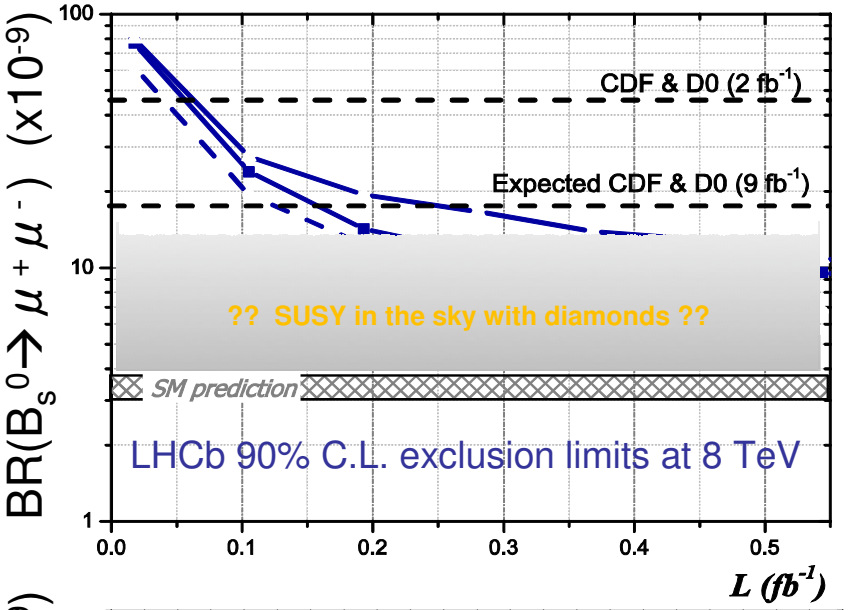
Compare sensitivity to Tevatron with 8 fb^{-1}
(only H→WW→ lνlν)

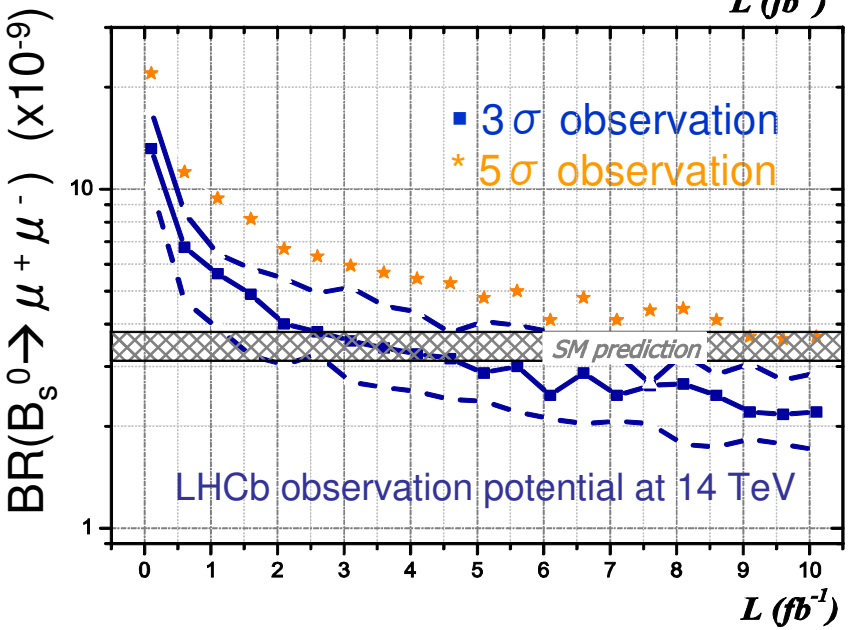


- Massive loss of sensitivity below 6 TeV

To challenge Tevatron with **$s^{1/2}$ = 7-10 TeV**, we need ~**300-200 pb^{-1} g.d.**

Physics reach for BR($B_s^0 \to \mu^+\mu^-$)





- as function of integrated luminosity (and comparison with Tevatron)

At $\mathbf{s^{1/2} = 8\ TeV}$, need ~**0.3-0.5 fb^{-1} g.d.** to improve on expected Tevatron limit

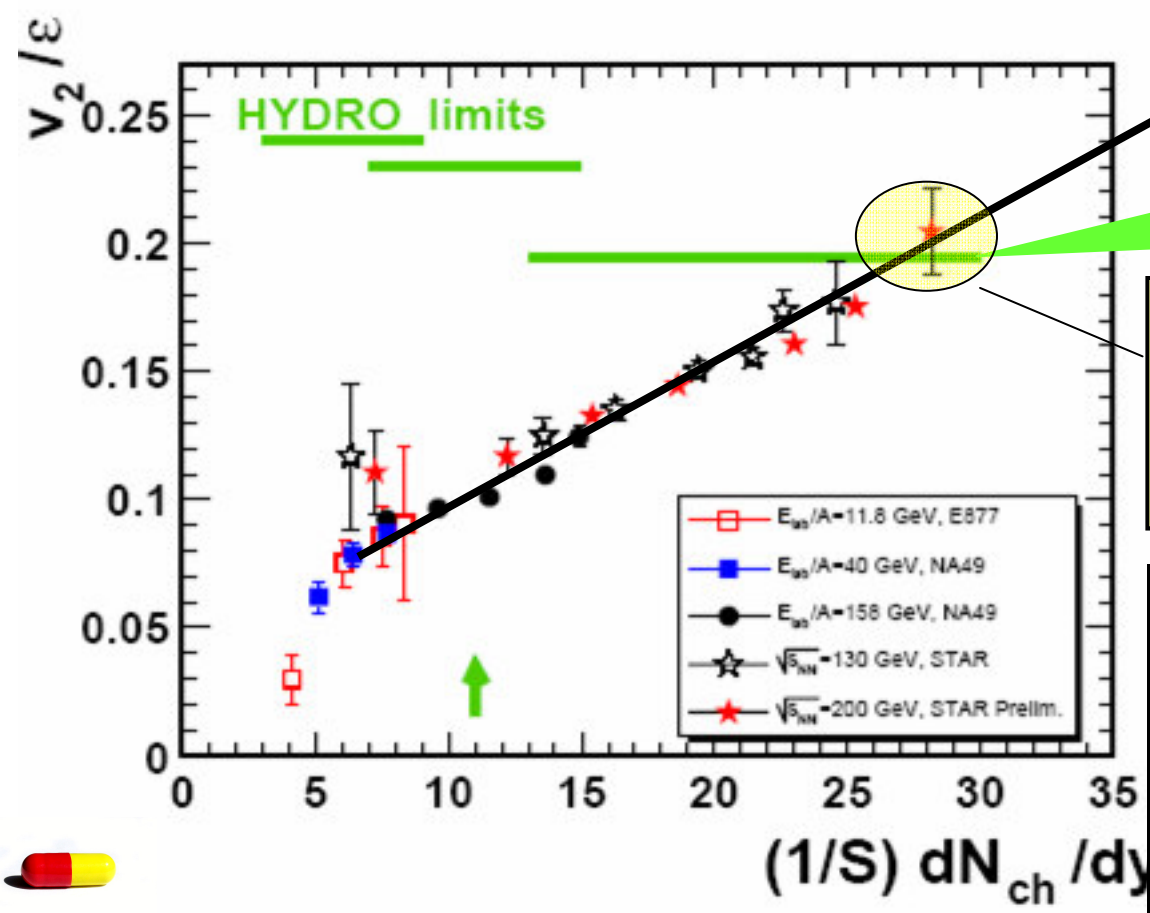
Collect ~3 fb^{-1} for 3σ observation of SM value

Heavy Ions: Flow at LHC

- one of the first and most anticipated answers from LHC
  - 2nd RHIC paper: Aug 24, 22k MB events, **flow surprise** (v_2)
    - Hydrodynamics: modest rise (Depending on EoS, viscosity, speed of sound)

LHC ?

increase of flow



BNL Press release, April 18, 2005:

Data = ideal Hydro

"Perfect" Liquid

New state of matter more remarkable than predicted – raising many new questions

LHC will either

confirm the RHIC interpretation

(and measure parameters of the QGP EoS)

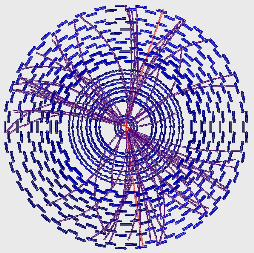
OR

.....

LHC:

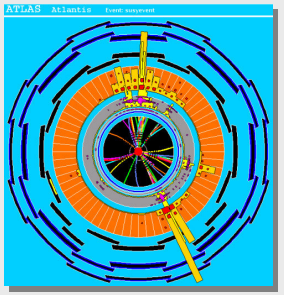
the present and the (near) future

LHC Physics in 2010-2011



First beams: very early physics - **rediscover SM physics**

Detector synchronization, in-situ alignment and calibration



10 pb^{-1}: Standard Model processes

measure jet and lepton rates, observe W, Z bosons

first look at possible **extraordinary signatures**…

30 pb^{-1}

Measure Standard Model Processes (at 10TeV need ~ 30pb^{-1}):

~ 10^4 Z $\rightarrow$ e+e- (golden Z's for detector studies (1%))

~ 10^5 W $\rightarrow$ eν

~ 10^3 ttbar (measure σ to 10%)

Background for new physics

Need to understand very well

Initial Higgs searches and searches for physics beyond the SM

> 200 pb^{-1}

Entering Higgs discovery era and explore large part of SUSY and new resonances at ~ few TeV

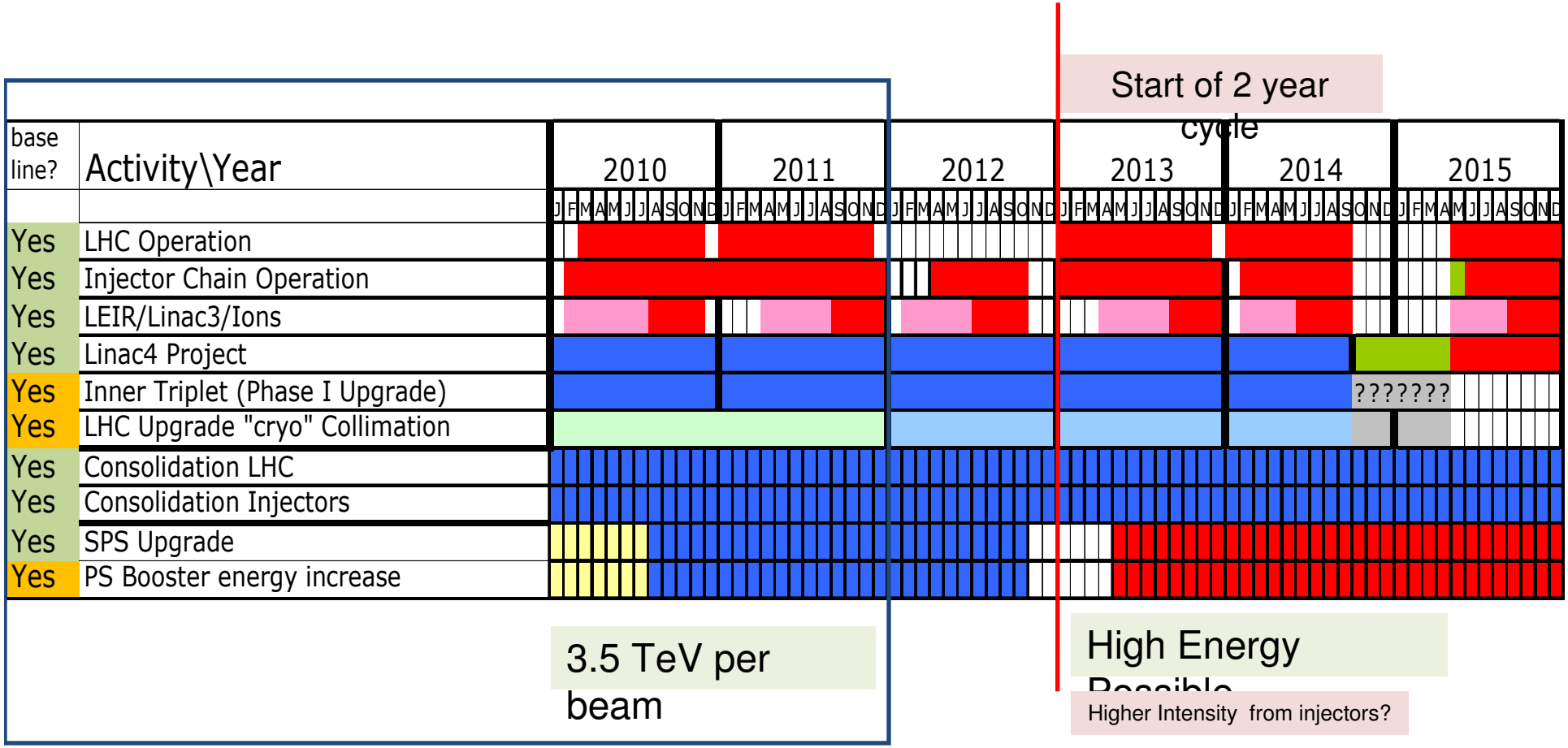
Beam Energy; Chamonix

- Simulations for safe current used pessimistic input parameters (RRR.....) but have no safety margins
- For 2010, 3.5 TeV is safe
  - **Measure the RRR (asap) to confirm the safety margin for 3.5TeV/beam**
- Without repairing the copper stabilizers, **5 TeV is risky**

Decision from Management/detectors following Chamonix

- Run at 3.5 TeV/beam up to a predefined integrated luminosity with a date limit. Then consolidate the whole machine for 7TeV/beam.

Time lines (Very Preliminary)



Next year we talk about the far future!

Luminosity

$$L = \frac{N^2 k_b f}{4\pi\sigma_x\sigma_y} F = \frac{N^2 k_b f \gamma}{4\pi\varepsilon_n \beta^*} F$$

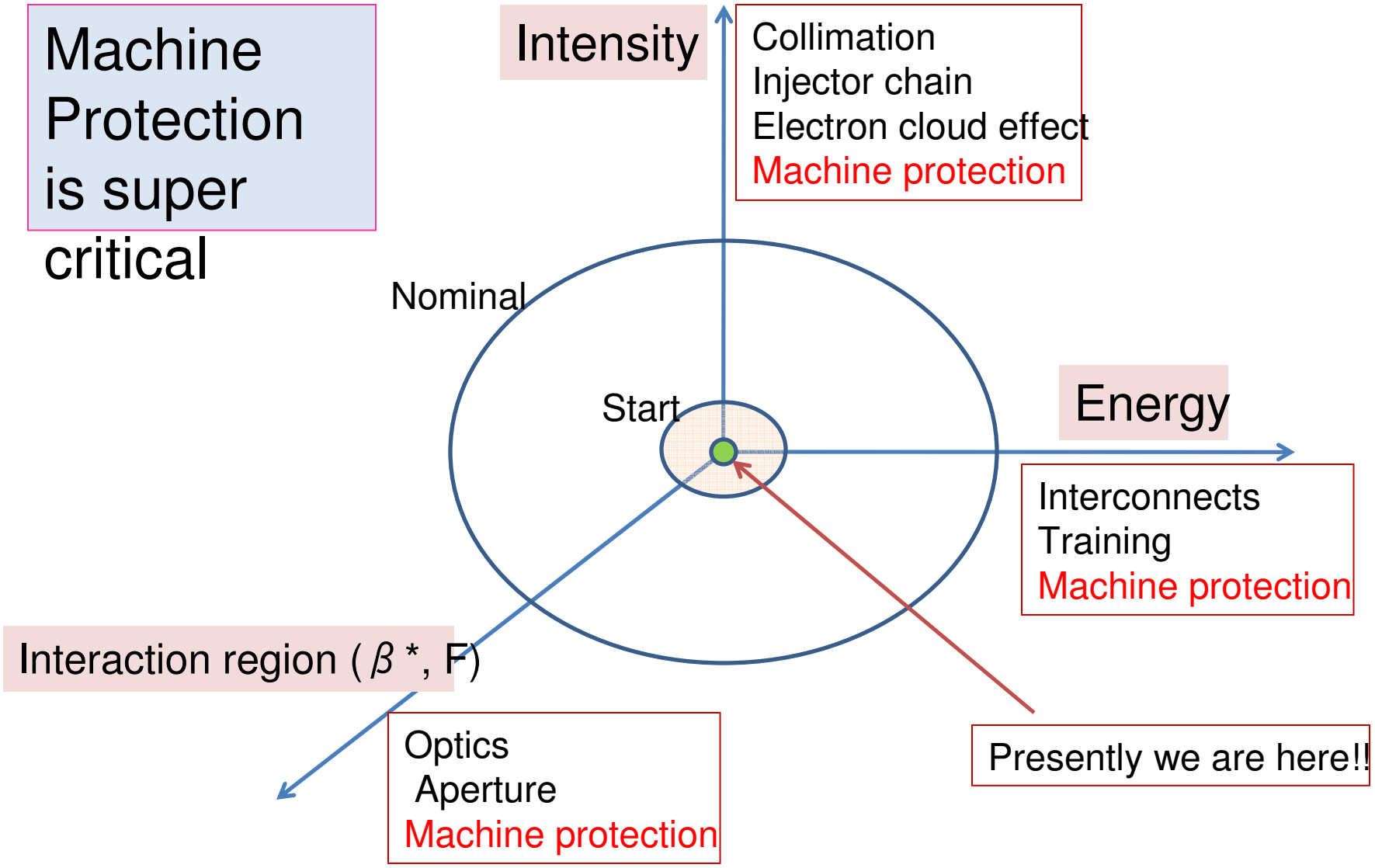
- Nearly all the parameters are variable (and not independent)
  - Number of particles per bunch N — Intensity
  - Number of bunches per beam k_b — Intensity
  - Relativistic factor (E/m_0) γ — Energy
  - Normalised emittance ε_n
  - Beta function at the IP β^* — Interaction Region
  - Crossing angle factor F — Interaction Region
    - Full crossing angle θ_c
    - Bunch length σ_z
    - Transverse beam size at the IP σ^*

$$F = 1/\sqrt{1+\left(\frac{\theta_c \sigma_z}{2\sigma^*}\right)^2}$$

Roger Bailey

LHC performance drivers/limiters

Machine Protection is super critical



β^* and F in 2010

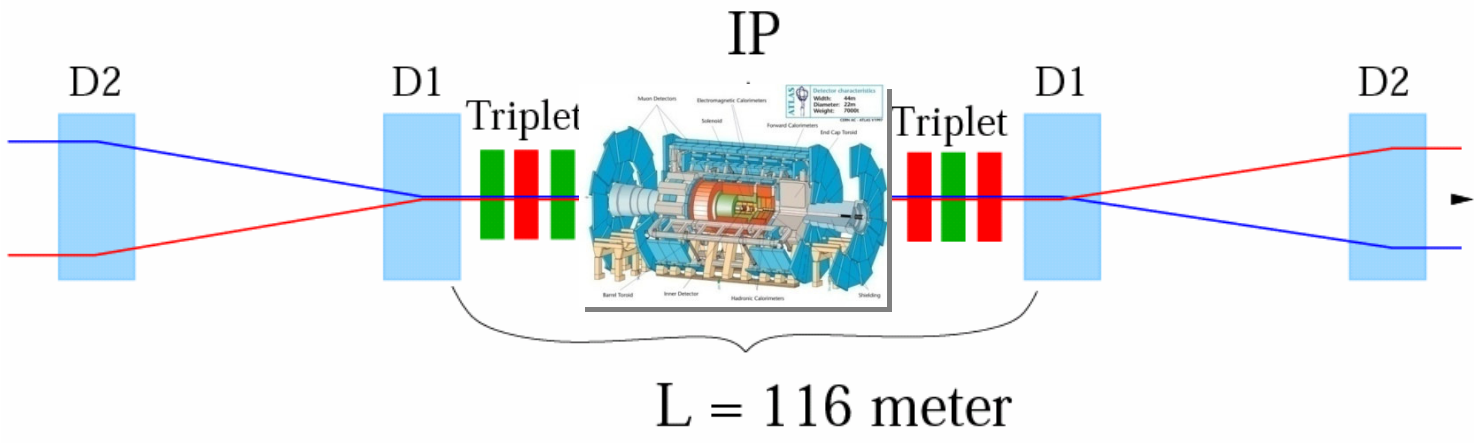
- Lower energy means bigger beam $\varepsilon_n = \varepsilon\gamma$ $\sigma = \sqrt{\varepsilon\beta}$
  - Less aperture margin
  - Higher β^*

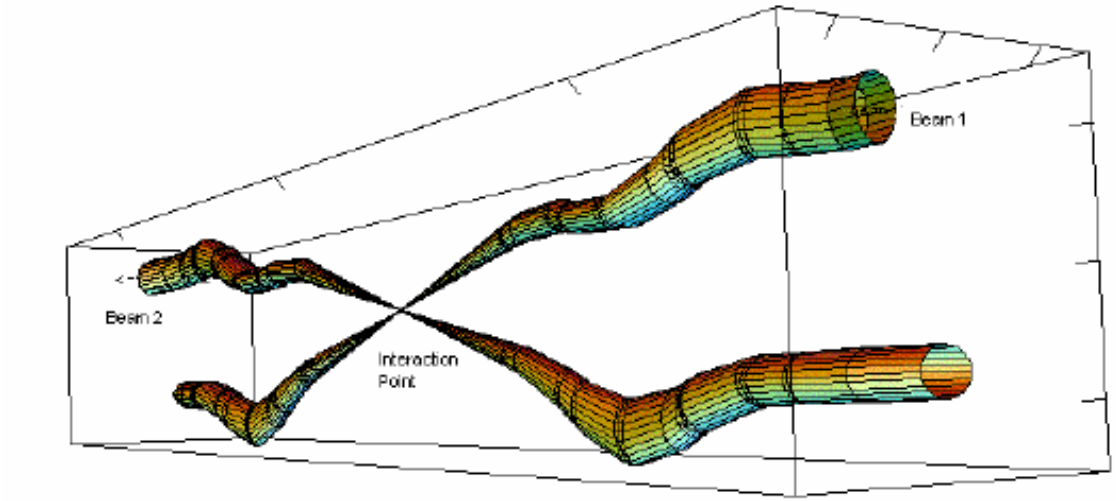
At max

- > 150 bunches requires crossing angle (beam-beam)
  - Requires more aperture
  - Higher β^*

- Targets for 3.5TeV
  - 2/2.5 m without/with crossing angle in 2010
  - 2m with crossing angle in 2011

Interaction Region - F

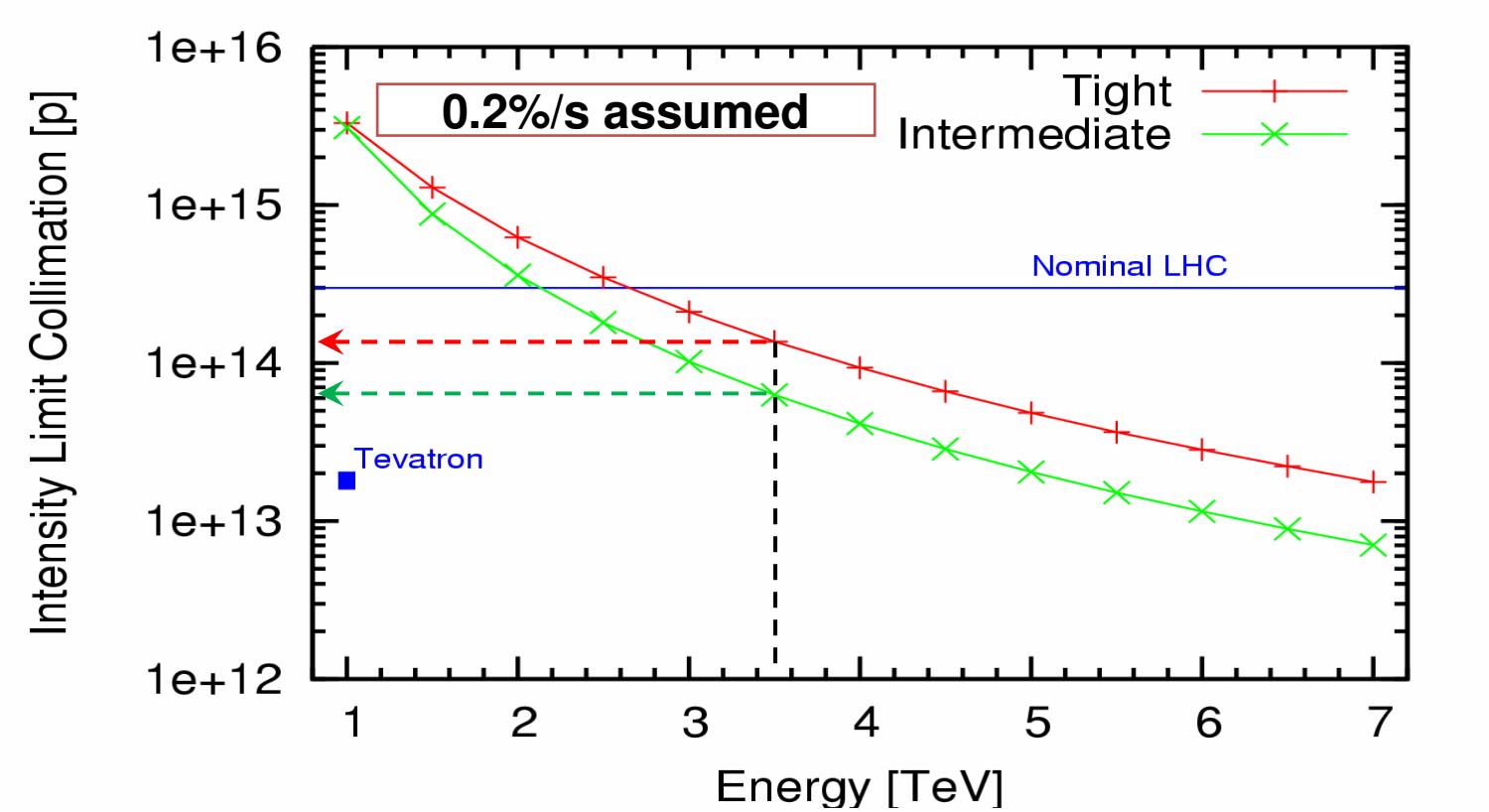




Relative beam sizes around IP1 (Atlas) in collision

With > 150 bunches per beam, need a crossing angle to avoid parasitic

“Intensity limits” Collimation (2010)



Collimator “limit” around 6 10^{13} protons per beam at 3.5TeV with “intermediate” settings (about 20% nominal intensity)

33.6 MJ stored beam energy

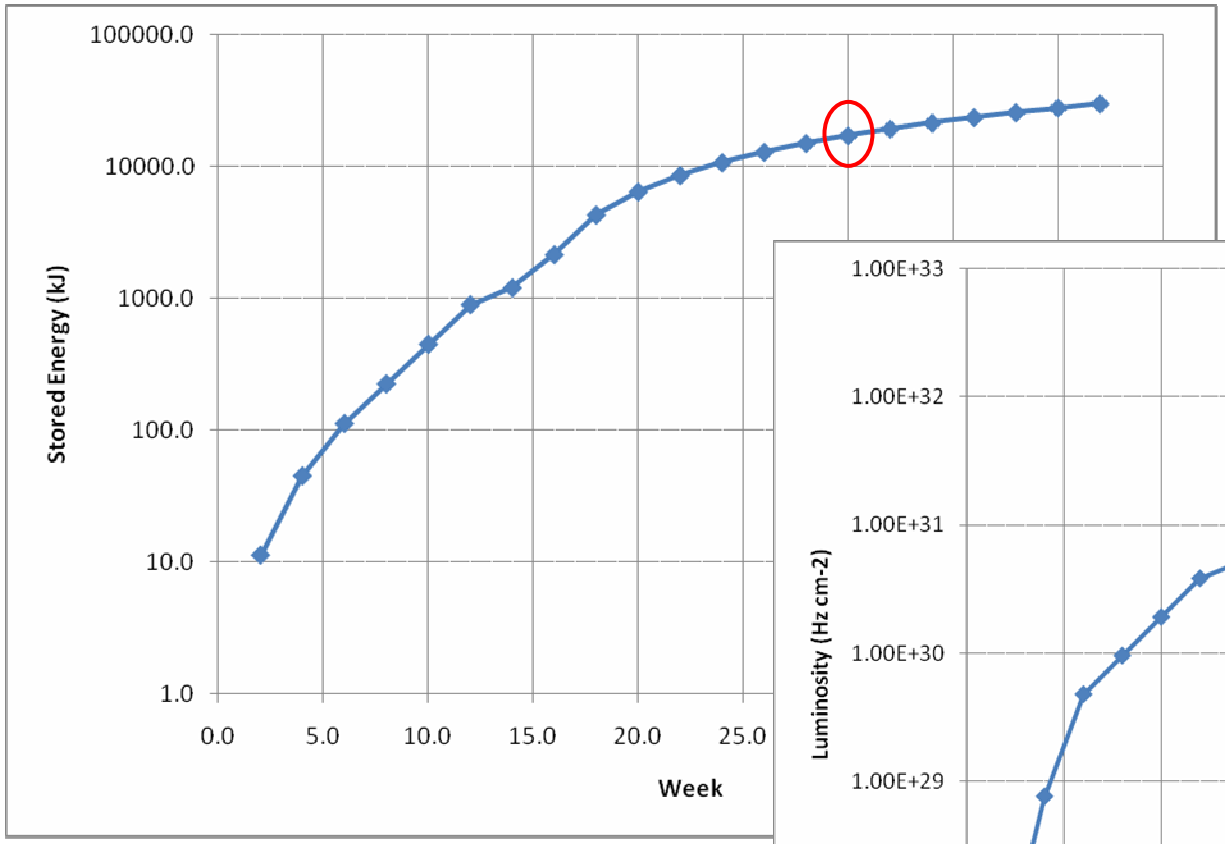
Soft limit, not yet well defined, 0.2%/s loss rate totally arbitrary (8 minute lifetime)

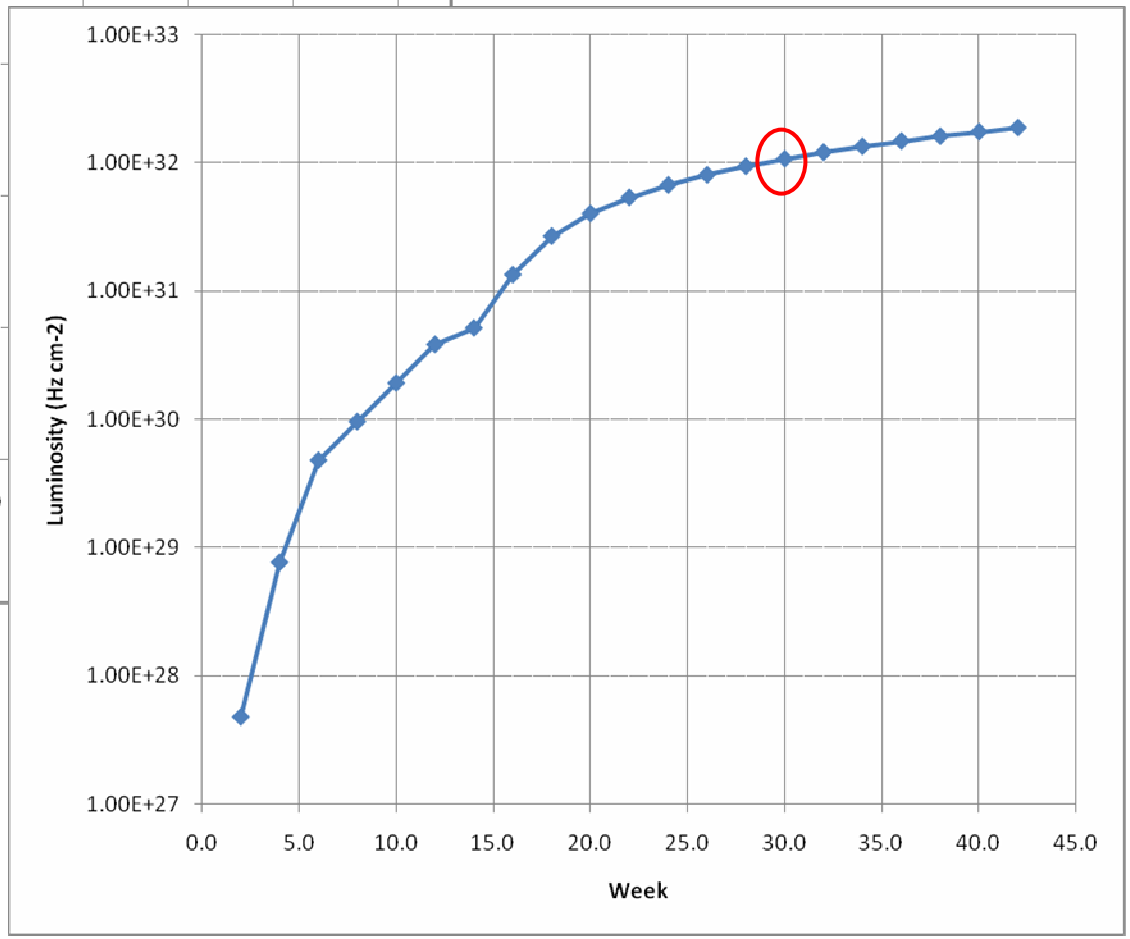
Strategy for Increasing the Beam Intensity

- The magic **number for 2010/11 is 1 fb^{-1}**. To achieve this, the LHC must **run flat out at $2x10^{32}$ $cm^{-2}s^{-1}$ in 2011**,
    - Correspond to 8e10 ppb, 700 bunches, with a stored energy of 35 MJ (with β^*=2 m and nominal emittance).

Progression (2)

- After 30 weeks: ~1E32 cm-2s-1, 12 MJ.



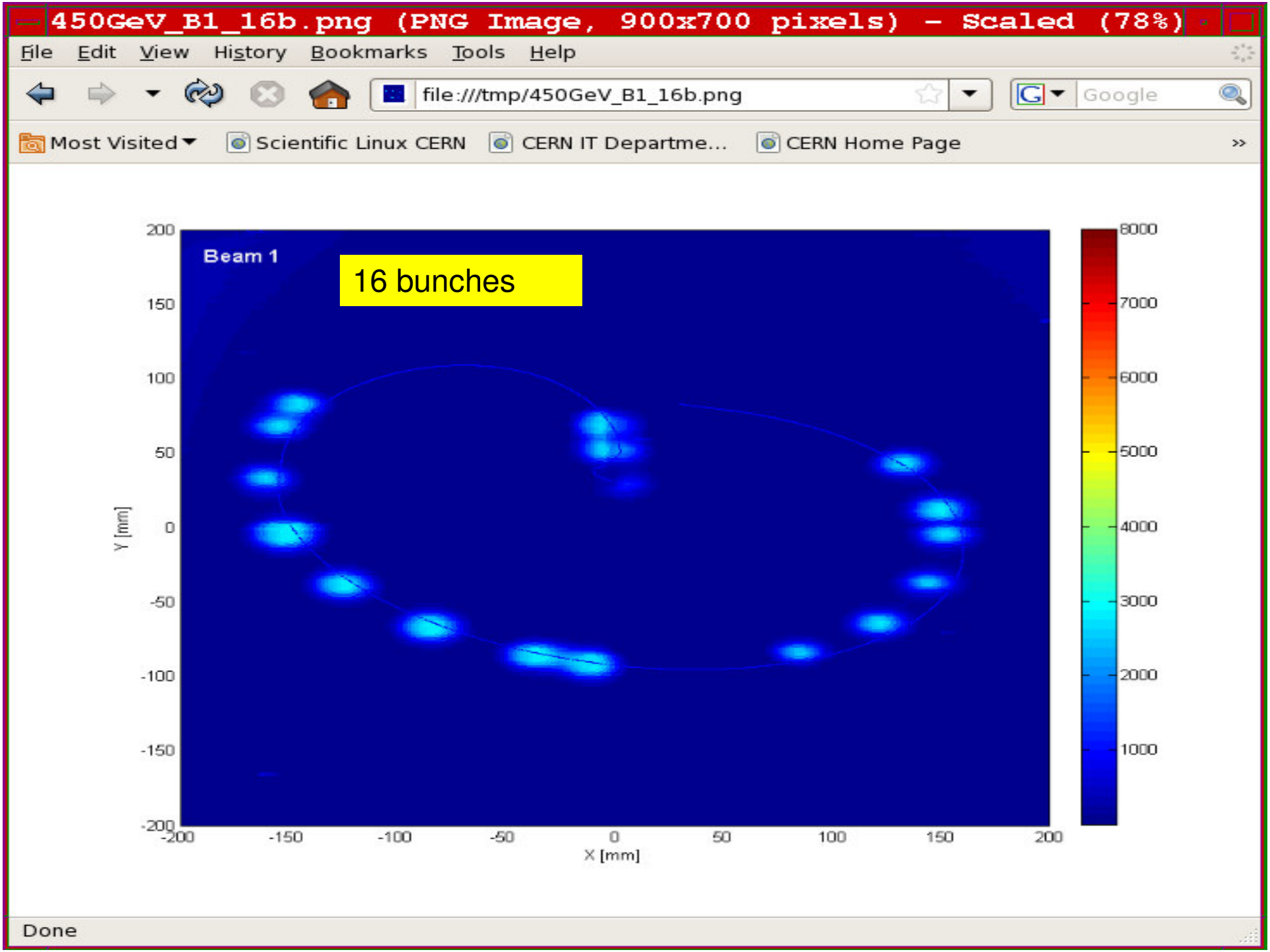


2011

3.5 TeV: run flat out at ~100 pb^{-1} per month

	No. bunches	ppb	Total Intensity	Beam Stored Energy (MJ)	beta*	Peak Lumi	Int Lumi per month
50 ns	432	7 e10	3 e13	17	2	1.3 e32	~85
Pushing intensity limit	720	7 e10	5.1 e13	28.2	2	2.2 e32	~140
Pushing bunch current limit	432	11 e10	4.8 e13	26.6	2	3.3 e32	~209

With these parameters we should be able to deliver 1 fb^{-1}


450GeV_B1_16b.png (PNG Image, 900x700 pixels) – Scaled (78%)
File Edit View History Bookmarks Tools Help
file:///tmp/450GeV_B1_16b.png
Google
Most Visited
Scientific Linux CERN
CERN IT Departme...
CERN Home Page
Beam 1
16 bunches
Y [mm]
X [mm]
200
150
100
50
0
-50
-100
-150
-200
8000
7000
6000
5000
4000
3000
2000
1000
Done

In summary

- We are finally entering the LHC era
- Ready to rediscover all the Standard Model
- ..and use it for “calibration”
- An entire new space of parameters opens up for the discovery of the “known unknown”..

In summary

…and there might be welcomed surprises

…without forgetting that….

…the only place in which success comes before work is in the dictionary