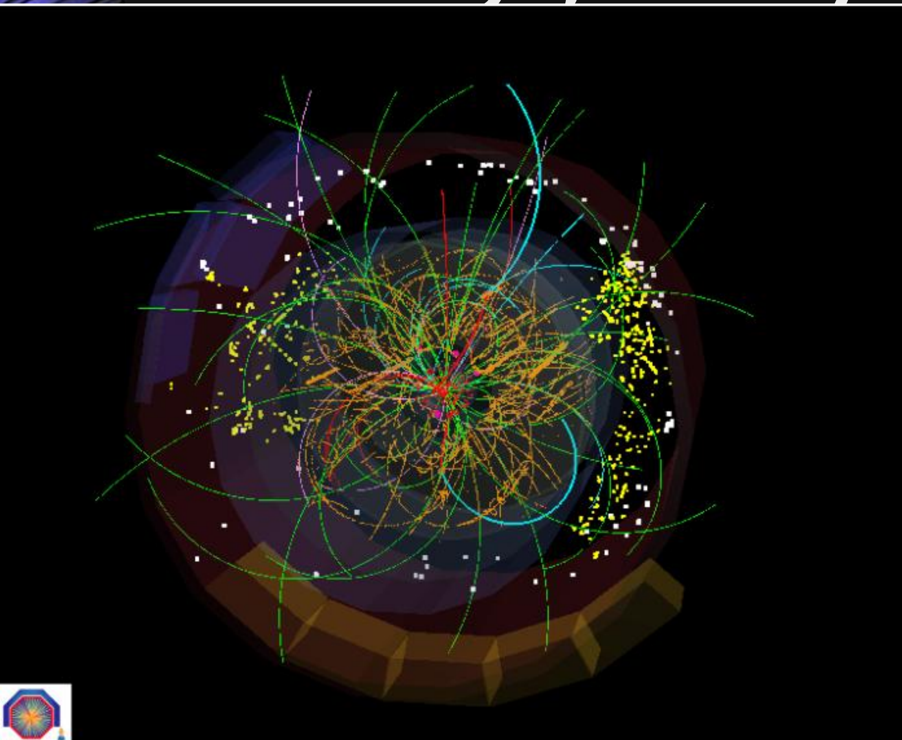
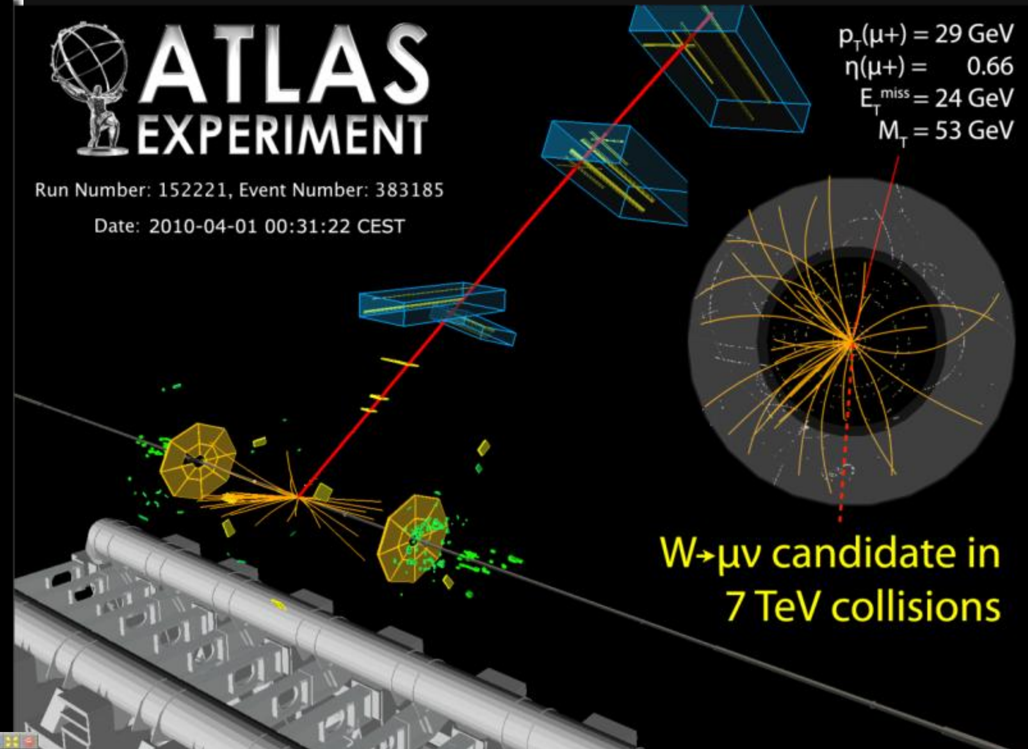
Status Report on the LHC Experiments and Computing

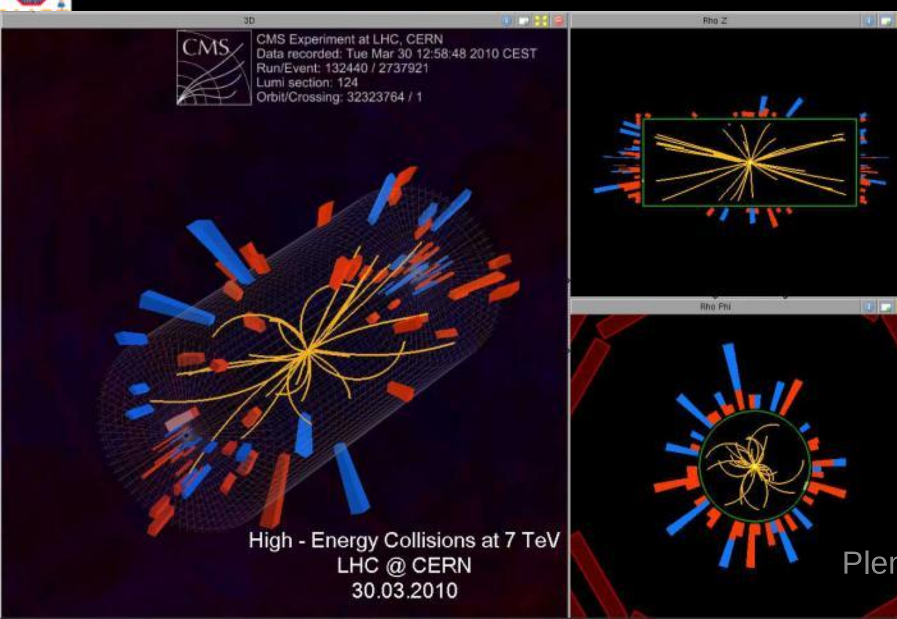
Plenary ECFA

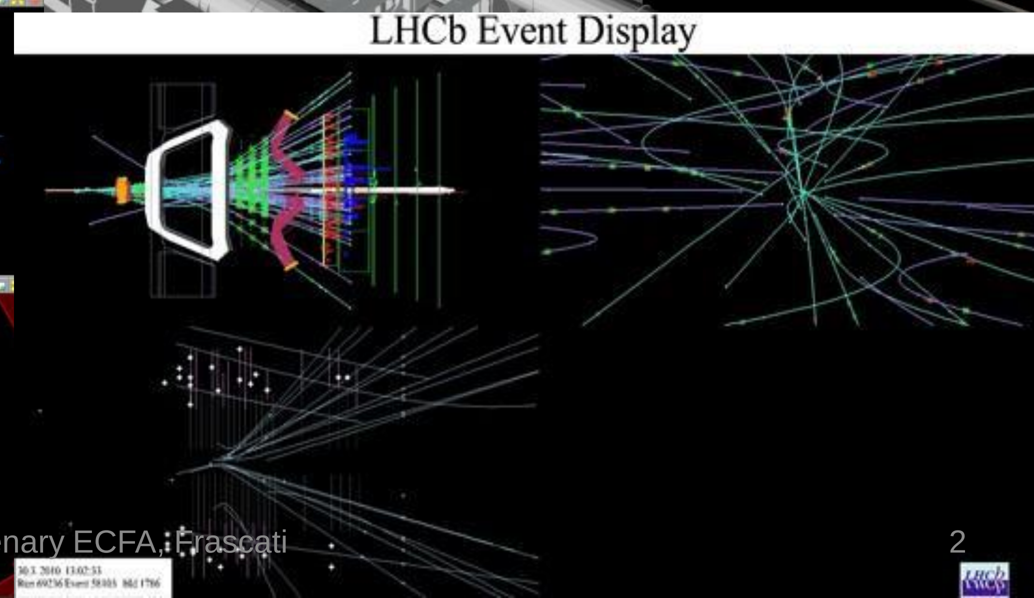
July 1, 2010
Sergio Bertolucci
CERN

March 30, 2010 7 TeV!





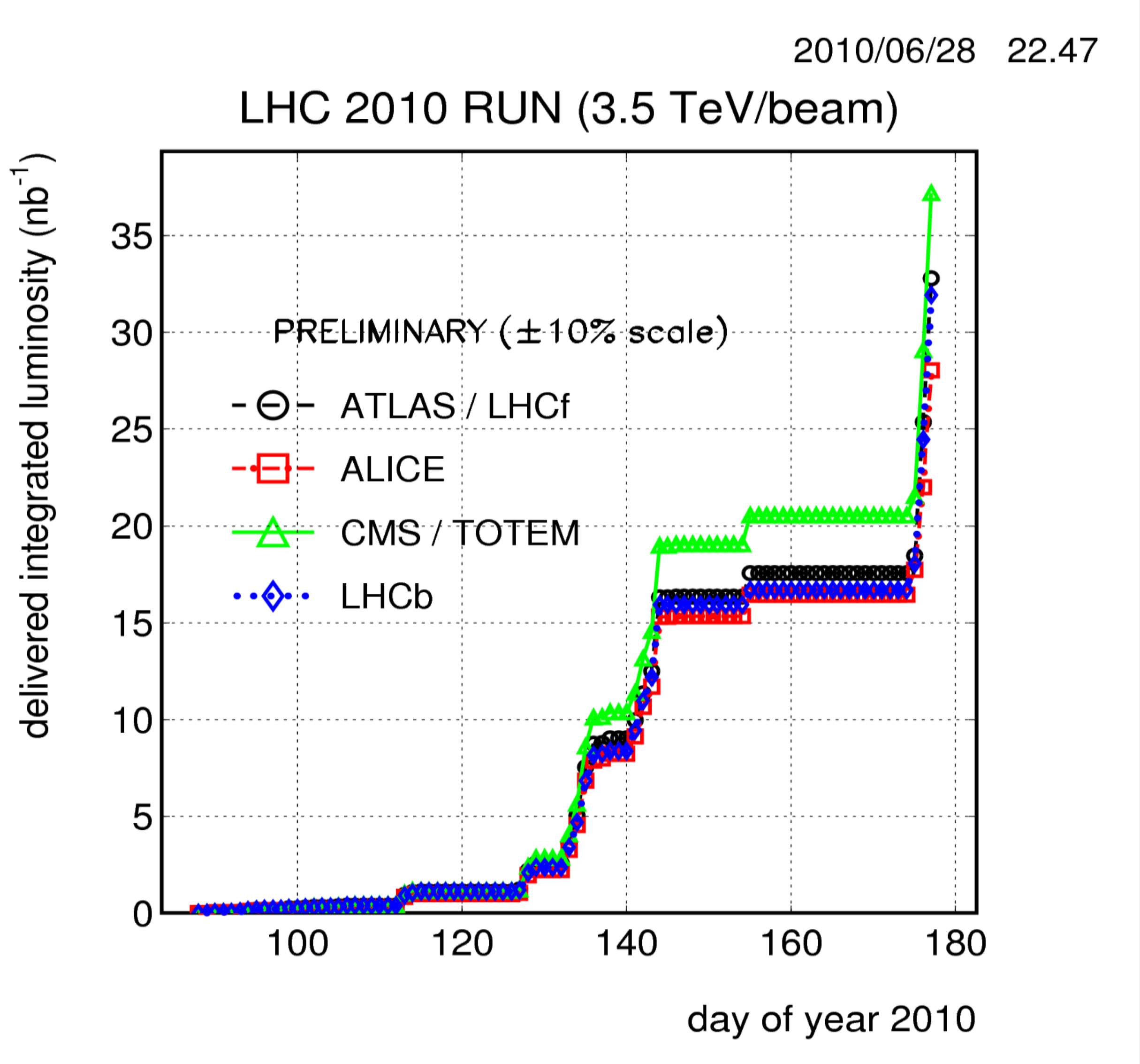




Main Progress on LHC

- **Collimation setup and MP qualification for nominal bunch intensity completed**. Settings into sequence.
- **Machine setup for July/August configuration:**
  - Squeeze with separated beams to $\beta^* = 3.5$ m
  - Beta beat measurements
  - 100 μrad crossing angle in IR1 and IR5
  - Transverse damper for beam stabilization up to 3.5 TeV
  - Reduction of chromaticity during ramp (measurements)
- **Four physics fills with nominal bunch intensity:**
  - New step up in instantaneous luminosity: **$7\text{-}8 \times 10^{29}$ cm^{-2} s^{-1}**.
  - Approaching the **100 nb^{-1}** earlier than promised.
  - Working on characterizing interesting loss features.

…and luminosity is growing!

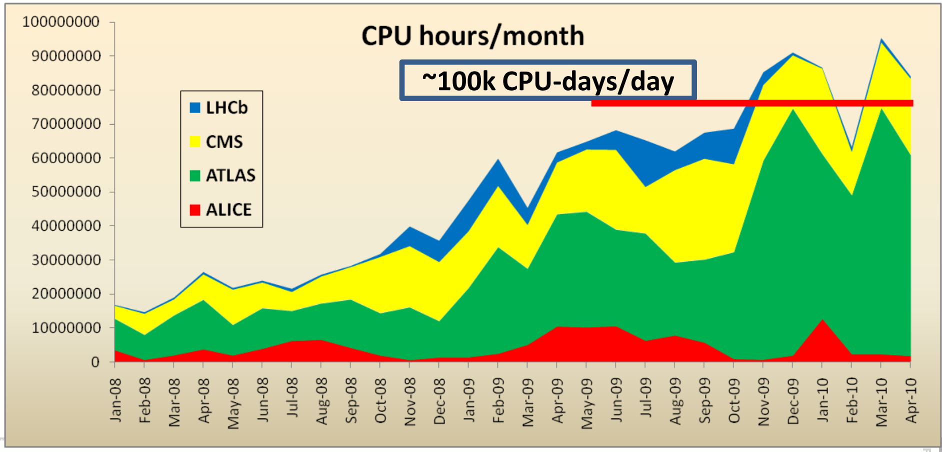


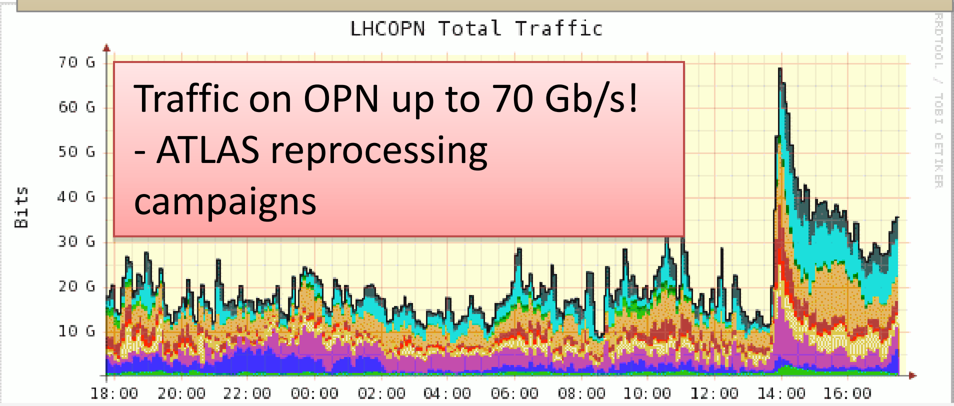
General considerations on experiments

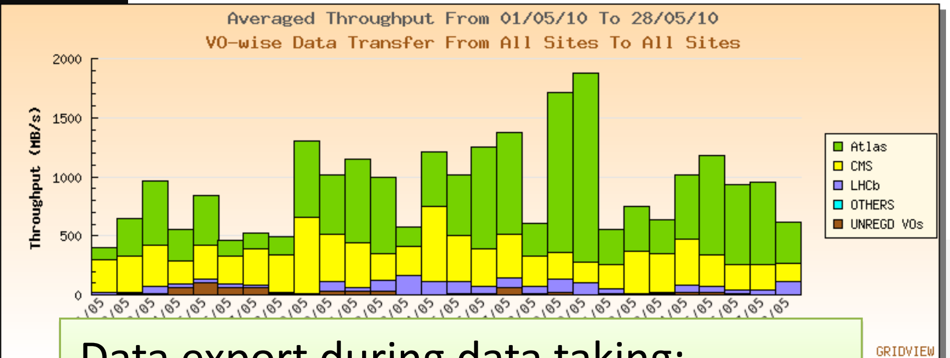
- Experiments demonstrating their readiness in the exploitation of the 7 TeV data…
- …ready to follow with more complex triggers the increase of luminosity.
- Experiments greedy for more L_{int} for the summer conferences.
- Analyses proceeding very rapidly and results being submitted for publication.
- More emphasis put on precision tuning of the algorithms/simulations/detector description
- Performances of the computing environment is consistently satisfactory, and capable to react to (small) crises

WLCG Status – 1

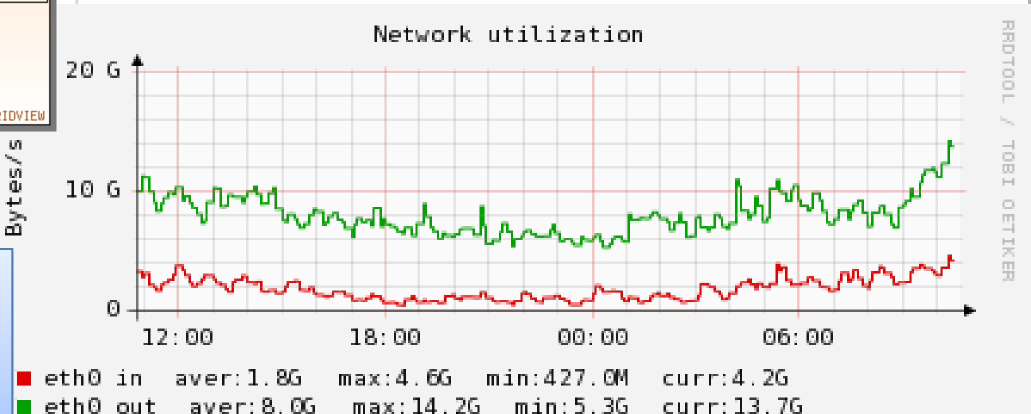
- WLCG running increasingly high workloads:
  - ~1 million jobs/day
    - Real data processing and re-processing
    - Physics analysis
    - Simulations
  - ~100 k CPU-days/day
- Unprecedented data rates







Data export during data taking:
- According to expectations on average



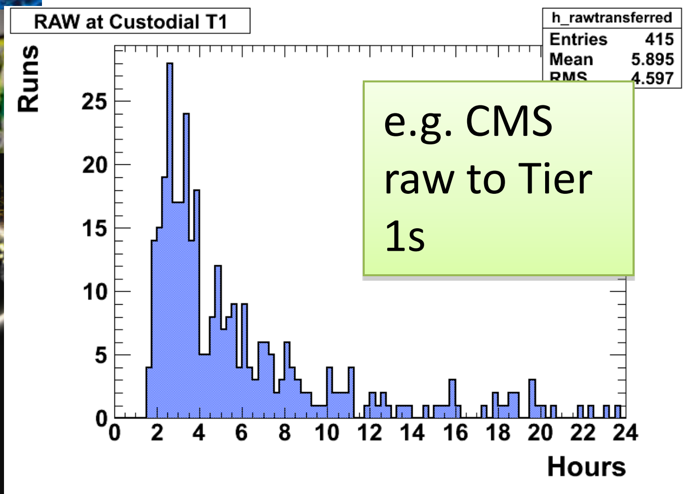
Castor traffic last month:

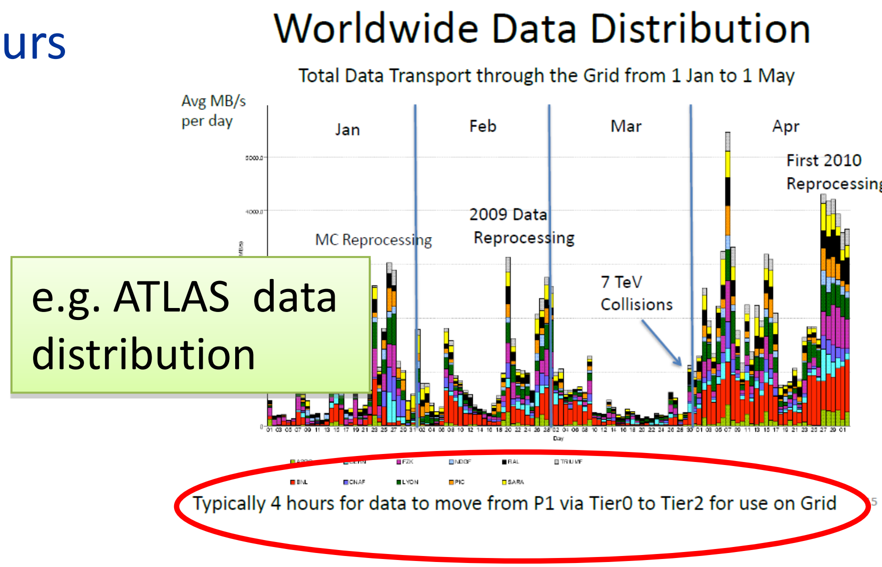
> 4 GB/s input

> 13 GB/s served

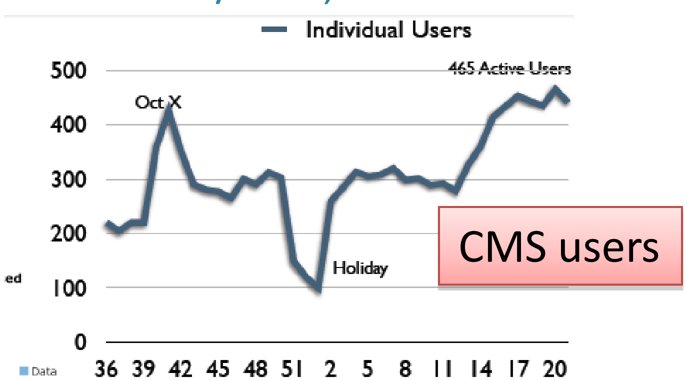
WLCG Status – 2

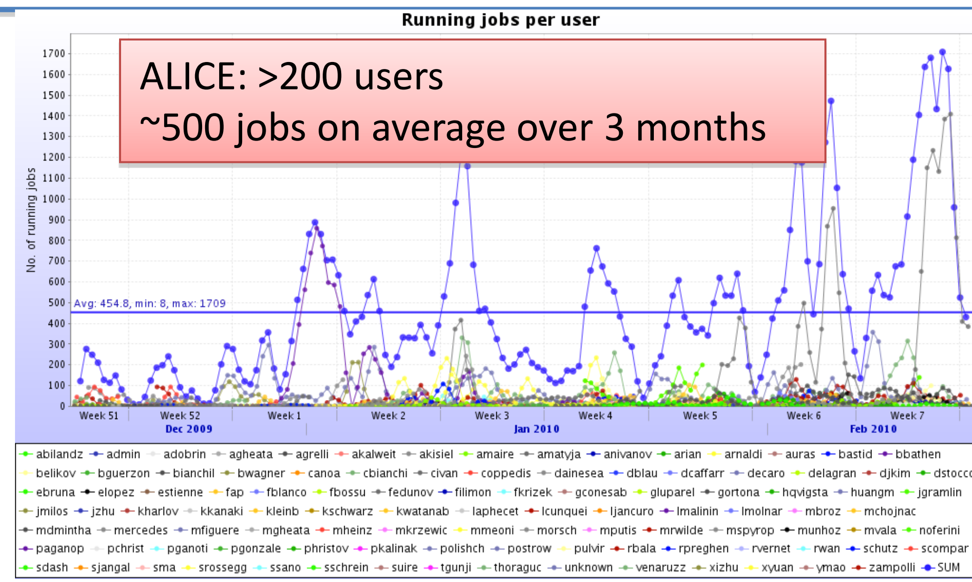
- Data reaches Tier 2s within hours





- Increasing numbers of (analysis users)
  - E.g.:~500 grid users in each ATLAS/CMS; ~200 in ALICE





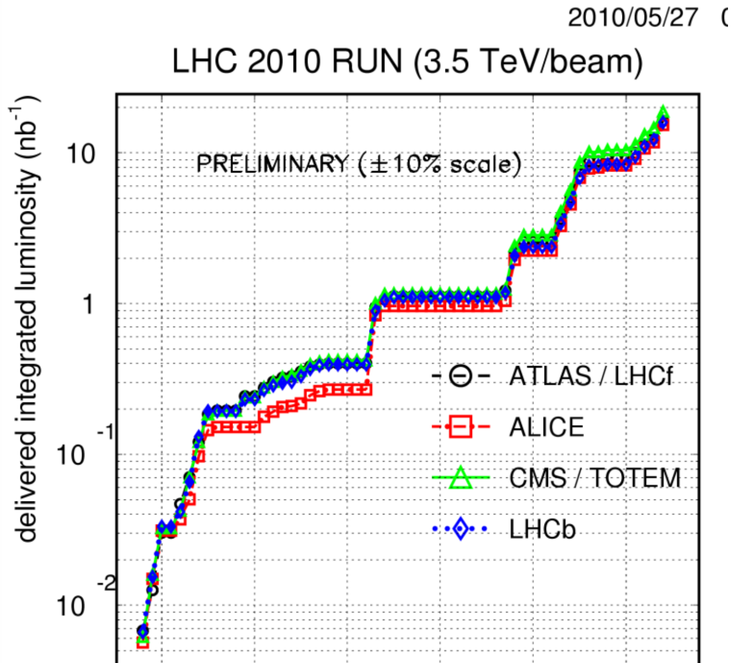
ALICE data loss

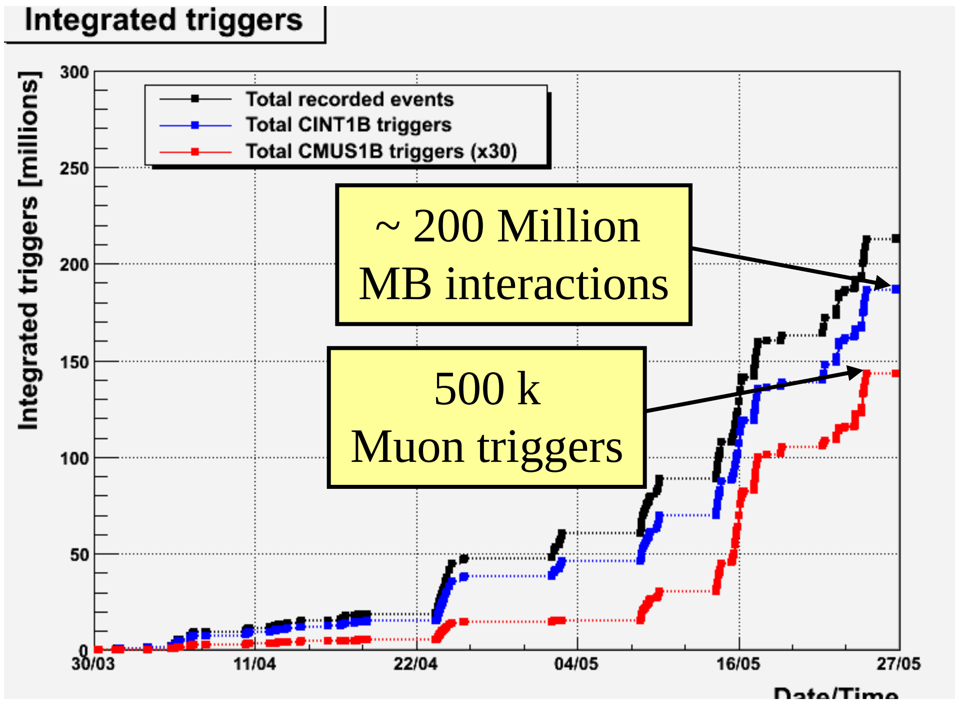
- A configuration error in Castor resulted in data being directed across all available tape pools instead of to the dedicated raw data pools
  - For ALICE, ATLAS, CMS this included a pool where the tapes were re-cycled after a certain time
- The result of this was that a number of files were lost on tapes that were recycled
- For ATLAS and CMS the tapes had not been overwritten and could be fully recovered (fall back would have been to re-copy files back from Tier 1s)
- For ALICE 10k files were on tapes that were recycled, inc 1700 files of 900 GeV data
- Actions taken:
  - Underlying problem addressed; all recycle pools removed
    - Software change procedures being reviewed now
  - Action to improve user-facing monitoring in Castor
  - **Tapes sent to IBM and SUN for recovery – have been able to recover ~97% of critical (900 GeV sample) files, ~50% of all ALICE files**
  - Work with ALICE to ensure that always 2 copies of data available
    - In HI running there is a risk for several weeks until all data is copied to Tier 1s; several options to mitigate this risk under discussion
  - As this was essentially a procedural problem: we will organise a review of Castor operations procedures (sw dev, deployment, operation etc) together with experiments and outside experts – timescale of September.

A few examples

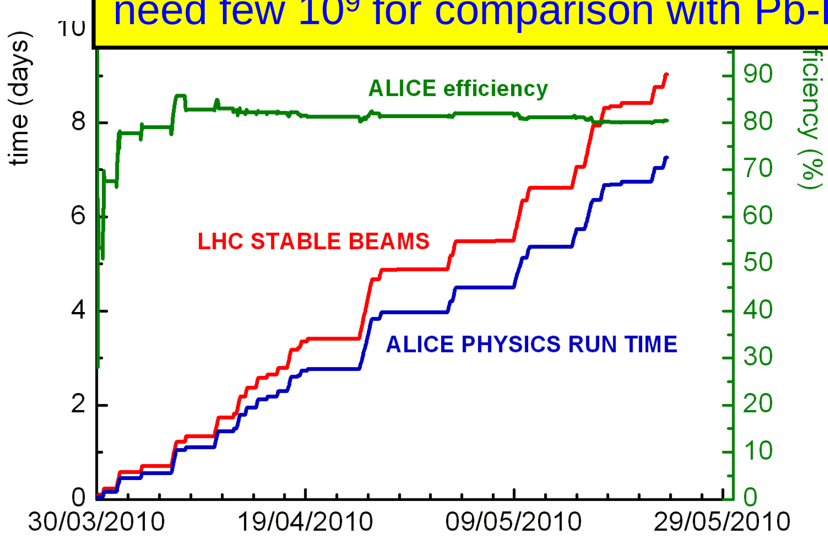
for a detailed overview see
http://plhc2010.desy.de/

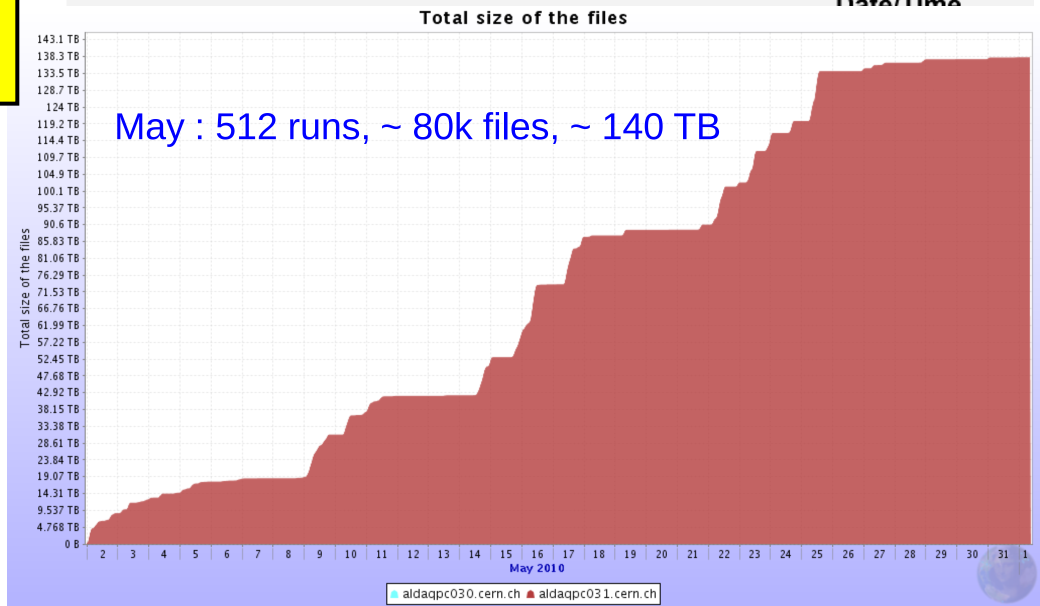
Data Taking





Emphasis so far on MinBias triggers
need few 10^9 for comparison with Pb-Pb

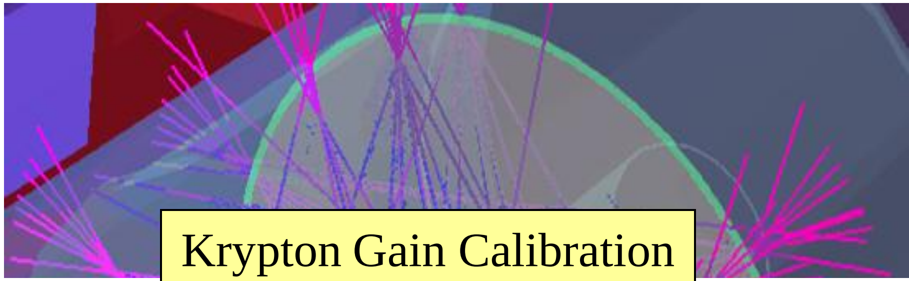




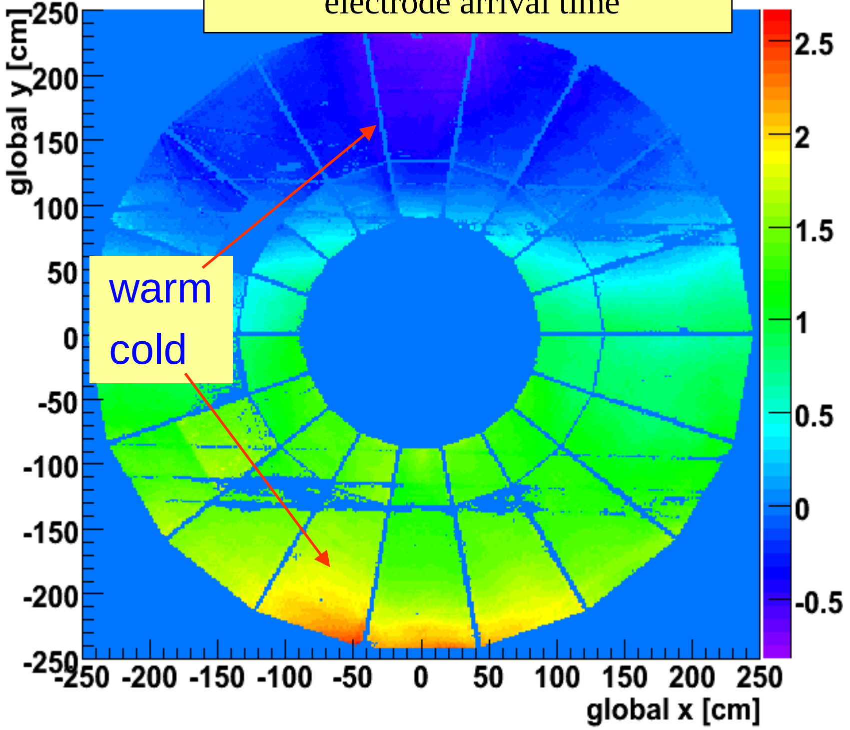
May : 512 runs, ~ 80k files, ~ 140 TB

Getting to know : Calibration (non)constants

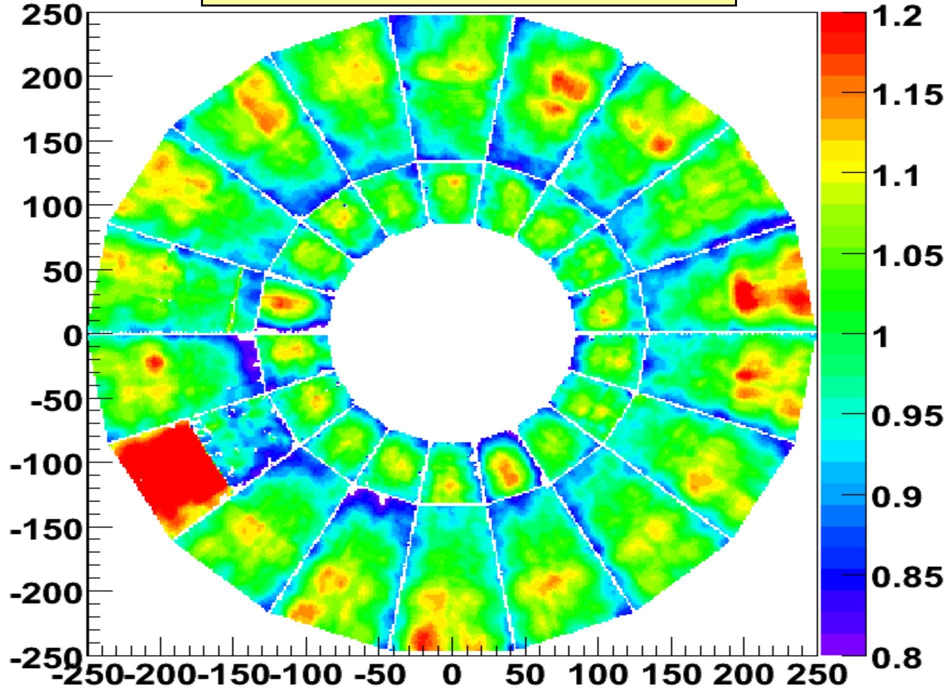
- TPC: concept simple, devil is in the details..
  - v_drift = f(T, P, gas, ..), $\Delta v/v < 10^{-4}$, => 4 different methods used
  - geometry, planarity (200μm/2m), ..
  - Field distortions, ExB effect, $\omega\tau$, …
  - pad-by-pad gain calibration (dE/dx < 5.5%



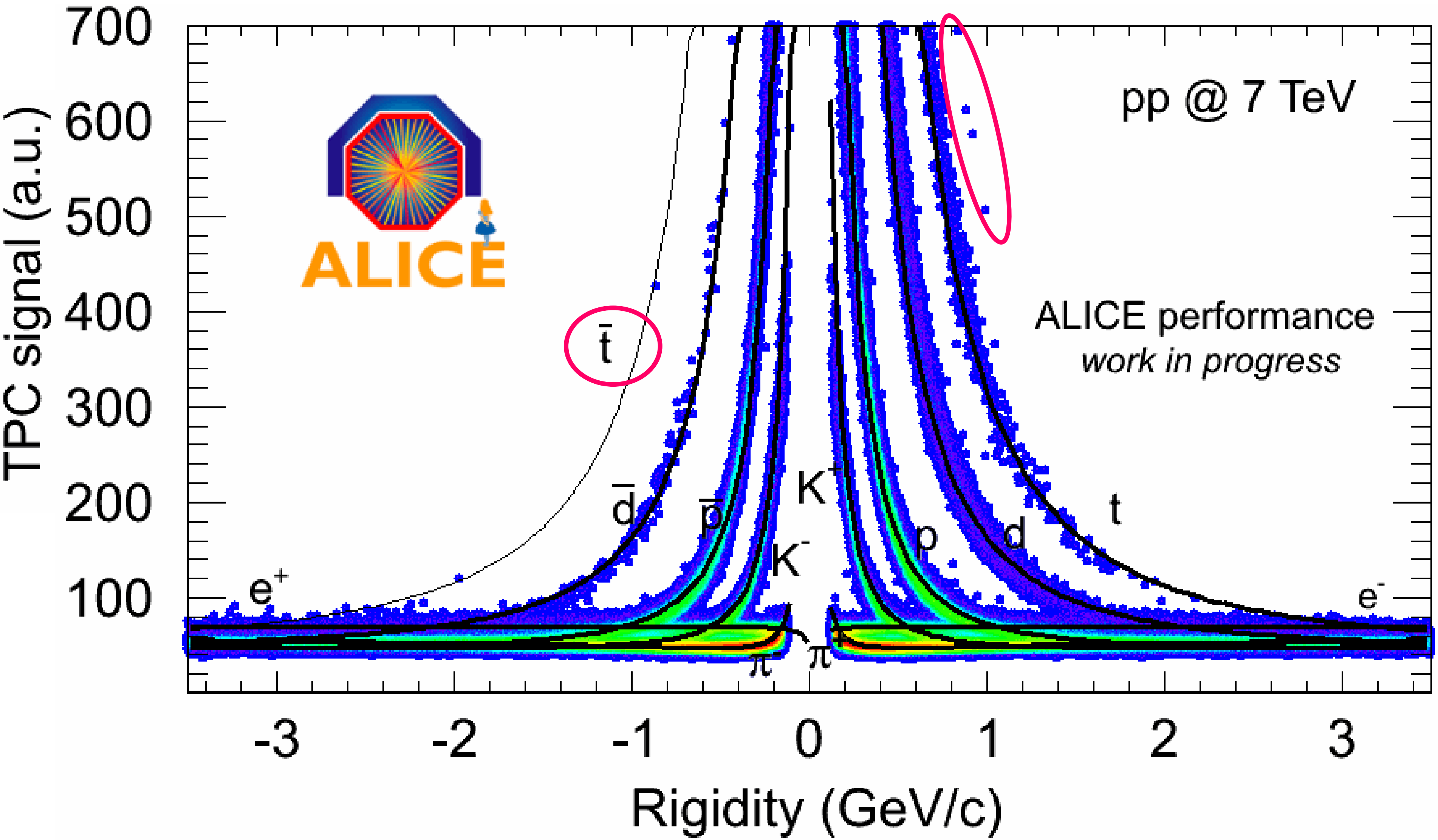
Laser Photo electrons from central electrode arrival time



Krypton Gain Calibration

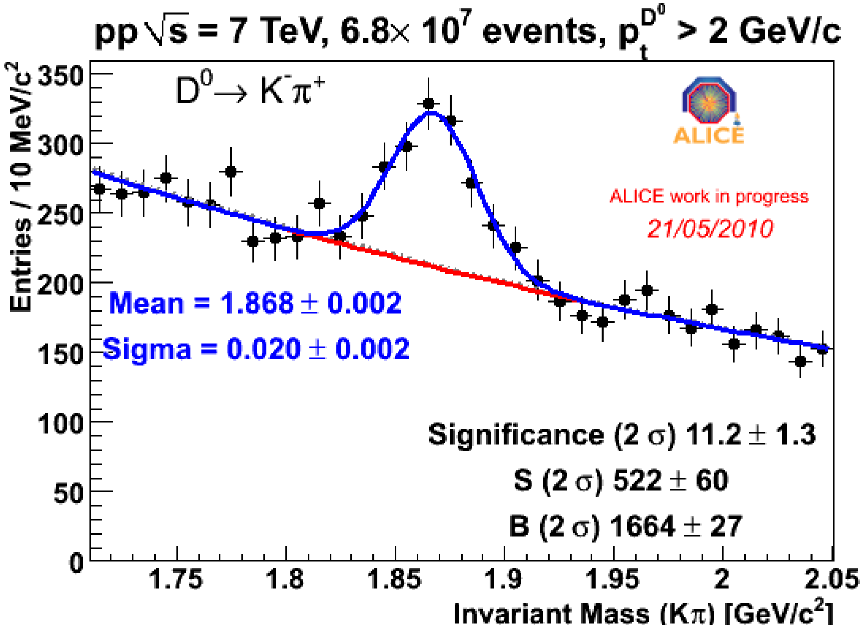


(Anti)Nuclei

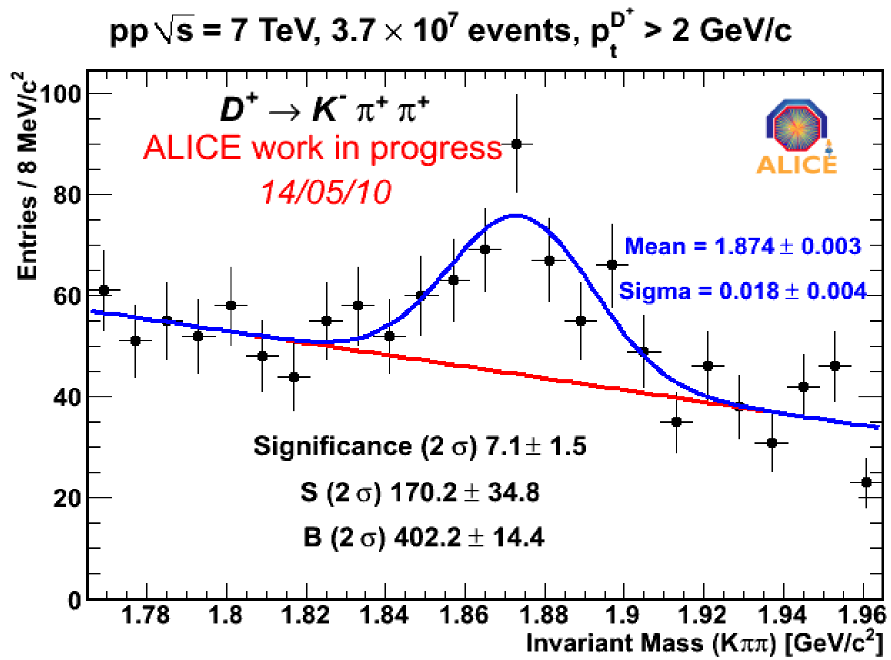


pp @ 7 TeV
ALICE performance
work in progress
ALICE
TPC signal (a.u.)
Rigidity (GeV/c)
700
600
500
400
300
200
100
-3
-2
-1
0
1
2
3
e+
e-
t̄
d̄
p̄
K+
K-
π-
π+
p
d
t

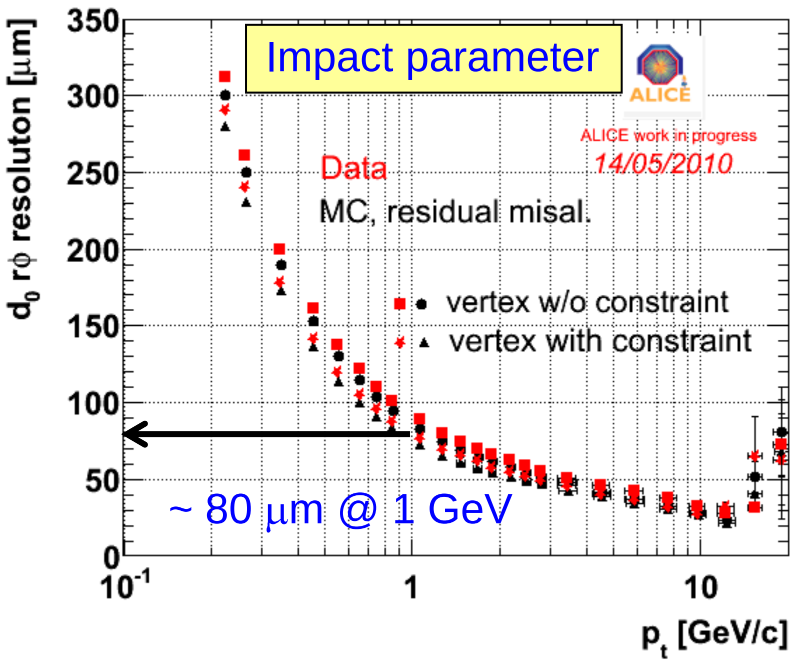
Charm



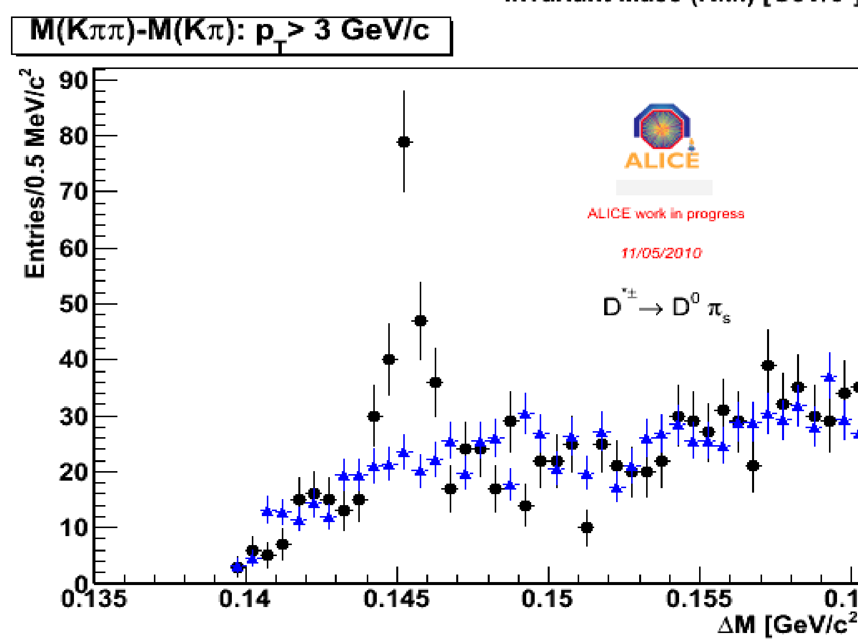
pp $\sqrt{s}$ = 7 TeV, 6.8× 10^7 events, $p_t^{D^0}$ > 2 GeV/c
$D^0 \to K^- \pi^+$
ALICE
ALICE work in progress
21/05/2010
Mean = 1.868 ± 0.002
Sigma = 0.020 ± 0.002
Significance (2 σ) 11.2 ± 1.3
S (2 σ) 522 ± 60
B (2 σ) 1664 ± 27
Entries / 10 MeV/c^2
Invariant Mass (Kπ) [GeV/c^2]



pp $\sqrt{s}$ = 7 TeV, 3.7 × 10^7 events, $p_t^{D^+}$ > 2 GeV/c
$D^+ \to K^- \pi^+ \pi^+$
ALICE work in progress
14/05/10
ALICE
Mean = 1.874 ± 0.003
Sigma = 0.018 ± 0.004
Significance (2 σ) 7.1 ± 1.5
S (2 σ) 170.2 ± 34.8
B (2 σ) 402.2 ± 14.4
Entries / 8 MeV/c^2
Invariant Mass (Kππ) [GeV/c^2]

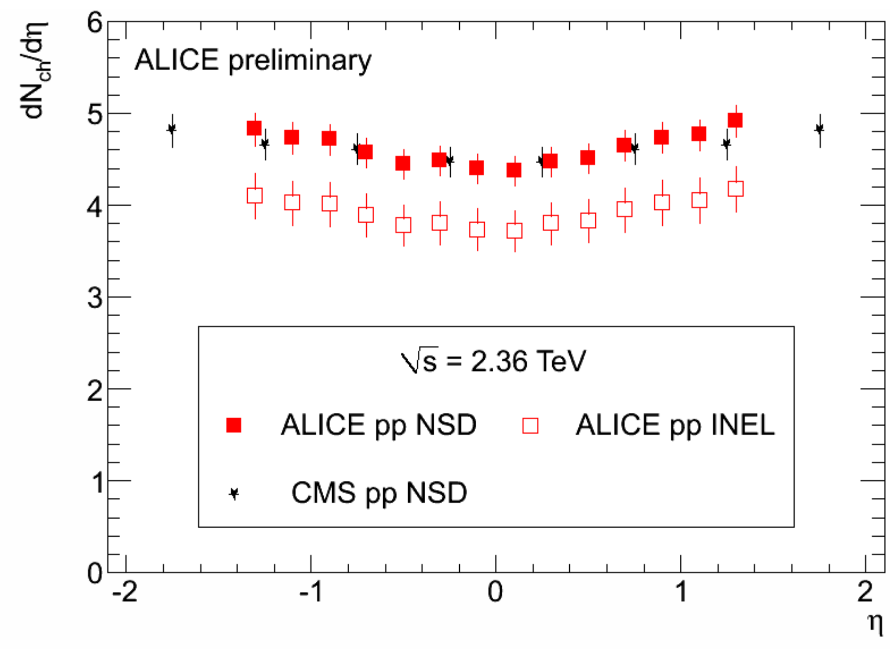


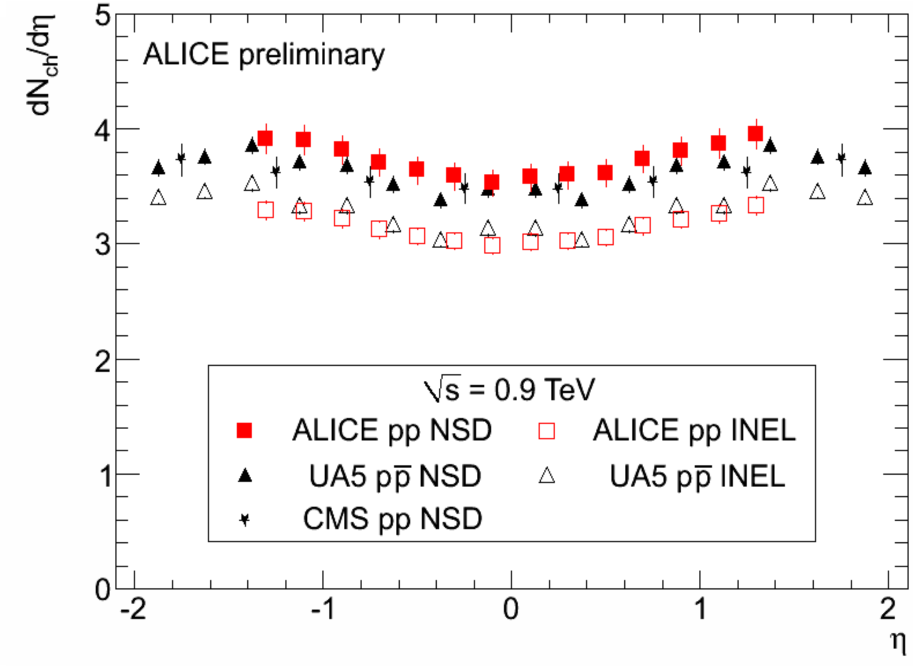
Impact parameter
ALICE
ALICE work in progress
14/05/2010
Data
MC, residual misal.
vertex w/o constraint
vertex with constraint
~ 80 μm @ 1 GeV
d_0 rφ resoluton [μm]
p_t [GeV/c]



M(Kππ)-M(Kπ): p_T > 3 GeV/c
ALICE
ALICE work in progress
11/05/2010
$D^{*\pm} \to D^0 \pi_s$
Entries/0.5 MeV/c^2
ΔM [GeV/c^2]

Getting quantitative



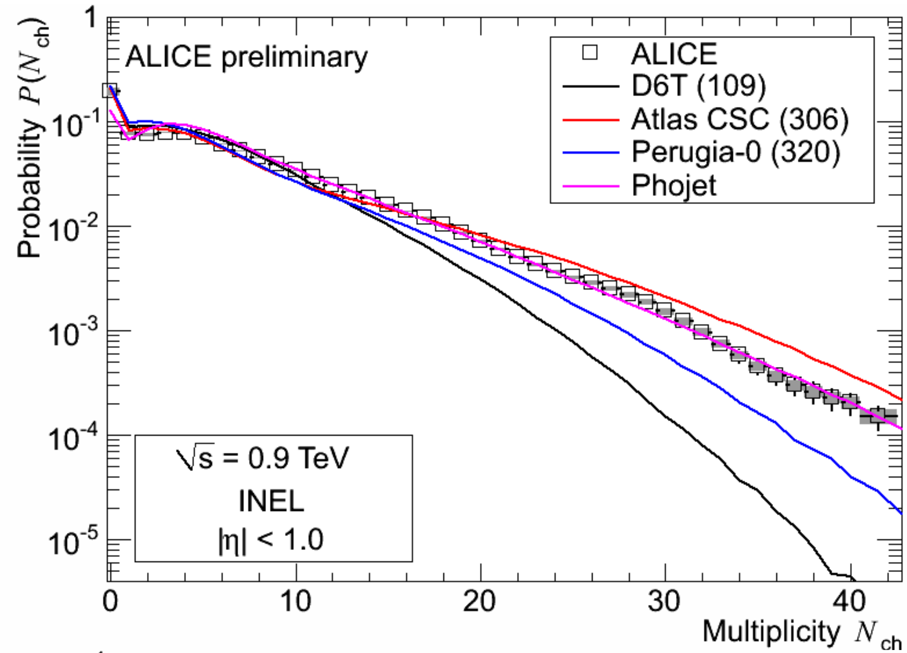


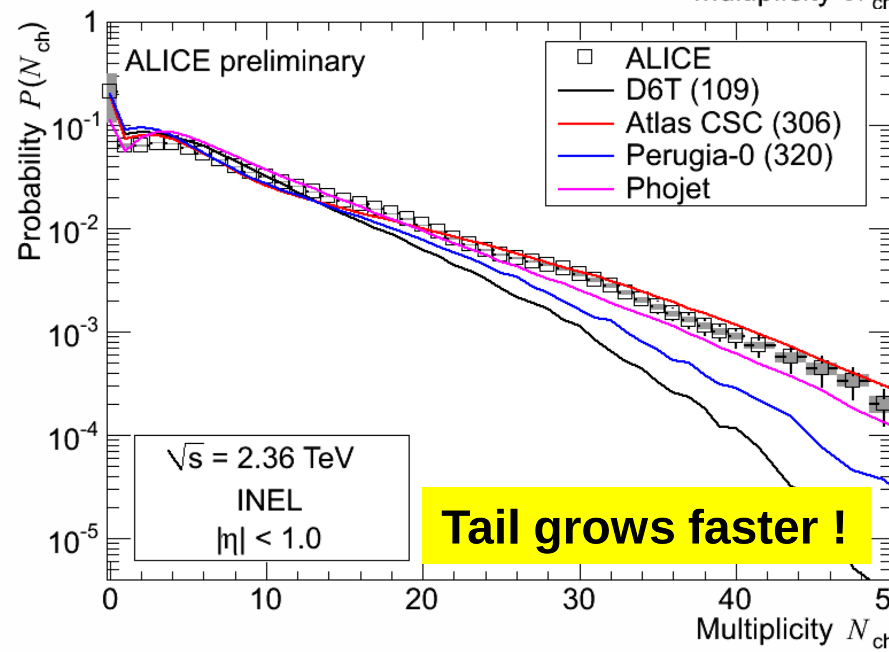
Systematic error of 2-3% !

	NSD 2.36 TeV	NSD 900 GeV	INEL 900 GeV
ALICE preliminary	4.43 ± 0.01 ± 0.16	3.58 ± 0.01 ± 0.12	3.02 ± 0.01 ± 0.07
ALICE EPJC 65 111 (2010)		3.51 ± 0.15 ± 0.25	3.10 ± 0.13 ± 0.22
CMS JHEP 02 (2010) 041	4.47 ± 0.04 ± 0.16	3.48 ± 0.02 ± 0.13	
UA5 Z. Phys. C33 1 (1986)		3.43 ± 0.05 ± ?	3.09 ± 0.05 ± ?

Life starts to get interesting..

Increase .9 to 2.3 TeV (%)	NSD
ALICE preliminary*	23.7 ± 0.5 +4.6-1.1 %
CMS	28.4 ± 1.4 ± 2.6 %
Pythia D6T (109)	18.7 %
Pythia ATLAS CSC (306)	18.3 %
Pythia Perugia-0 (320)	18.5 %
Phojet	14.5 %
QGSM	19 %



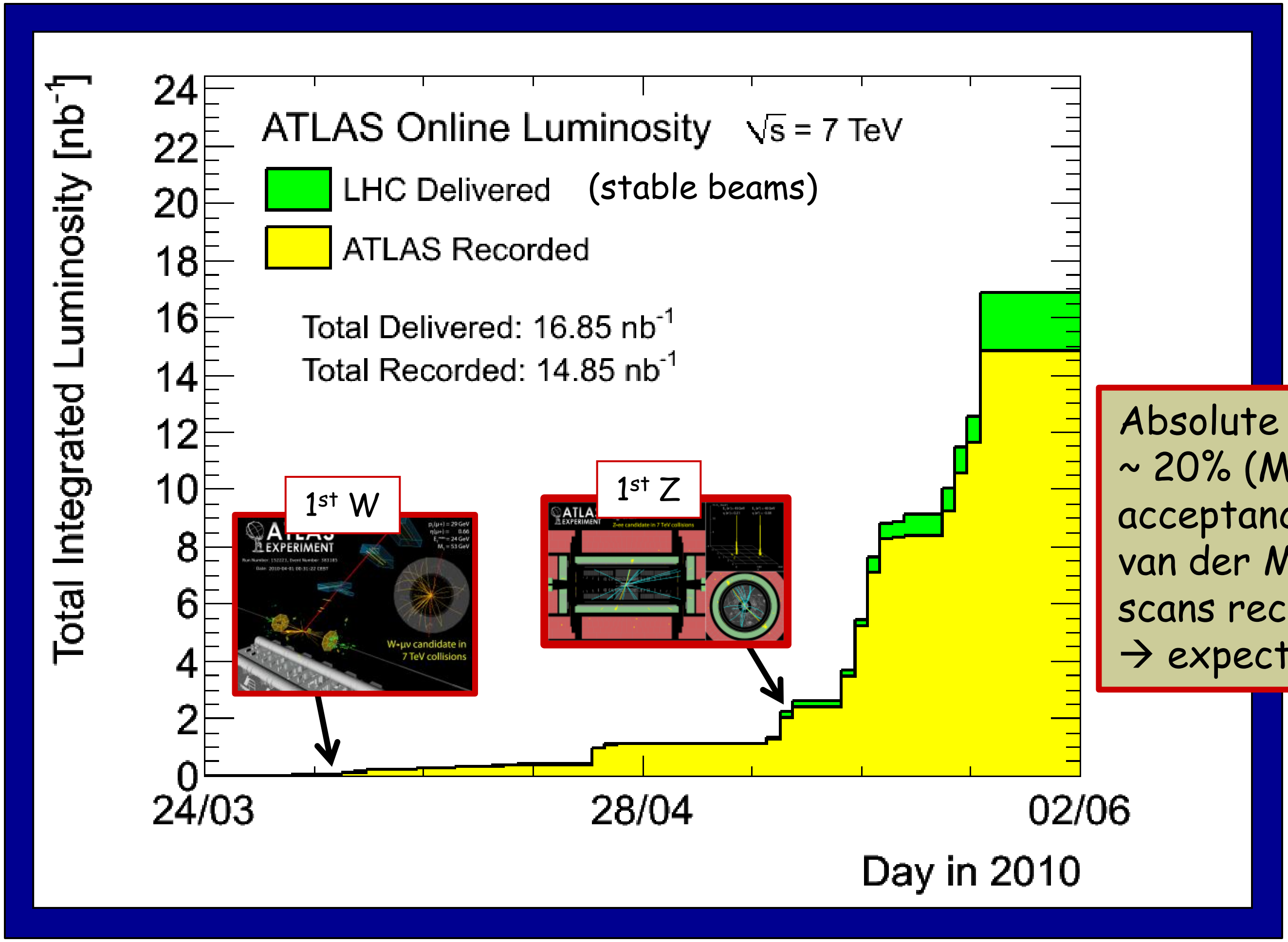


Larger increase of multiplicity at mid-rapidity than in MC generators

Good news for the Heavy Ion program:
More charged particles will create
a denser and hotter system !

ATLAS

Integrated luminosity vs time since 30 March 2010



Absolute luminosity known today to ~ 20% (MC-based cross-section and acceptance of luminosity detectors)
van der Meer beam separation scans recorded recently
→ expect to achieve < 10% soon

Overall data taking efficiency: ~ 92%
Recorded with all detectors at nominal voltage (including Pixels): ~ 88 %

Results presented here are based on up to ~ 7.9 nb^{-1} of reprocessed data

Detector status

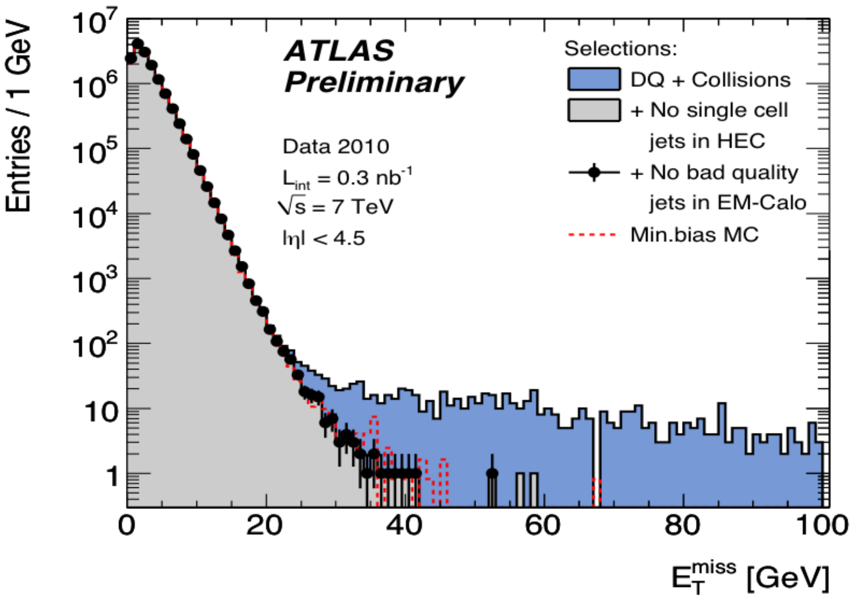
Subdetector	Number of Channels	Approximate Operational Fraction
Pixels	80 M	97.5%
SCT Silicon Strips	6.3 M	99.3%
TRT Transition Radiation Tracker	350 k	98.0%
LAr EM Calorimeter	170 k	98.5%
Tile calorimeter	9800	97.3%
Hadronic endcap LAr calorimeter	5600	99.9%
Forward LAr calorimeter	3500	100%
LVL1 Calo trigger	7160	99.8%
LVL1 Muon RPC trigger	370 k	99.7%
LVL1 Muon TGC trigger	320 k	100%
MDT Muon Drift Tubes	350 k	99.7%
CSC Cathode Strip Chambers	31 k	98.5%
RPC Barrel Muon Chambers	370 k	97.3%
TGC Endcap Muon Chambers	320 k	98.8%

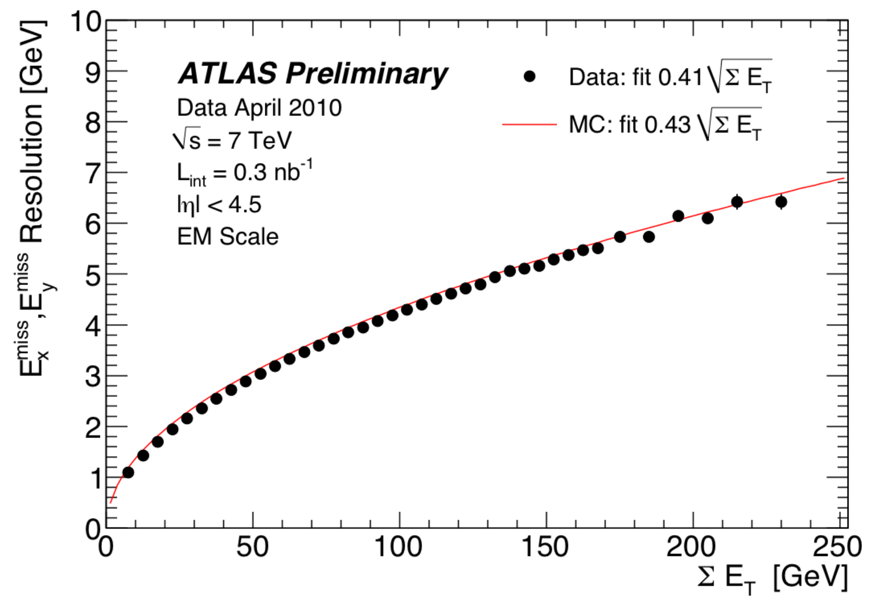
To be watched:
- -- Inner Detector: cooling system, Pixels busy
- -- Calorimeters: LVPS, LAr optical readout links, sporadic noise bursts from discharges in the hadronic end-cap
- -- Muons: LV and HV power supplies

Some repairs in the 2010-2011 technical stop, more definitive solutions in 2012 shut-down

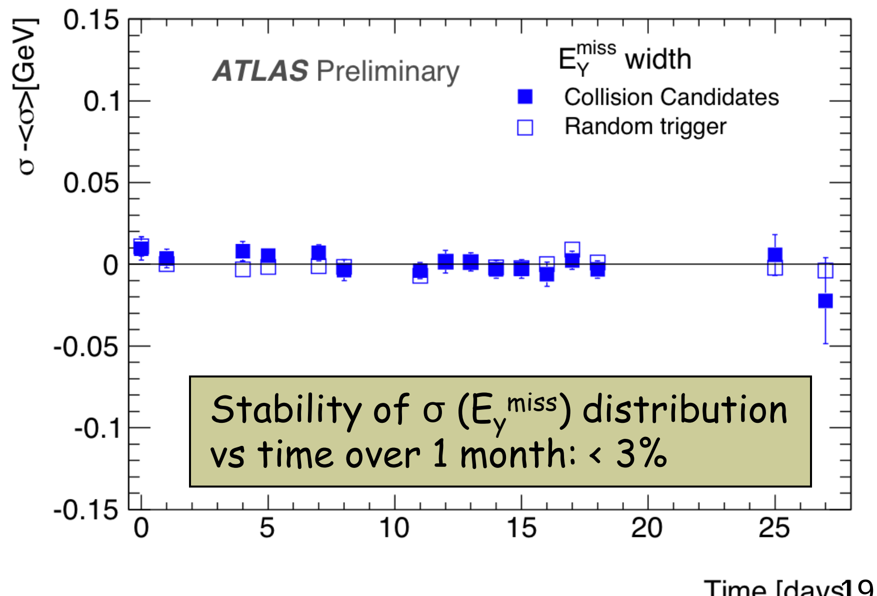
Missing transverse energy

Measured over ~ full calorimeter coverage (360^0 in φ, |η| < 4.5, ~ 200k cells)





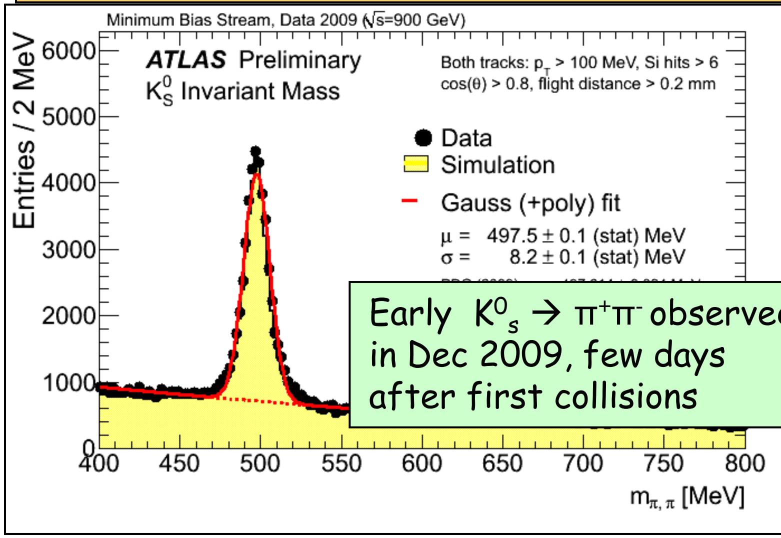
Event fraction removed by additional cleaning cuts: ~ 10^{-4}



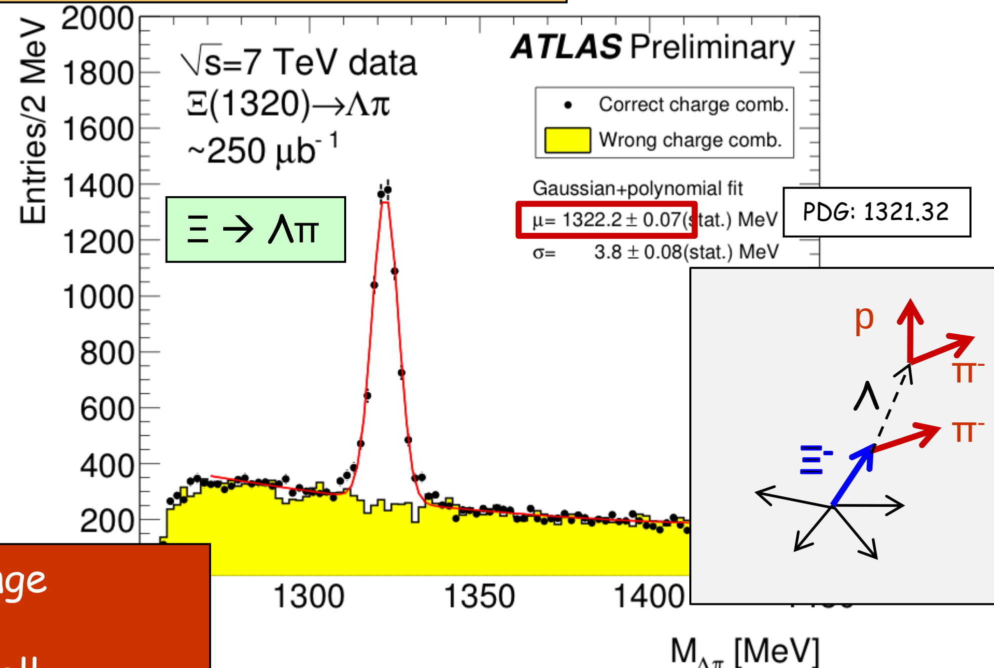
Stability of σ (E_y^{miss}) distribution vs time over 1 month: < 3%

E_T^{miss} is sensitive to calorimeter performance (noise, coherent noise, dead cells, mis-calibrations, cracks, etc.), and cosmics and beam-related backgrounds

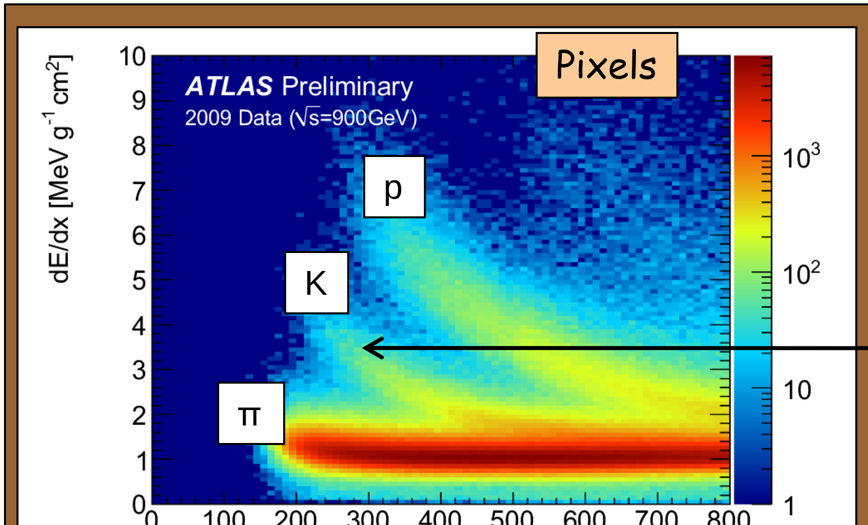
Tracking : from early observation of peaks to cascade decays

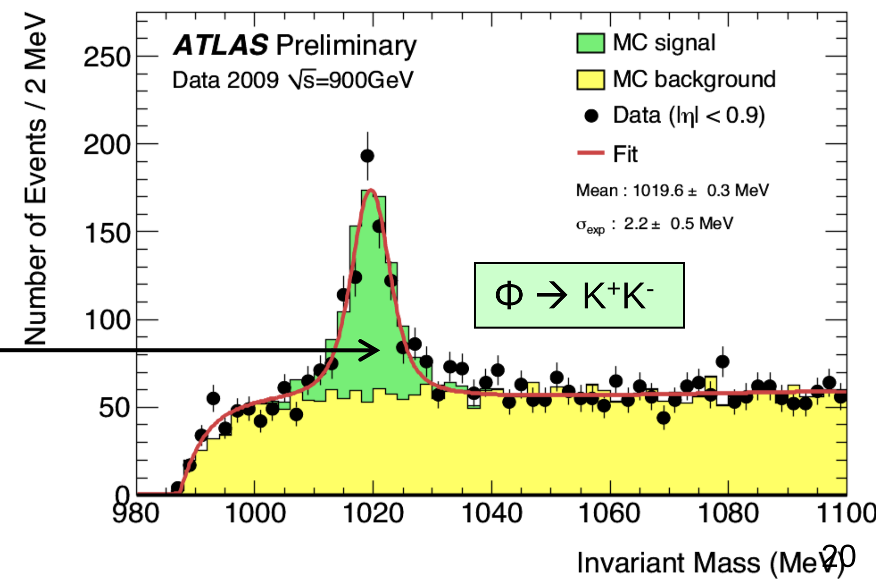


Early $K^0_s \to \pi^+\pi^-$ observed in Dec 2009, few days after first collisions

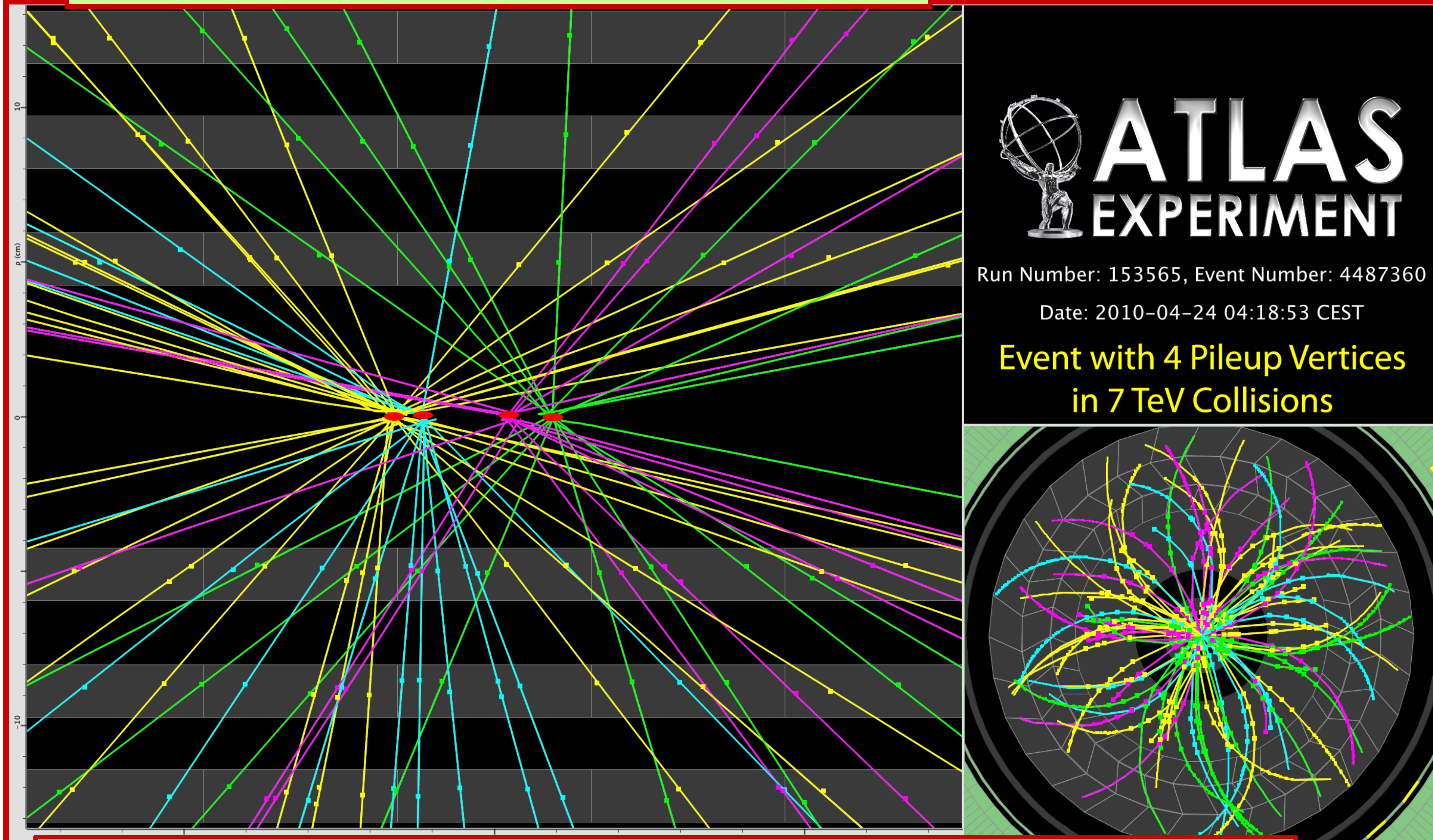


- Momentum scale known to few permil in this range
- Resolution as expected (multiple scattering)
- Complex algorithms (cascades, b-tag, …) work well
- Working on material, alignment, data-driven efficiency, …





Preparing for the future : pile-up reconstruction
4 pp interactions in the same bunch-crossing



~ 10-45 tracks with p_T >150 MeV per vertex
Vertex z-positions : −3.2, −2.3, 0.5, 1.9 cm (vertex resolution better than ~200 μm)
Expect handful of 4-vertex events in this run

Observation of W → eν, μν and Z → ee, μμ production

Fundamental milestone in the "rediscovery" of the Standard Model

New : $\sqrt{s}$ = 7 TeV, pp collisions

$\sigma^{NNLO}(W \to l\nu)$ = 10.45 nb

	W → eν	W → μν
Integrated luminosity	6.7 nb^{-1}	6.4 nb^{-1}
Observed number of events	17 (11+,6-)	40 (25+,15-)
Expected total	23.1±5.0 ±1.2(stat)±1.7(syst)±4.6 (lumi)	28.7± 6.9 ±0.5(stat)±3.9(syst)±5.7 (lumi)
Expected signal	20.7± 4.4	25.9 ± 6.3
Expected background	2.4 ± 1.4	2.8 ± 1.1

Main selections : W → eν
- -- $E_T(e)$ > 20 GeV, $|\eta|$<2.47
- -- tight electron identification criteria
- -- E_T^{miss} > 25 GeV
- -- transverse mass m_T > 40 GeV

Total efficiency : ~ 30%
Main background: QCD jets

Main selections : W → μν
- -- $p_T(\mu)$ > 20 GeV, $|\eta|$<2.4
- -- $|\Delta p_T$ (ID-MS)$|$ < 15 GeV
- -- combined muon; isolated; $|Z_\mu - Z_{vtx}|$<1 cm
- -- E_T^{miss} > 25 GeV
- -- transverse mass m_T > 40 GeV

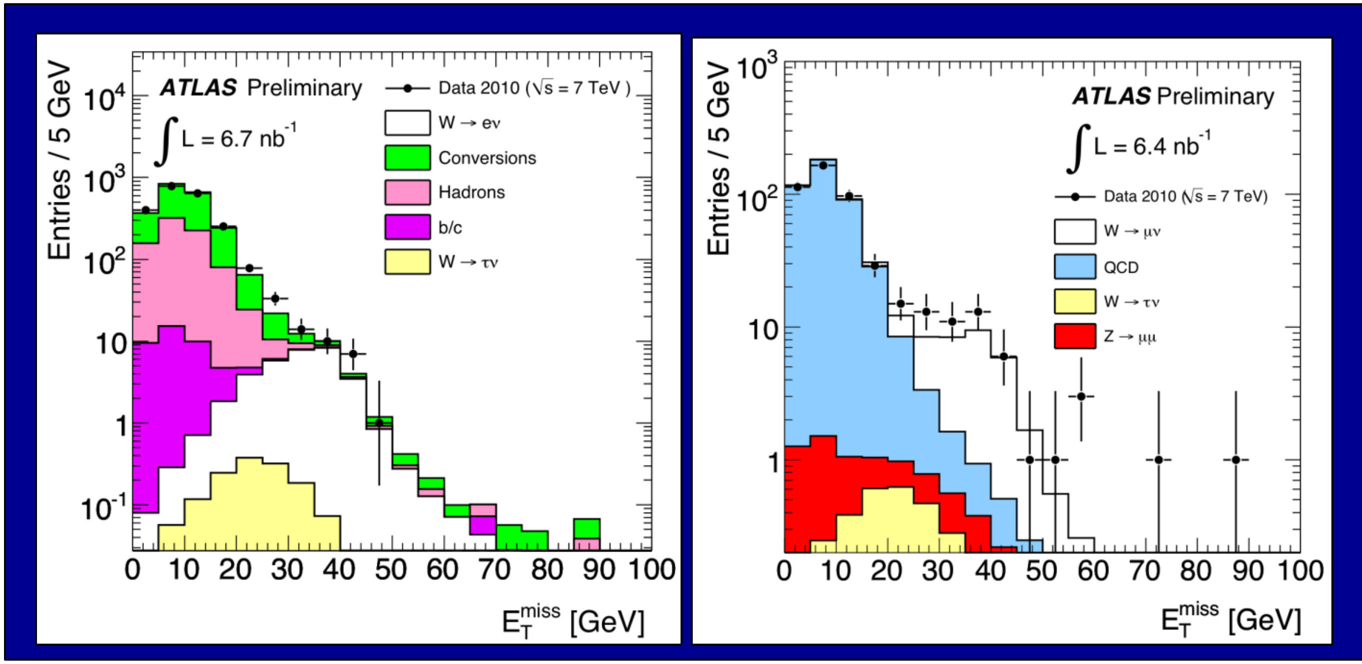
Total efficiency: ~ 40%
Main background: QCD and Z→μμ

Background estimation: several methods used, mostly data-driven: based on control-samples in background-enhanced regions (low E_T^{miss}, non-isolated topologies, ...).
Main uncertainties from low-statistics of data control samples and MC model (PYTHIA)

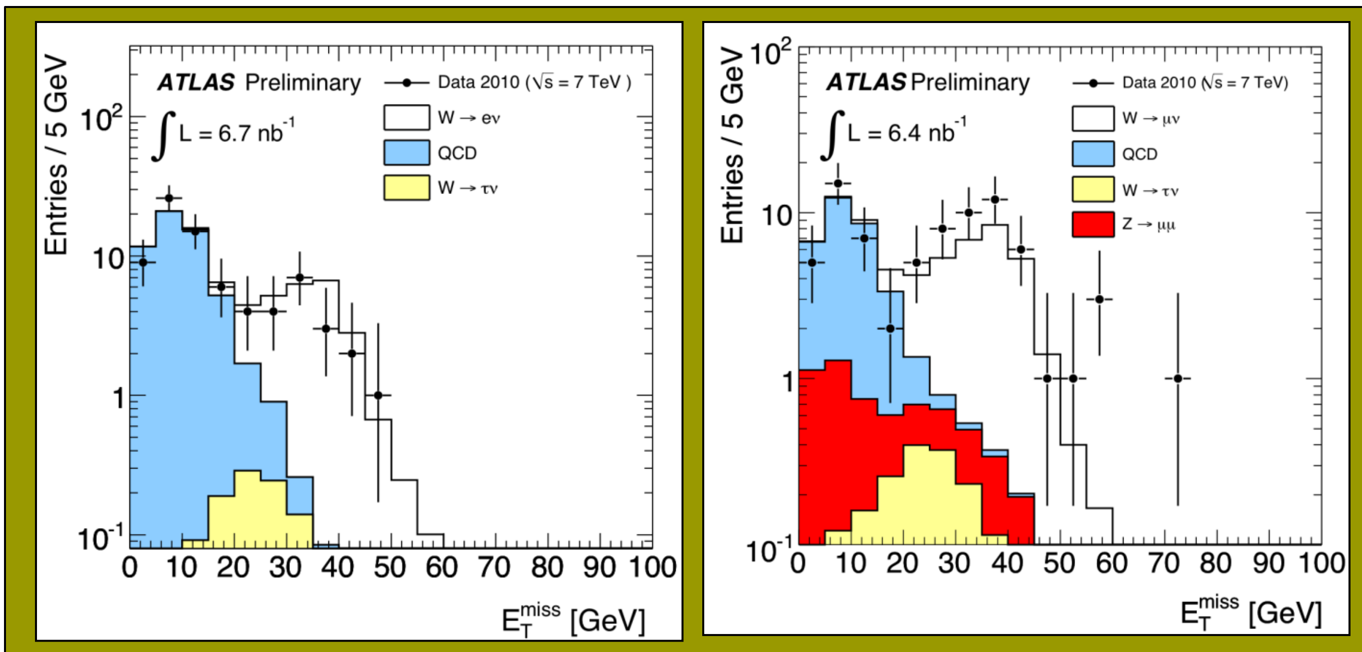
After pre-selection:

- W → eν:
  - loose $e^{\pm}$, E_T > 20 GeV
- W → μν:
  - p_T (μ)> 15 GeV
  - $|\Delta p_T(\text{ID-MS})|$ < 15 GeV
  - $|Z_\mu - Z_{vtx}|$<1 cm

MC: normalised to data (total number of events)



After all cuts but E_T^{miss} and m_T

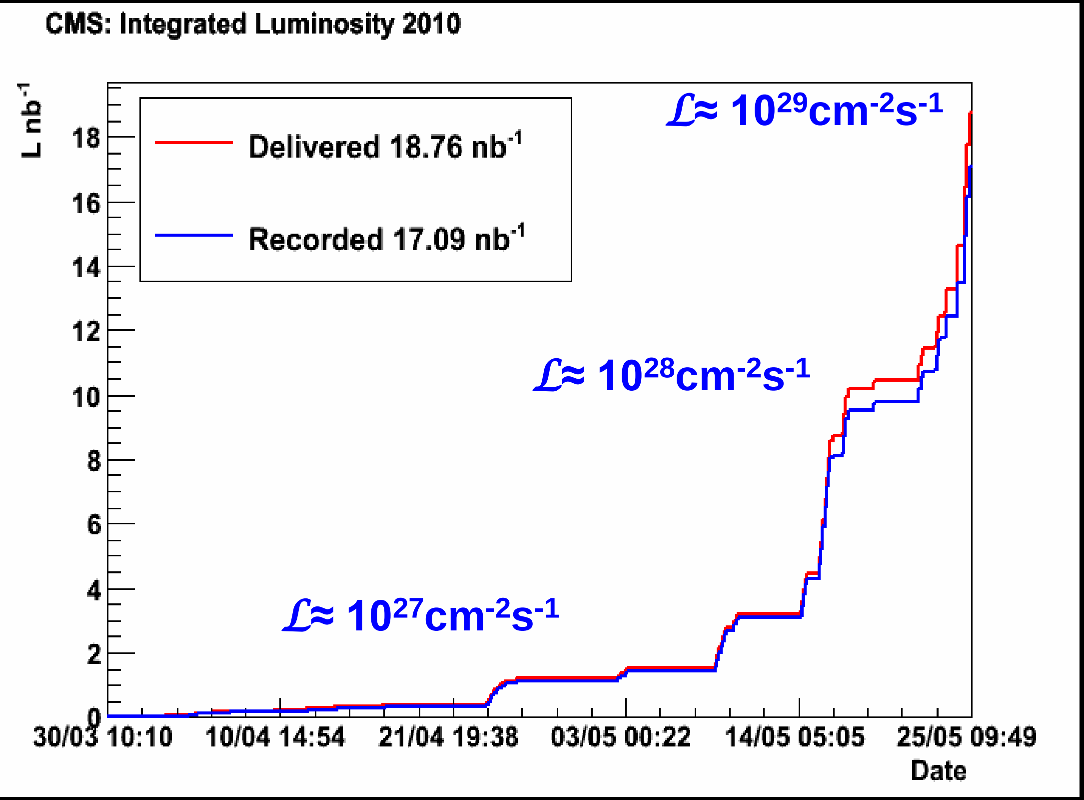


Final candidates inspected in detail → timing, lepton reconstruction quality, event topology …

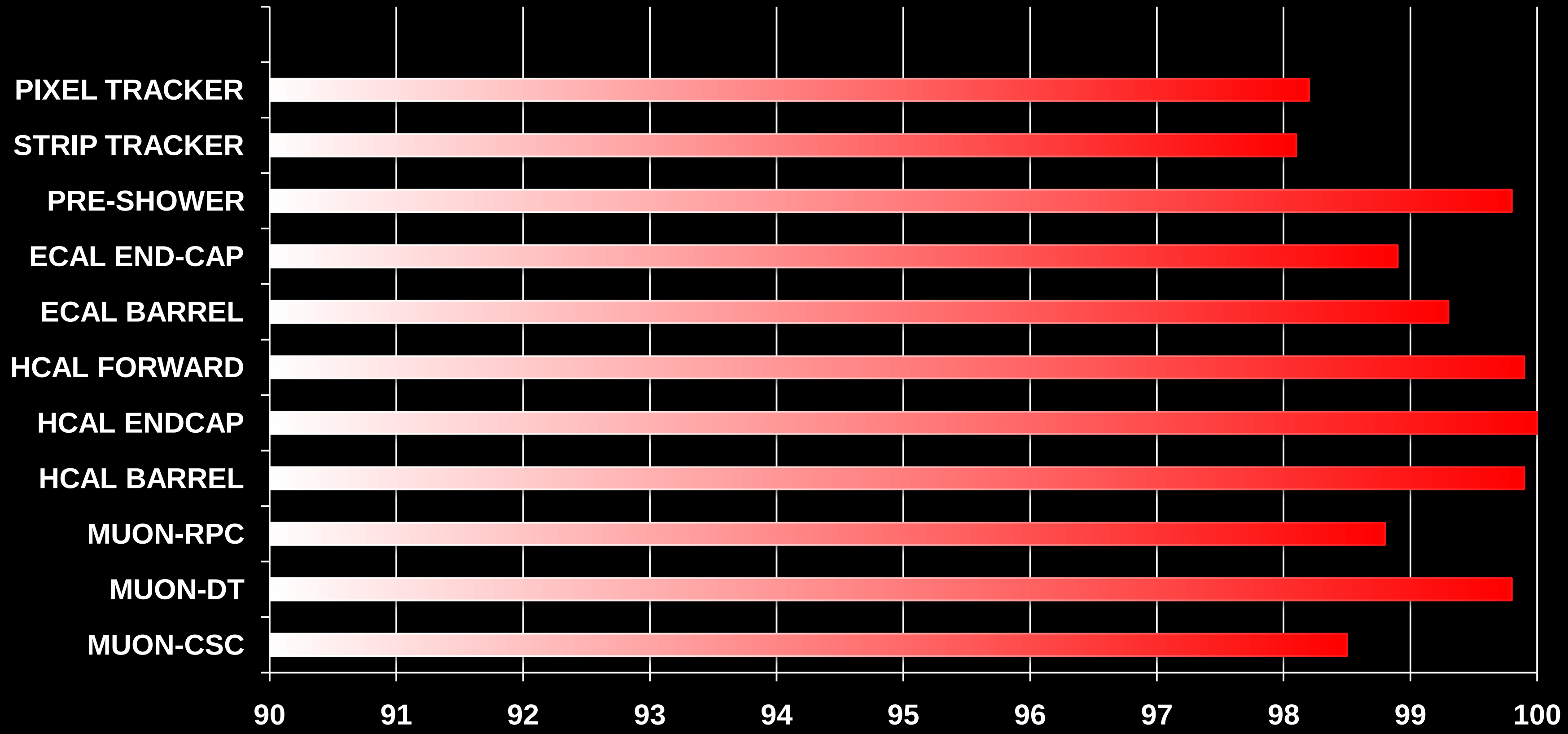
CMS

First 2 months of 7 TeV operations

Reliable operations with **~19nb^{-1}** delivered by LHC and **~17nb^{-1}** of data collected by CMS. Overall data taking efficiency **>91%**. After quality flags and data certification for physics (**~95%**) we end up with **~16nb^{-1}** of good data for physics.



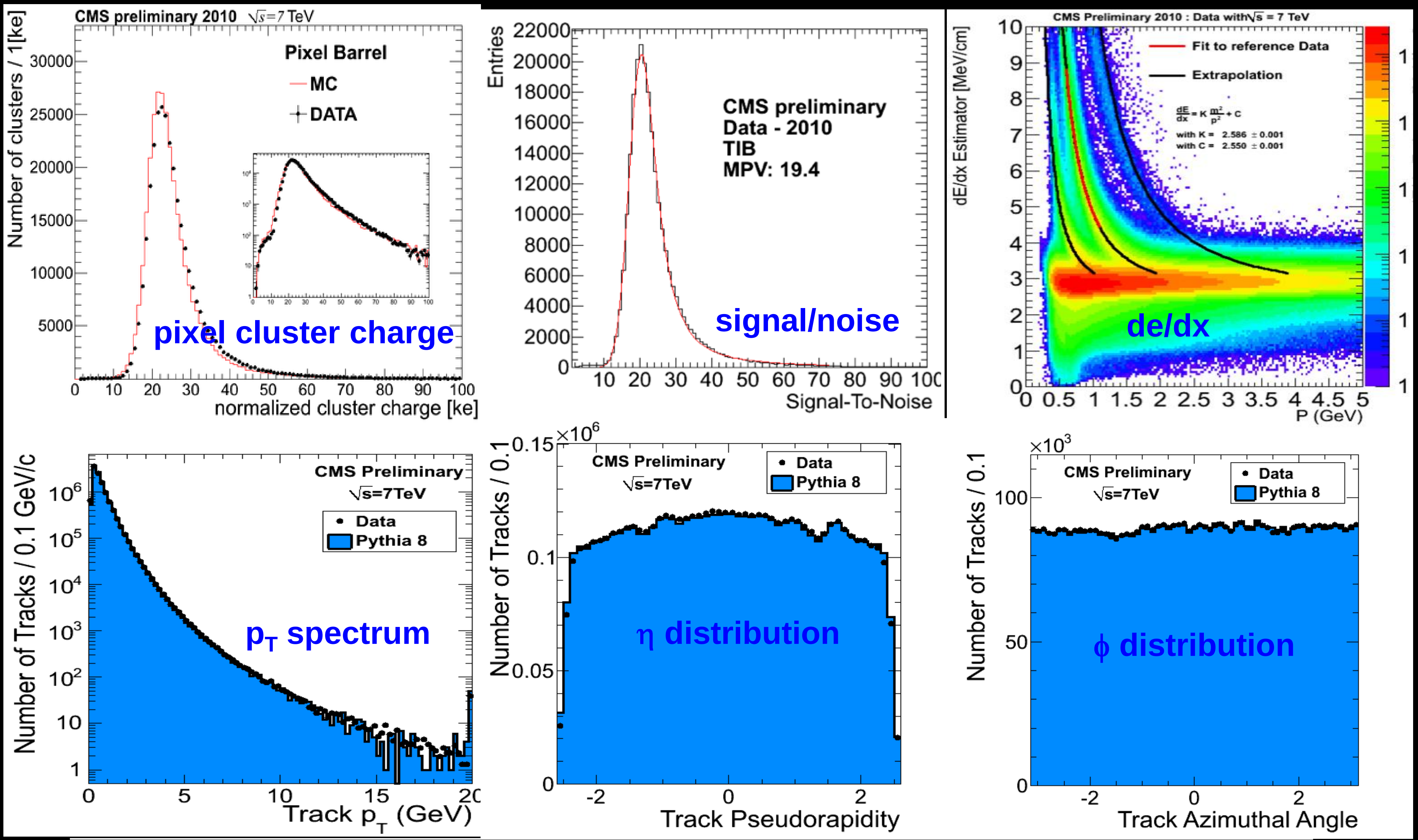
Sub-detectors operational status



	MUON-CSC	MUON-DT	MUON-RPC	HCAL BARREL	HCAL ENDCAP	HCAL FORWARD	ECAL BARREL	ECAL END-CAP	PRE-SHOWER	STRIP TRACKER	PIXEL TRACKER	
Series1	98.5	99.8	98.8	99.9	100	99.9	99.3	98.9	99.8	98.1	98.2	

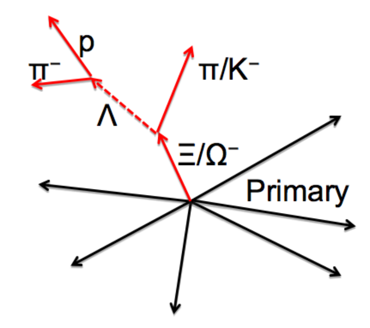
Tracker Performance

(see talks from L. DeMaria. V. Radicci. A. Bonato)

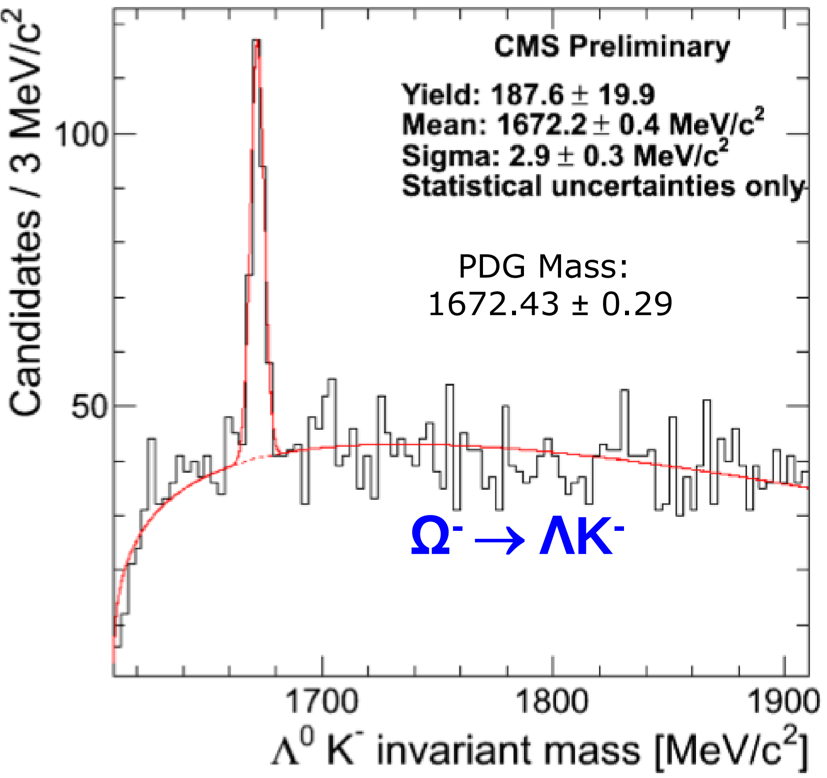


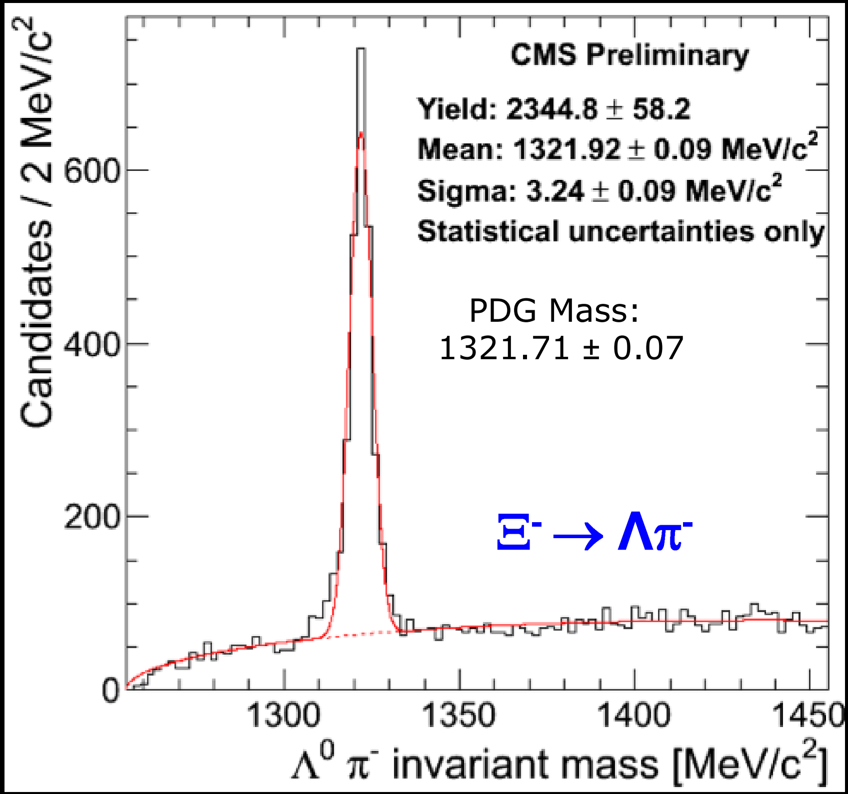
Low mass resonances

- Tracks displaced from primary vertex ($d_{3D} > 3\sigma$)
- Common displaced vertex ($L_{3D} > 10\sigma$)

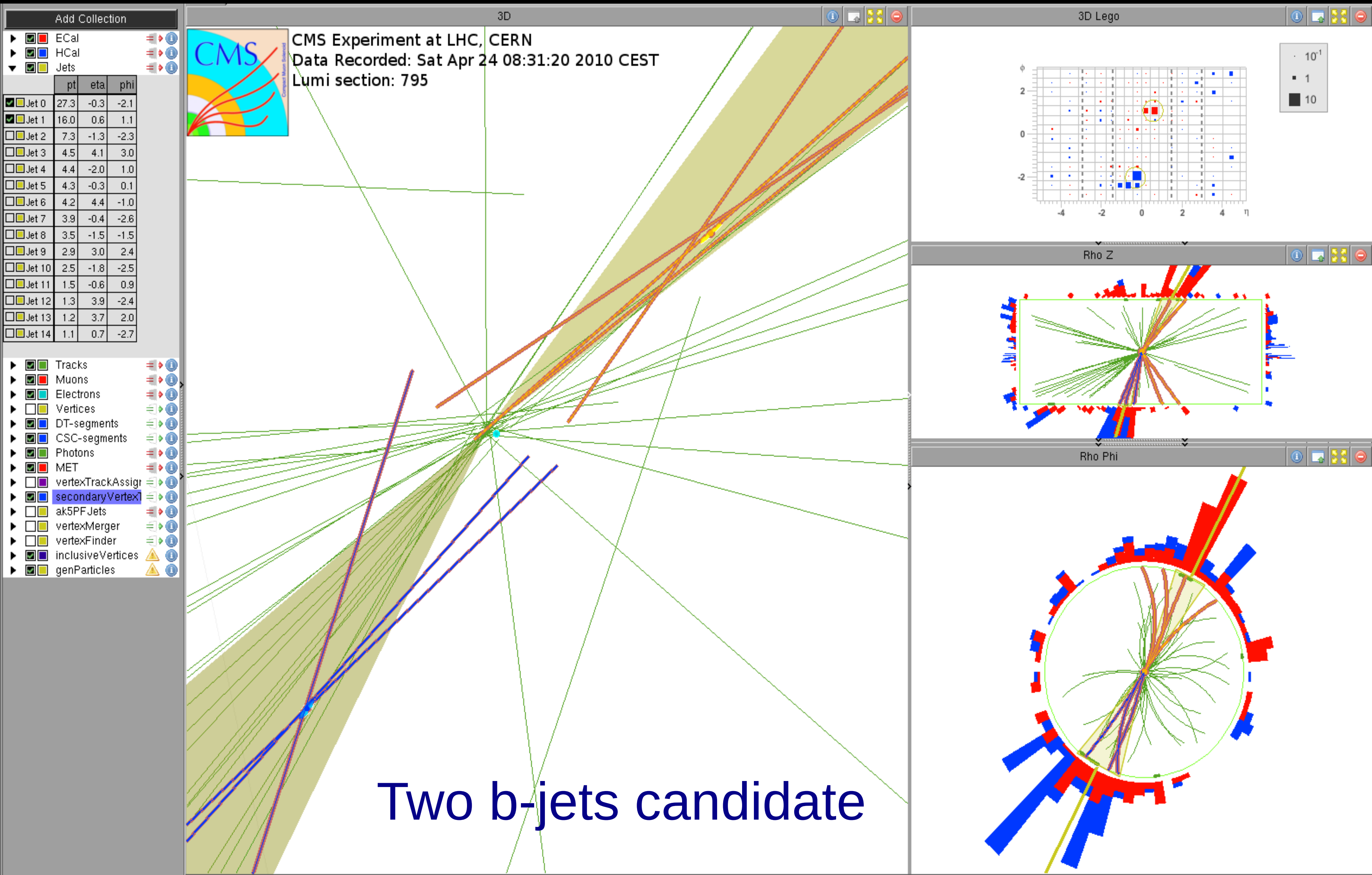


Invariant mass distribution for different combinations ($\Omega^{\pm} \to \Lambda K^{\pm}$ or $\Xi^{\pm} \to \Lambda\pi^{\pm}$) fit to a common vertex.





Ready for b physics (and b-tagging in general)



MET resolution vs Sum

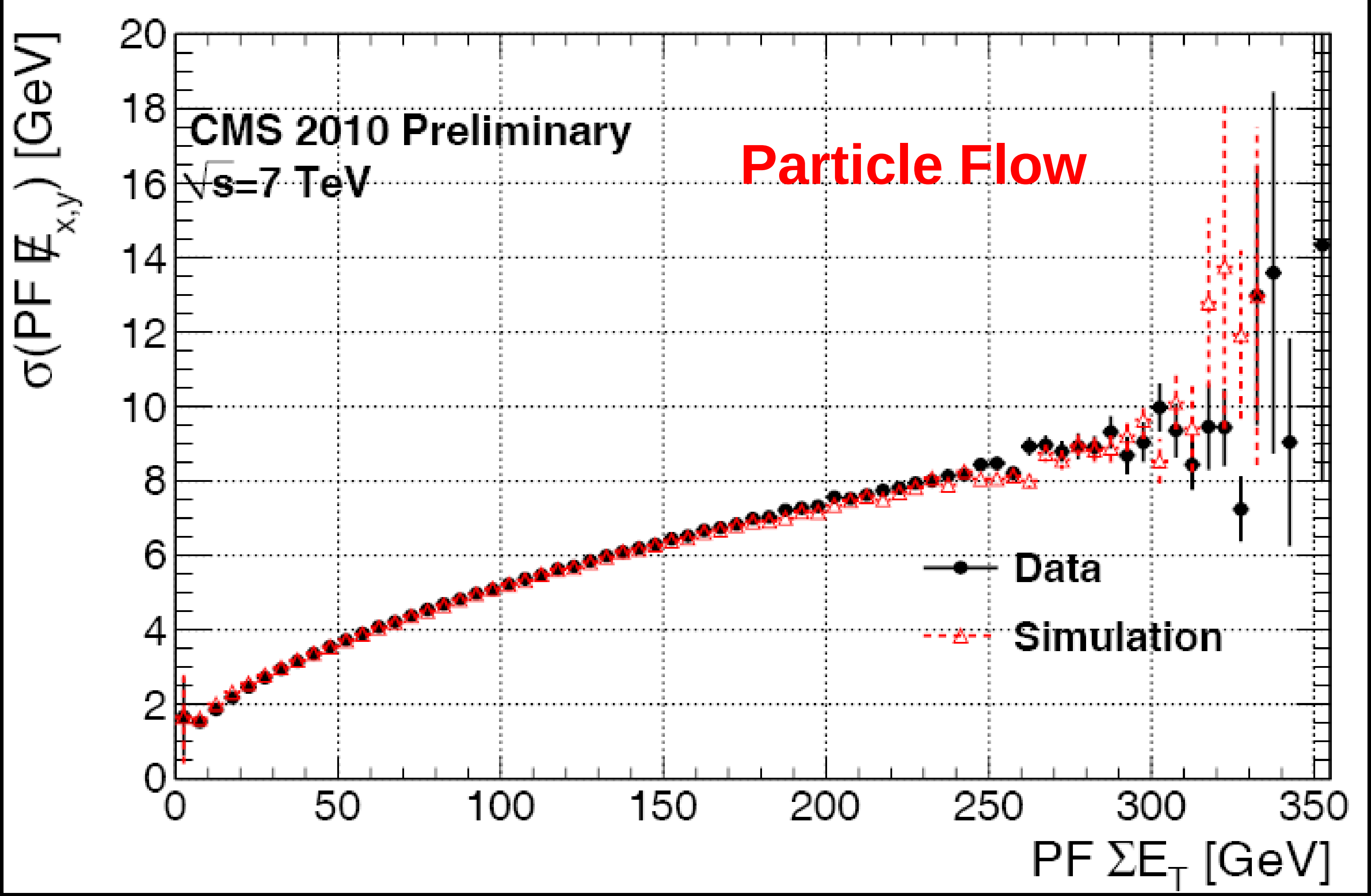
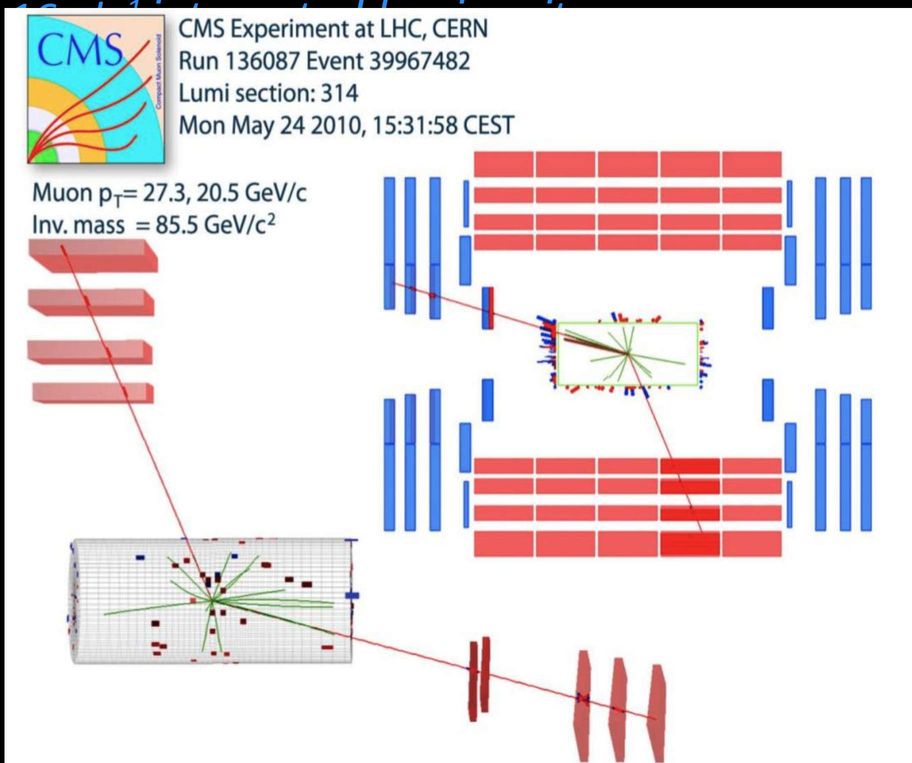


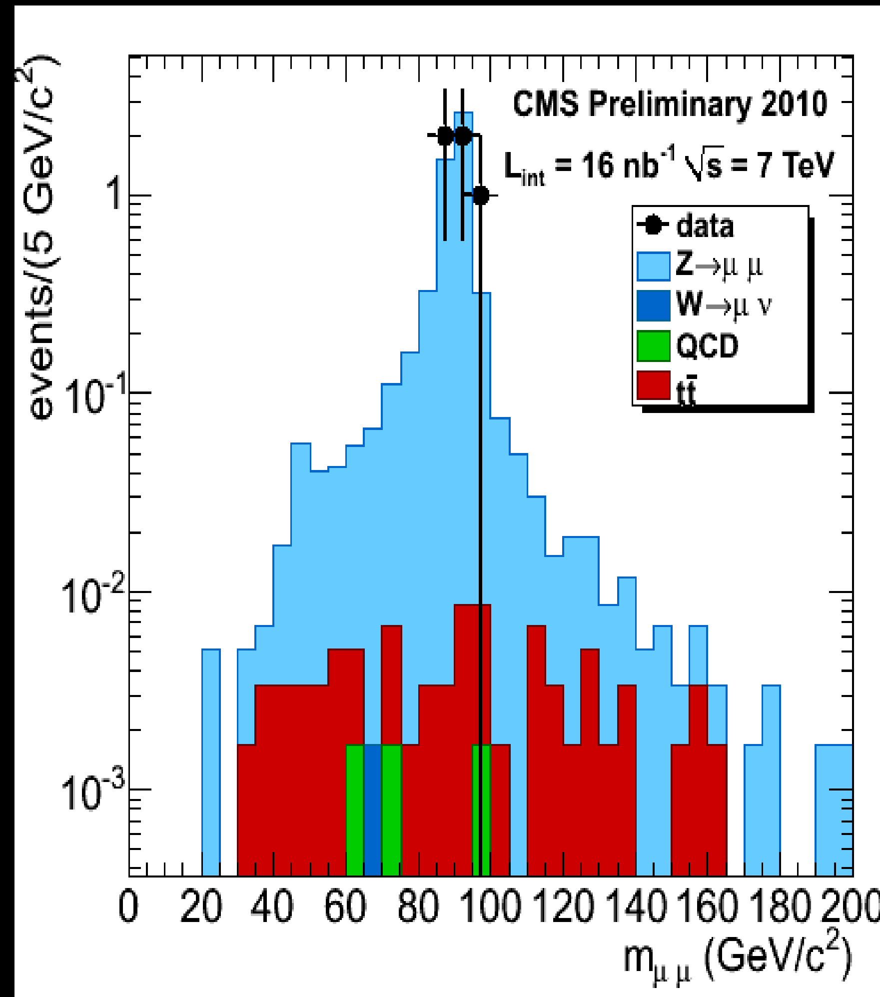
Figure: Data vs MC: PF $\not{E}_{xy}$ resolution as function of PF ΣE_{T}

$Z \rightarrow \mu^+\mu^-$ observation

Event selection : *muon id selection (global and tracker muons) ; loose Isolation, pT cut.*

Monte Carlo : *cross section normalized to*



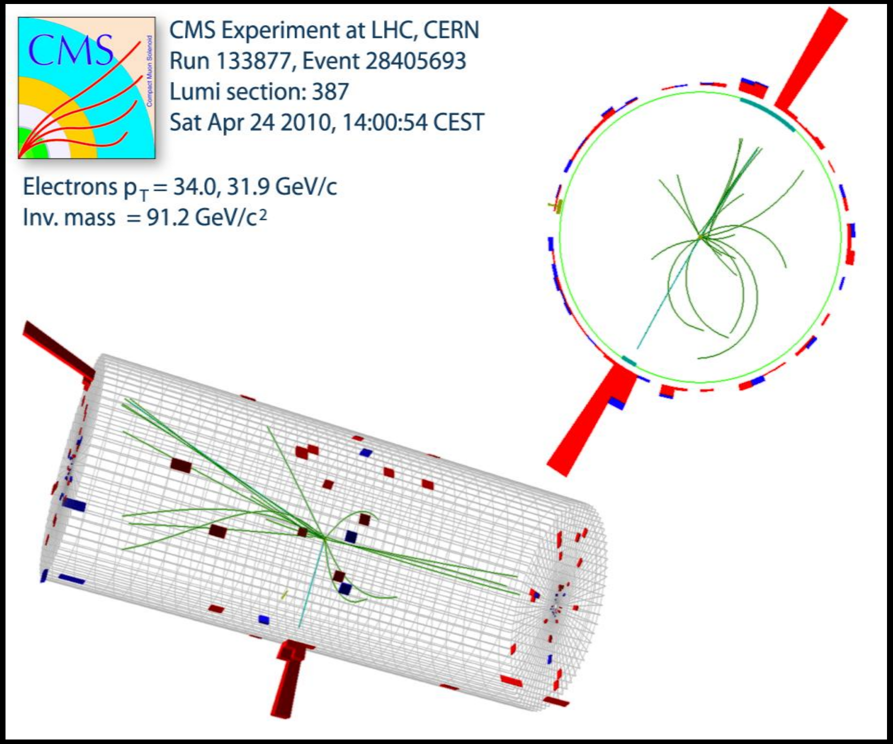


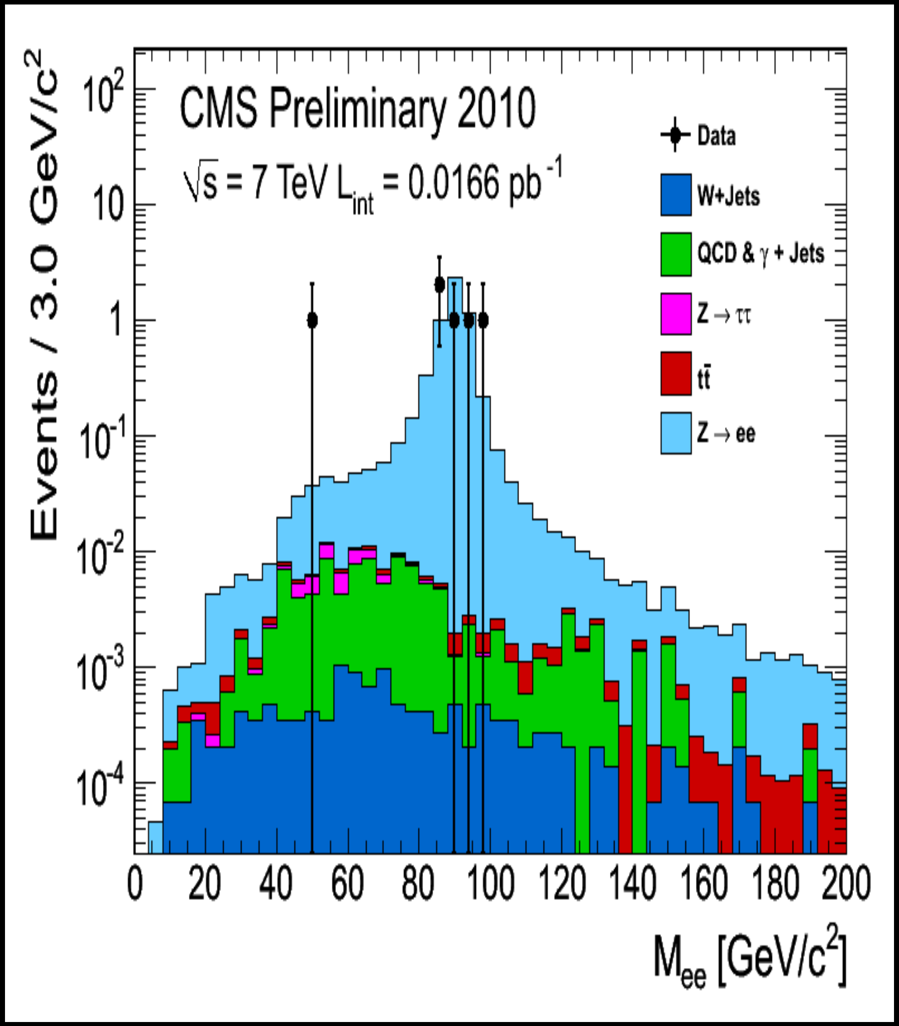
5 $Z \rightarrow \mu^+\mu^-$ candidates

$Z \rightarrow e^+e^-$ observation

Event selection: *both electrons with a SuperCluster with Et > 20 GeV*

Monte Carlo : *cross section normalized to 17 nb^{-1} integrated luminosity*



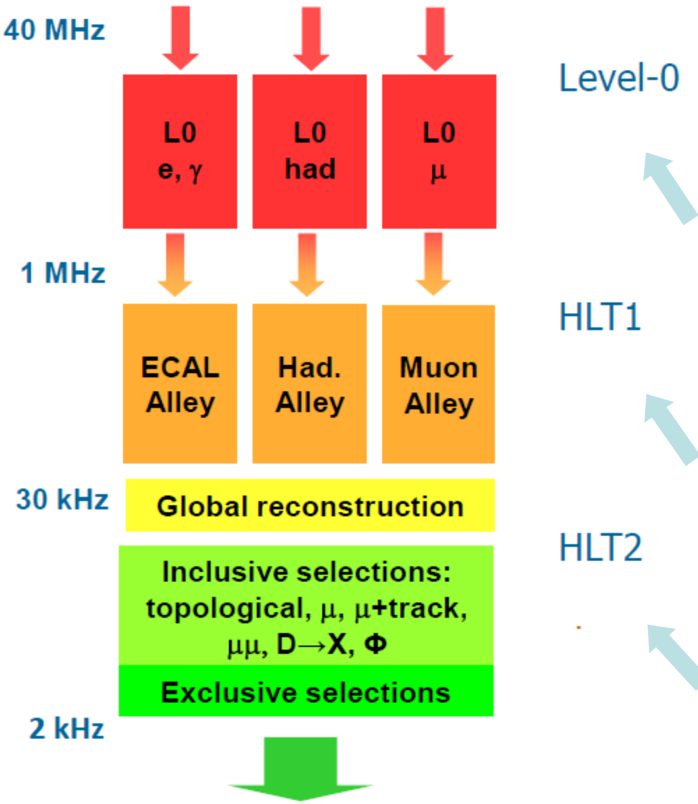


5 $Z \rightarrow e^+e^-$ candidates

LHCb

LHCb Trigger in 2010

For bulk of running foreseen this year, with luminosities up to a few 10^{31} cm^{-2} s^{-1} , we can afford to relax many of our trigger cuts, with large benefits for efficiencies



2010 approach

Apply very low pt cuts – main purpose of L0 is now to seed HLT1 regions of interest

Reduce requirements on track impact parameter w.r.t. nominal settings

Not needed at all initially, then introduce with rather loose suppression requirements

Boost trigger efficiencies for hadronic decays of promptly produced D's by factor 4-5 w.r.t. nominal settings. Golden opportunity for charm physics studies ! Total efficiencies for hadronic B decays now 75-80%, with those for leptonic decay modes >90%.

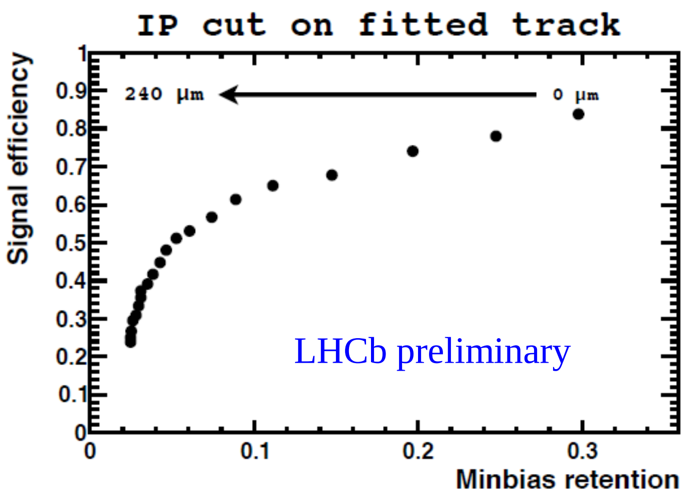
Trigger Efficiencies

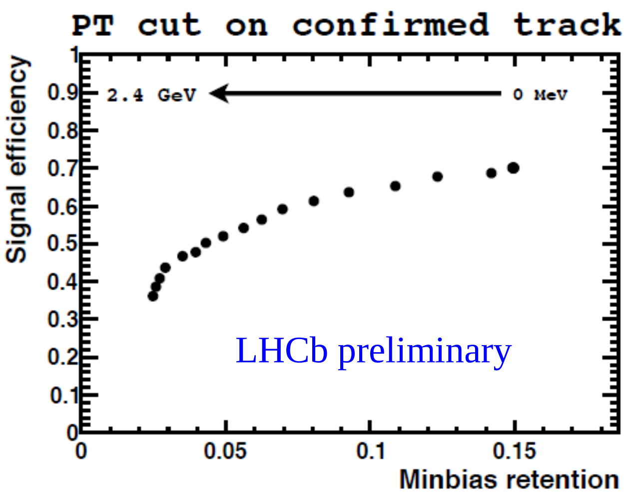
Take D*, $D^0 \rightarrow K\pi$ signal collected in minimum bias events
&
Evaluate L0*HLT1 performance with 2010 low luminosity trigger settings

good agreement with MC

Eff-trig$_{L0*HLT1}$(data) = 60 ± 4 %
MC expectation = 66 %

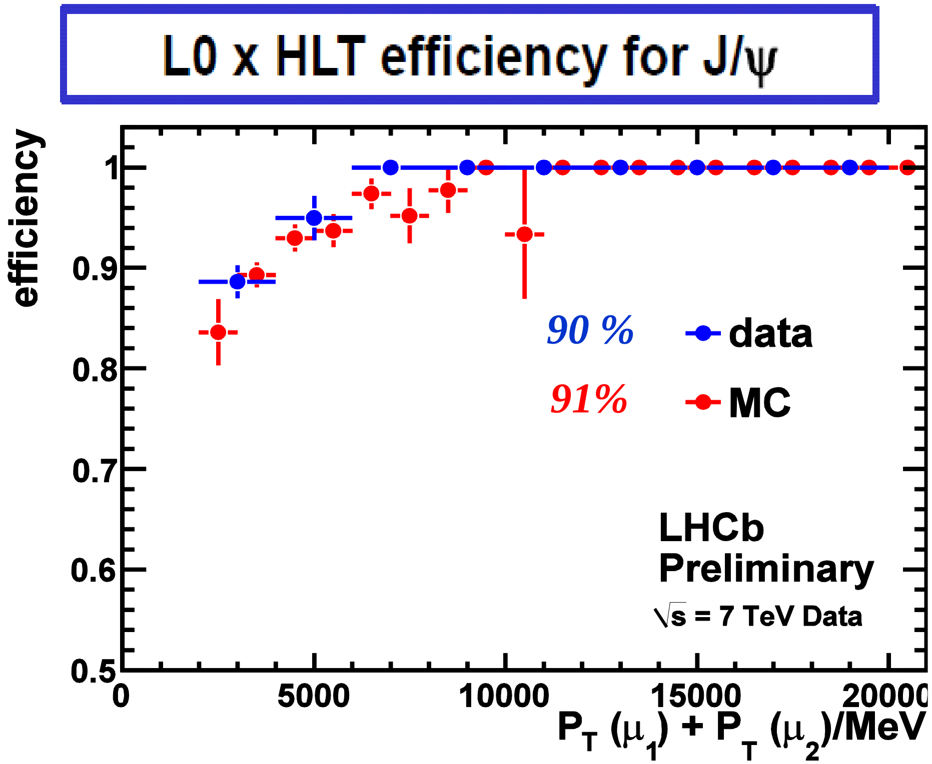
Performance of single-hadron HLT1 line on data

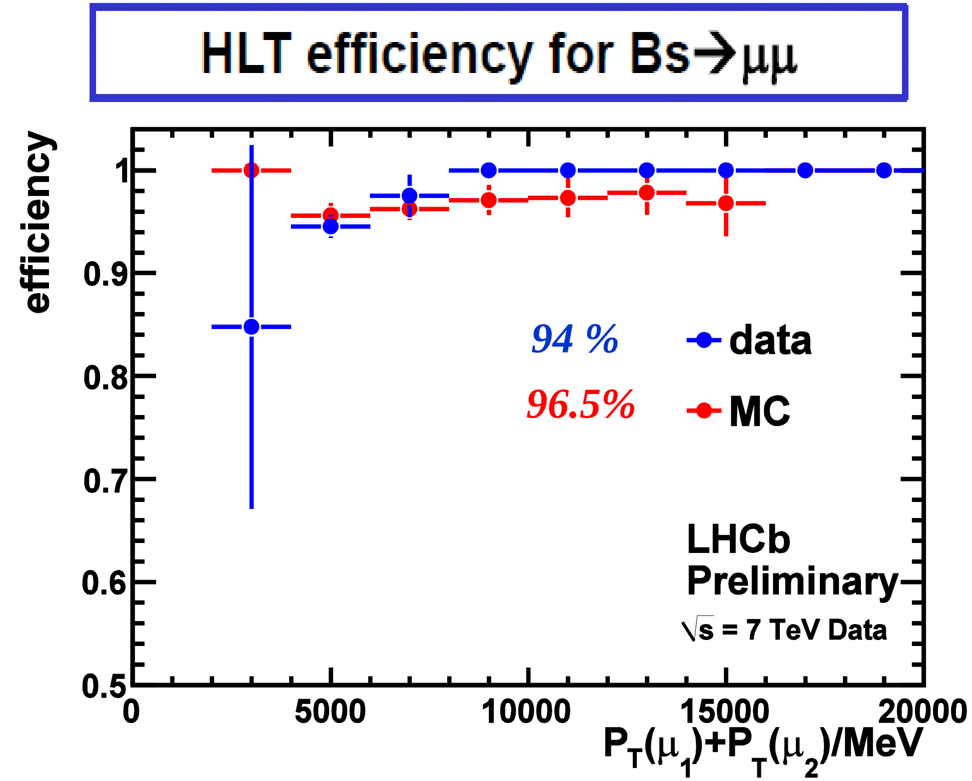




Trigger Efficiencies

- *Measure performance of L0*HLT1 (using lifetime unbiased HLT1 lines) for $J/\psi \to \mu\mu$*
- *Transport results to harder p_t spectrum of $B_s \to \mu\mu$*





Data agree well with MC

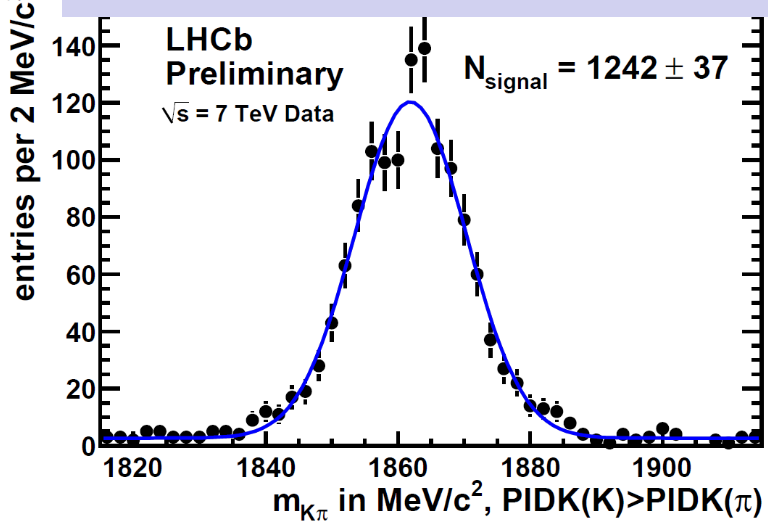
LHCb trigger concept has been proven with data !!!

LHCb is currently running with the pile-up close to expected at nominal conditions

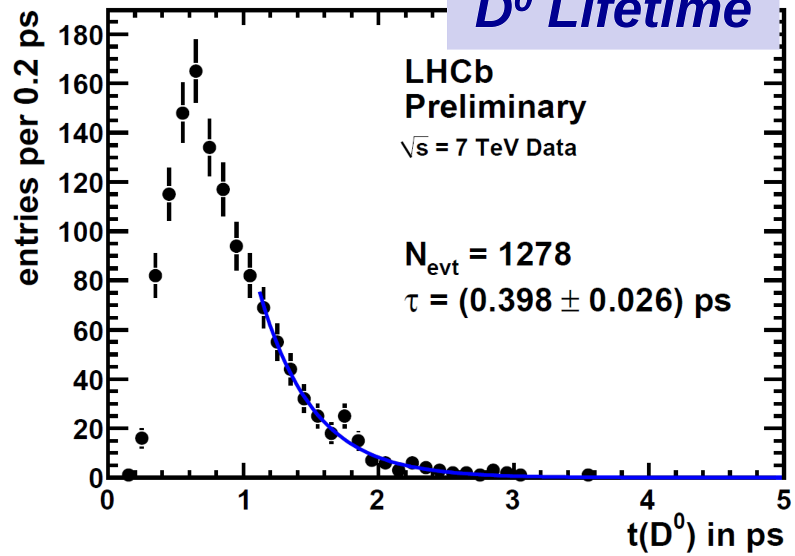
Proper Lifetime

(use sample of D^0 for calibration; D^0 lives 3.5 times shorter than B^0)

Clean sample of untagged $D^0 \rightarrow K\pi$



D^0 Lifetime



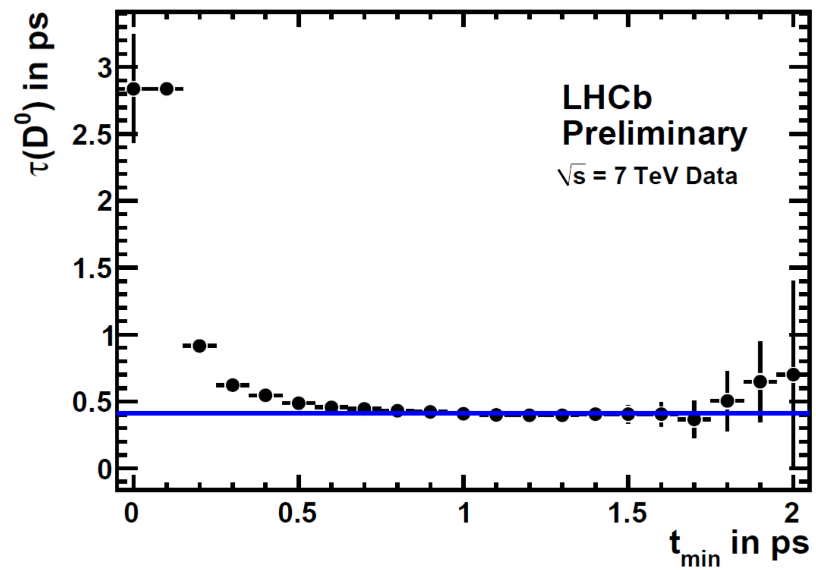
LHCb Lifetime fit gives:

$$\tau(D^0) = (0.398 \pm 0.026)\ \text{ps}$$

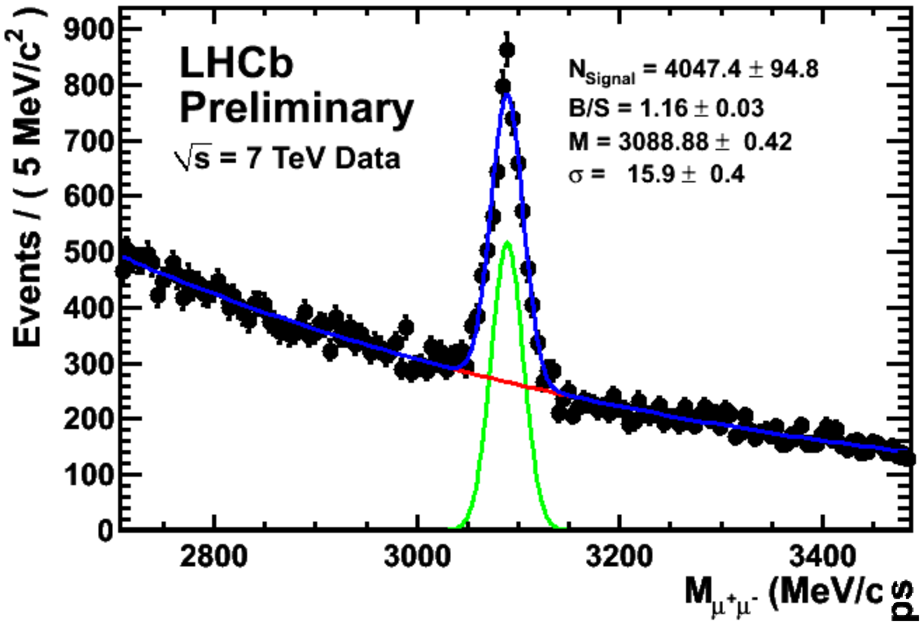
In good agreement with PDG:

$$\tau(D^0) = (0.4101 \pm 0.0015)\ \text{ps}$$

The fit is insensitive to the lower Bound of the lifetime, t_{min}, within a wide range

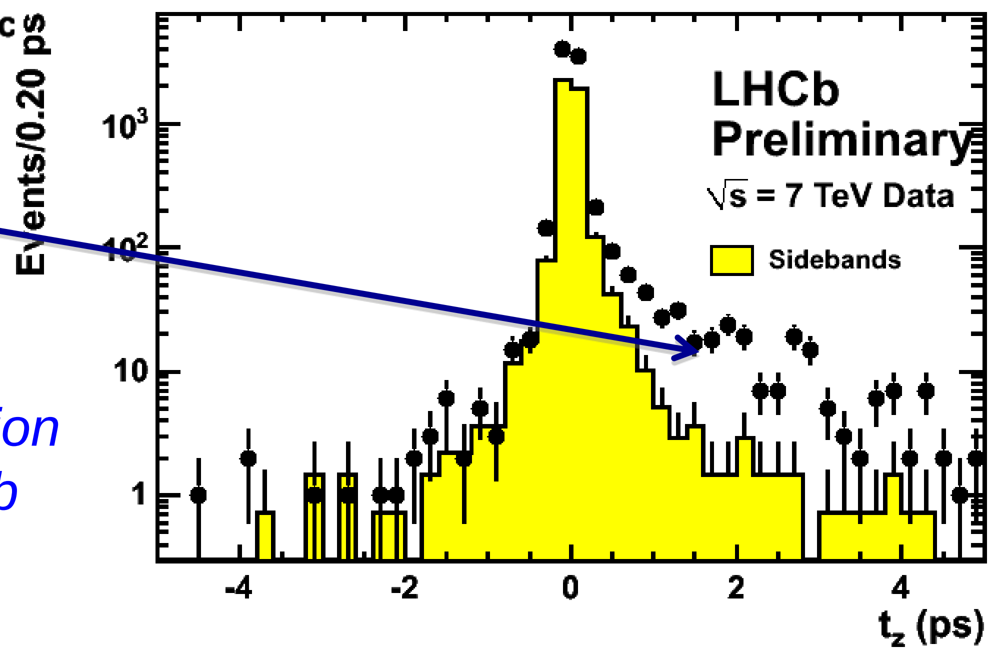


J/psi effective lifetime



A total of 4000 $J/\psi \rightarrow \mu\mu$ decays reconstructed

Signal window & normalized sideband

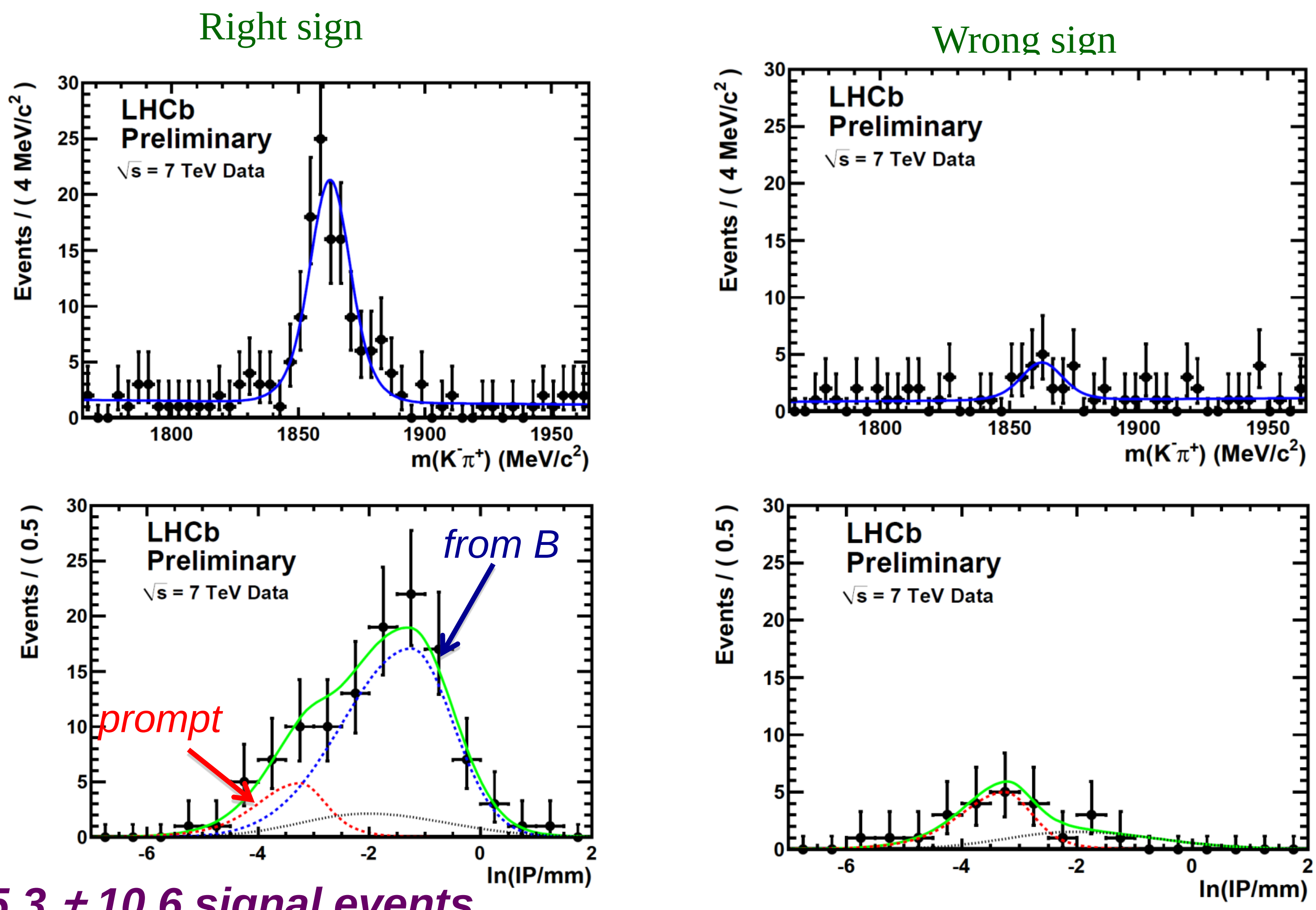


Proper life time distribution shows clear evidence for J/ψ produced in B decays

Solid prospects to measure production cross-sections for prompt J/ψ and bb at $\sqrt{s}$ = 7 TeV

$B^0 \rightarrow D^0 \mu\nu$ with $D^0 \rightarrow K\pi$

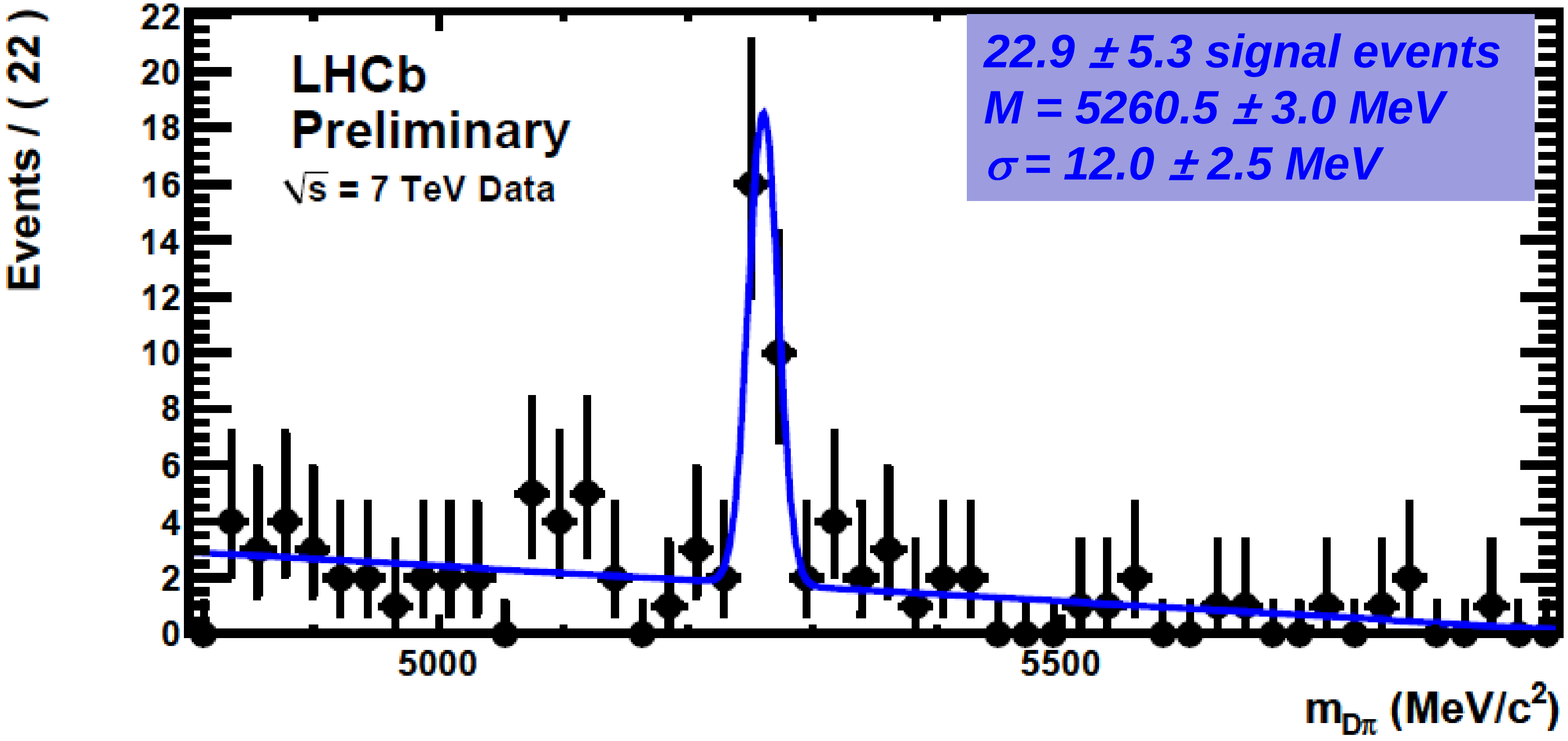
Correlate D^0 with the muon of the right (wrong) sign



85.3 ± 10.6 signal events with D from B

First fully reconstructed B mesons

$B^0 \rightarrow D^+\pi^- \ + \ B^+ \rightarrow D^0\pi^+$



Calibration of the mass scale and B-field is ongoing

LHC experiments summary

- So far, so good….
- Experiments tracking nicely the machine evolution, eagerly awaiting more data
- Computing infrastructure supports magnificently the swift data analysis
- …exciting times !

SPARES

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.

LHC @ 7 TeV

Run plan 2010-2011:

- 2010:

L = ~10^{28} –>10^{32} cm^{-2} s^{-1} –> total of 100-200 pb^{-1}

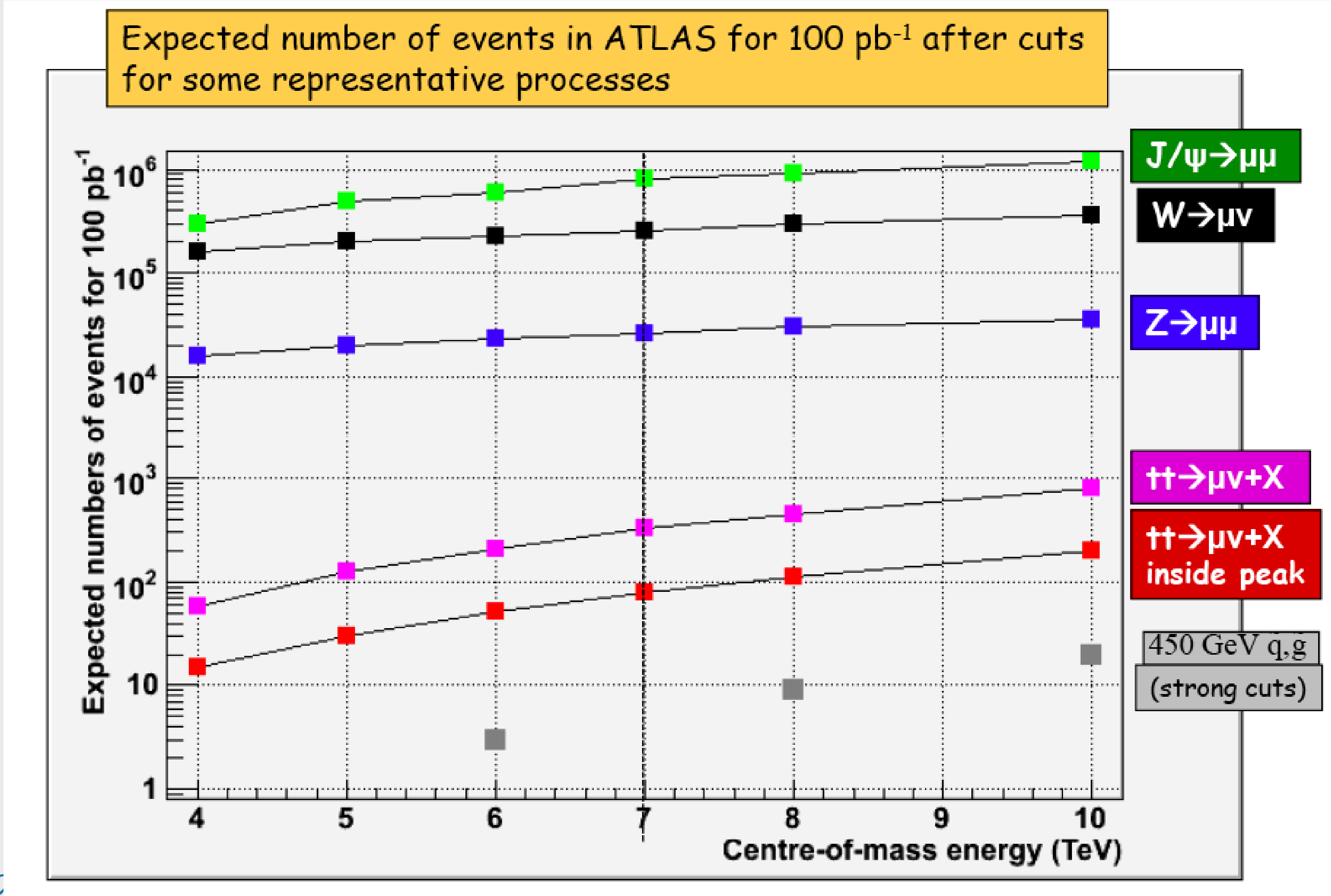
- 2011:

L = 1 –> few 10^{32} cm^{-2} s^{-1} –> collect ≥ 100 pb^{-1}/month

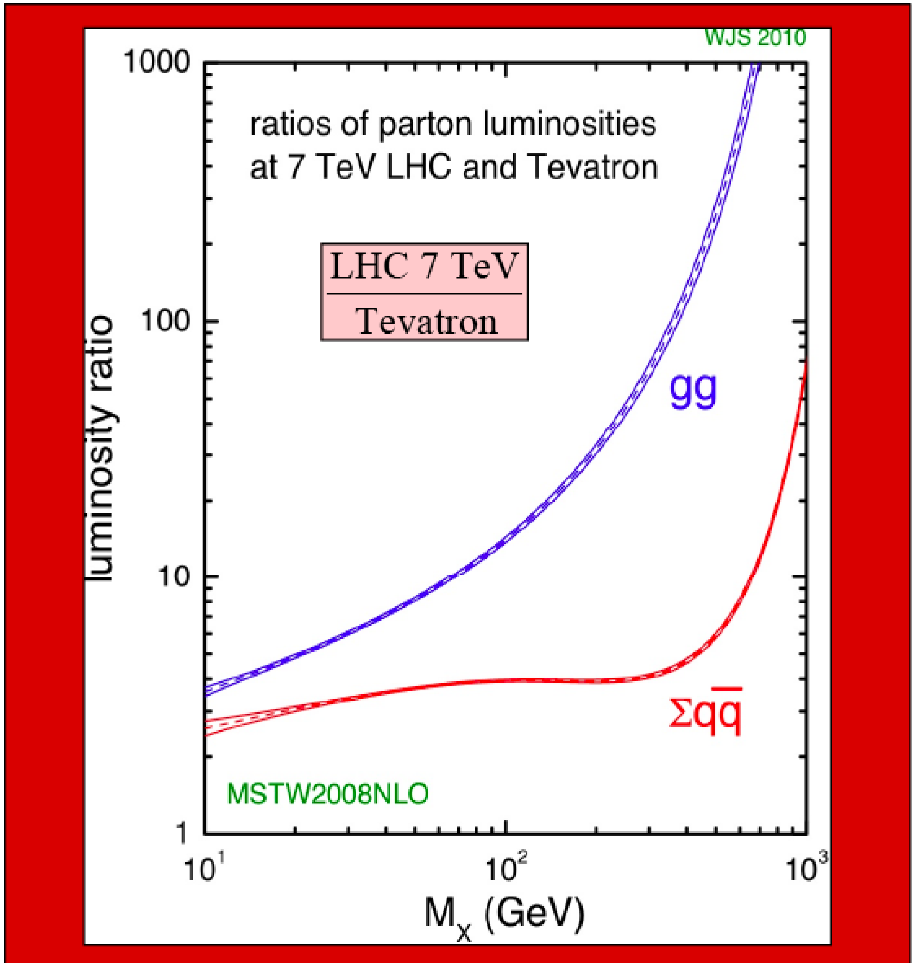
–> total of ~ 1 fb^{-1}

- Two heavy ions runs at the end of 2010 and 2011

LHC @ 7 TeV: the physics reach



LHC is a gluon collider



Cross-section	Tevatron	LHC@7TeV/Tevatron	LHC@14TeV/Tevatron
W/Z → lν, ll tt production	2.5/0.25 nb per family 7.2 pb	~ 5 ~ 20	~ 10 ~ 100

Two relevant examples

Process	7 TeV 200 pb^{-1}	7 TeV 1 fb^{-1}
$Z \rightarrow ee$	51300	256000
$tt \rightarrow$ l+jets	1200	5900

← Expected number of events after cuts for one experiment

$Z \rightarrow ll$: with 1 fb^{-1} large enough sample to calibrate the detector to the "ultimate" precision: e.g. ECAL inter-calibration ~ 0.5%, absolute E/p momentum scale to ~ 0.1%, etc; much less needed to understand trigger and lepton efficiency

$tt \rightarrow$ l+jets: statistics with 1 fb^{-1} is ~ 2 times larger than one Tevatron experiment with 10 fb^{-1}
Note: first observation of top-quark signal in Europe with few O(10 pb^{-1})

Note: Tevatron expects ~ 10 fb^{-1} of "analyzable" luminosity by end 2011

New Physics reach

New Physics : approximate LHC reach (one experiment) for some benchmark scenarios ($\sqrt{s}$ = 7 TeV, unless otherwise stated)

Z' (SSM): Tevatron limit ~ 1 TeV (95% C.L)

$50\ pb^{-1}$: exclusion up to ~ 1 TeV (95% C.L.)
$500\ pb^{-1}$: discovery up to ~ 1.3 TeV
exclusion up to ~ 1.5 TeV
$1\ fb^{-1}$: discovery up to ~ 1.5 TeV

W' : Tevatron limit ~ 1 TeV (95% C.L)

$10\ pb^{-1}$: exclusion up to 1 TeV
$100\ pb^{-1}$: discovery up to ~ 1.3 TeV
$1\ fb^{-1}$: discovery up to ~ 1.9 TeV
exclusion up to ~ 2.2 TeV

SUSY $(\tilde{q}, \tilde{g})$: Tevatron limit ~ 400 GeV (95% C.L)

$100\ pb^{-1}$: discovery up to ~ 400 GeV
$1\ fb^{-1}$: discovery up to ~ 800 GeV

Higgs boson

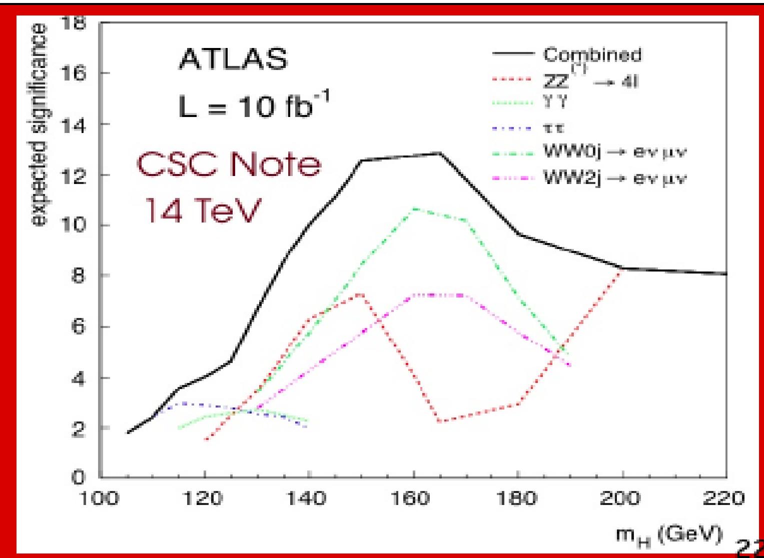
Very preliminary estimates

Higgs √s=7 TeV: H → WW, m_H ~ 160 GeV (Tevatron exclusion: 163-166 GeV)

300 pb^{-1} per experiment : ~ 3σ sensitivity combining ATLAS and CMS (similar to Tevatron)
1 fb^{-1} per experiment : could exclude 145 < m_H < 180 GeV
~ 4.5 σ combining ATLAS and CMS

- Exclusion of the full mass range down to m_H~115 GeV requires ~1.5 fb^{-1} per experiment at 14 TeV
- Discovery for m_H ~ 115 GeV requires ~ 10 fb^{-1} per experiment at 14 TeV

A long way to go if the Higgs is just above the LEP2 limit.
Note: Tevatron and LHC are complementary for m_H~ 115 GeV:
-- main channels at the Tevatron:
WH, ZH with H→ bb
-- main channels at LHC: H →γγ, qqH → ττ



F.Gianotti, La Thuile, 3-3-2010

22

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
  - Number of bunches per beam k_b
  - Relativistic factor (E/m_0) γ
  - Normalised emittance ε_n
  - Beta function at the IP β^*
  - Crossing angle factor F
    - Full crossing angle θ_c
    - Bunch length σ_z
    - Transverse beam size at the IP σ^*

Intensity

Energy

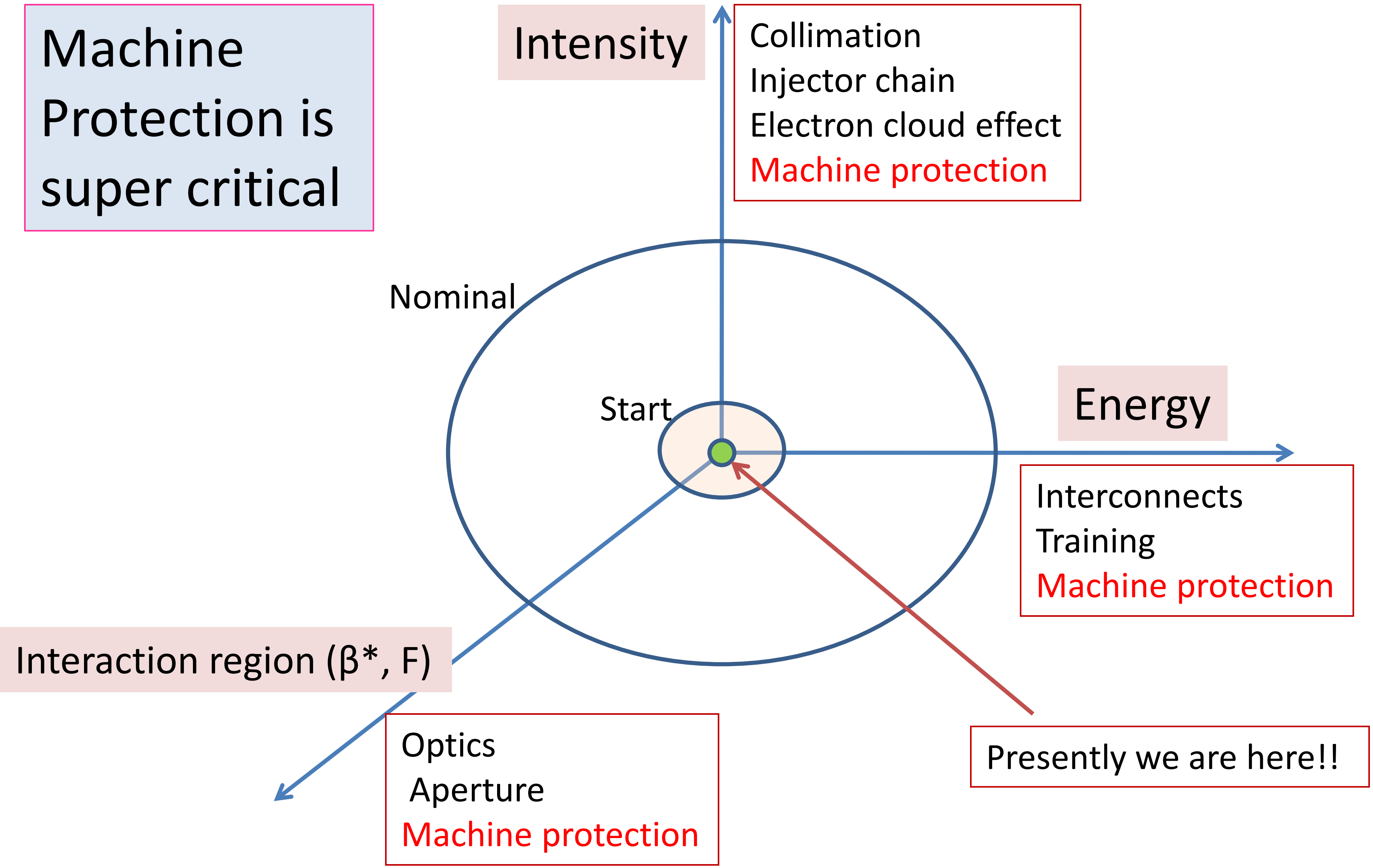
Interaction Region

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

Roger Bailey

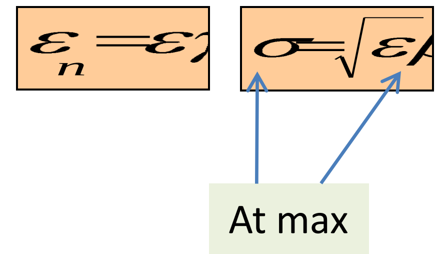
LHC performance drivers/limiters

Machine Protection is super critical



β* and F in 2010

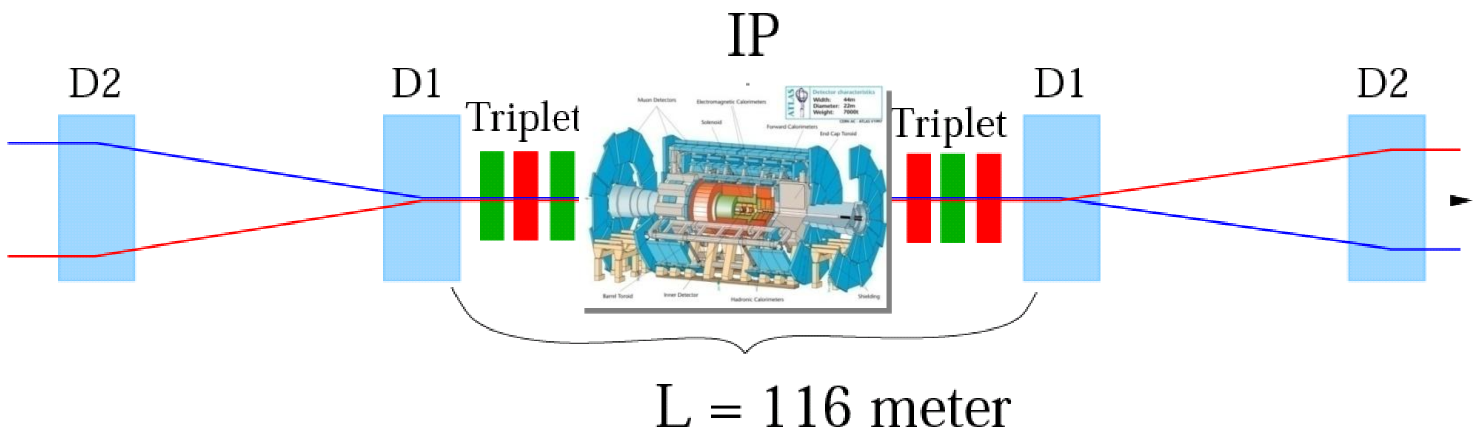
- Lower energy means bigger beams
  - Less aperture margin
  - Higher β*

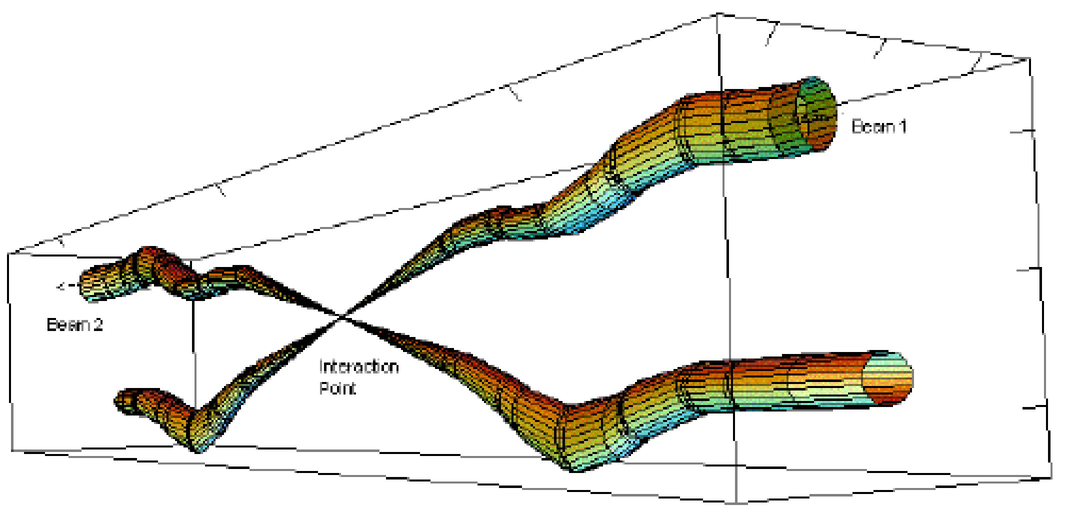


- > 150 bunches requires crossing angle (beam-beam)
  - Requires more aperture
  - Higher β*

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

Interaction Region - F

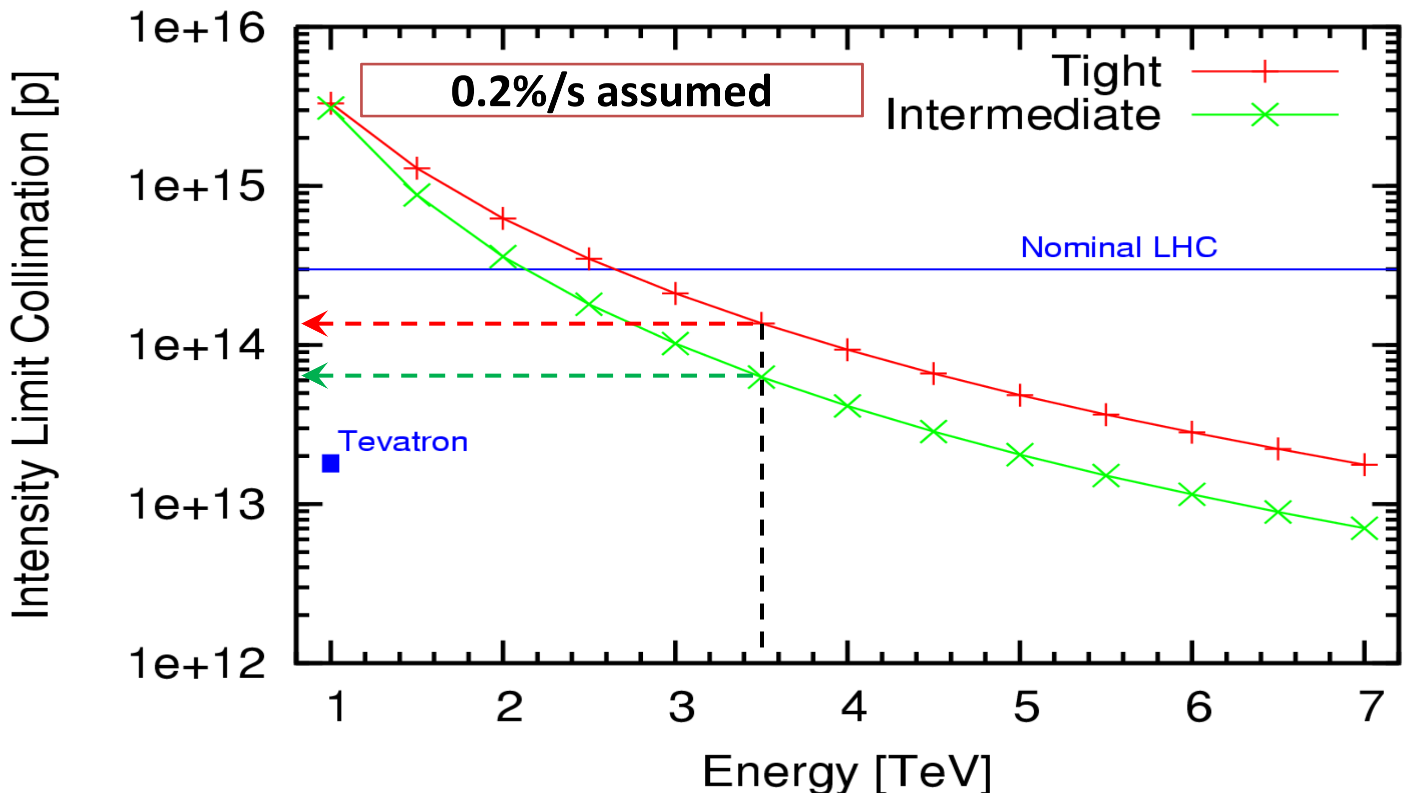




Relative beam sizes around IP1 (Atlas) in collision

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

“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

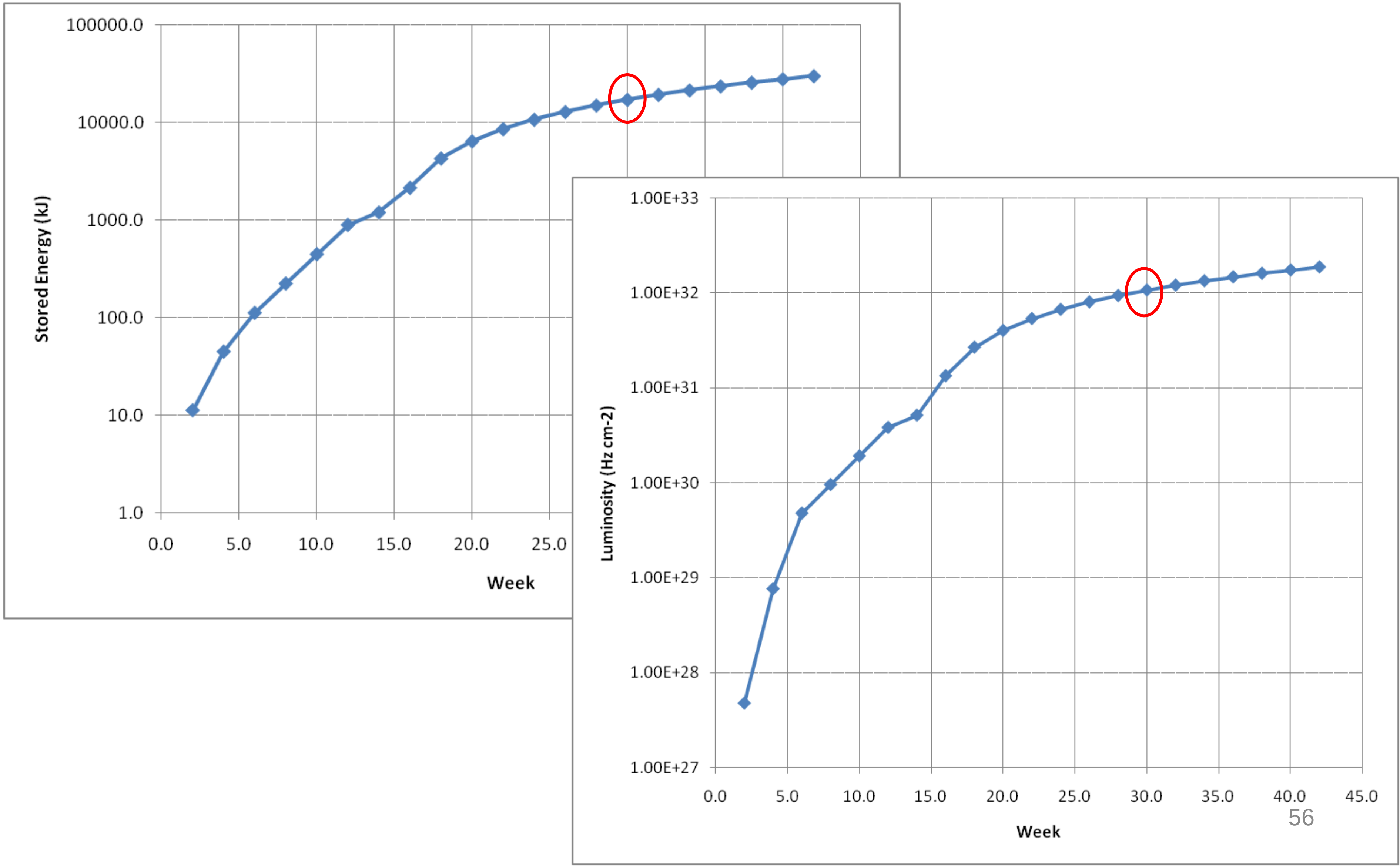
Soft limit, not yet well defined, 0.2%/s loss rate totally arbitrary (8 minute lifetime)

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.

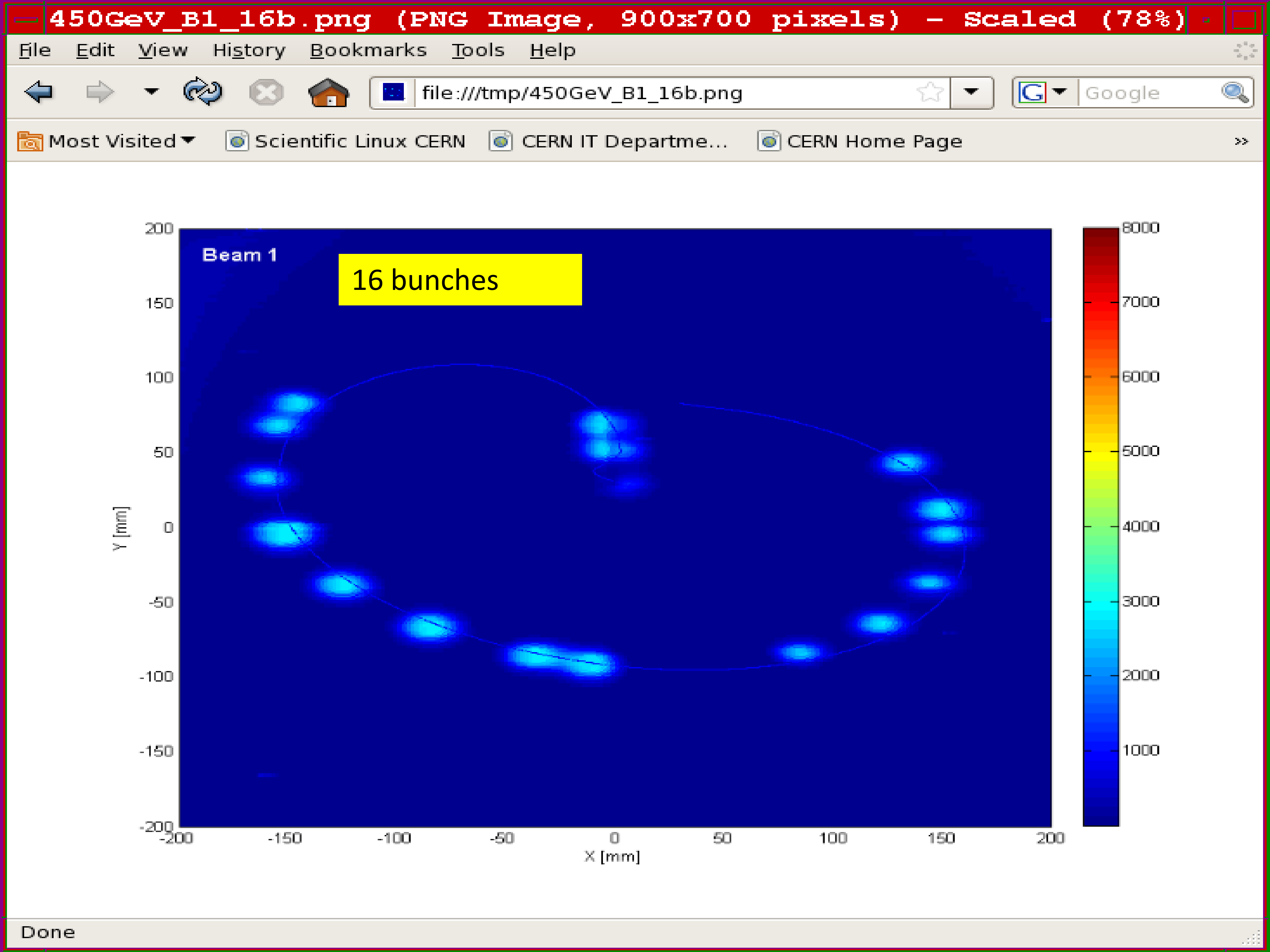


2011

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 [pb^{-1}]
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

Upgrades: Foreword

Studies have been launched about one year ago and are ongoing

- Performance Aim
  - To maximize the useful integrated luminosity over the lifetime of the LHC
- Targets set by the detectors are:

  3000fb^{-1} (on tape) by the end of the life of the LHC

  → 250-300fb^{-1} per year in the second decade of running the LHC

- Goals
  - Check the performance of the present upgrades
  - Check the coherence of present upgrades wrt
    - » Accelerator performance limitations,
    - » Detector requirements,
    - » manpower resources,
    - » shutdown planning for all activities

Performance: Injector Upgrades

- Present Peak Performance Situation

Intensity Limitations (10^{11} protons per bunch)		
	Present	
Linac2/LINAC4	4.0	
PSB or SPL	3.6	
PS or PS2	1.7	
SPS	~1.2	
LHC	1.7-2.3?	

Conclusion 1: SPS is the bottleneck!

SPS Bottleneck

- Other injectors are limited by a fundamental limitation, the space charge effect (ΔQ_{sc} = 0.3)
- In the SPS at injection: ΔQ_{sc} = 0.07! (no fundamental limitation)
- Actual Intensity Limitation in SPS (mitigation)
  - Electron cloud (vacuum chamber coating)
  - Transverse Mode Coupling Instability (Impedance reduction and/or transverse feedback)
  - RF effects such as beam loading etc (redesign of existing RF or build new system)

Immediately after Chamonix a hardware task force has been set up to investigate the removal of this SPS bottleneck (led by Volker Mertens)

Injectors Performance (Availability)

- From the LINAC2 to the SPS we have ageing machines
  - We need consolidation or replacement
- Proposed scenario (White Paper, 2006) is to replace LINAC2, PSB and PS
  - LINAC4, SPL, and PS2
- Recent study shows time scale for operation of the PS2 is at earliest 2020 and likely 2022.
  - Conclusion 2: We need to aggressively consolidate the existing injector chain to allow reliable operation of the LHC until at least 2022.
  - Task force set up late last year. (Simon Baird)
- BUT: **Resources** needed for the consolidation of the existing injectors are in direct competition with those needed for the construction of SPL/PS2
- Question: What would be the LHC performance implications of not constructing SPL/PS2??

Performance Limitations without SPL/PS2

- Alternative scenario to SPL/PS2
  - Consolidate existing injectors for the life of the LHC (2030)
  - During the same consolidation, improve the performance of PSB/PS as injectors for the LHC
- New "Idea"
  - Increase the extraction energy of the PSB which allows increase of the injection energy of the PS.
  - 2GeV injection energy in the PS allows ~3×10^{11} ppb with the same space charge tune shift (preliminary study presented in Chamonix)

"Project" set up immediately after Chamonix

Intensity Limits

Intensity Limitations (10^{11} protons per bunch)			
	Present	SPL-PS2	2GeV in PS
Linac2/LINAC4	4.0	4.0	4.0
PSB or SPL	3.6	4.0	3.6
PS or PS2	1.7	4.0	3.0
SPS	1.2	>1.7?	>1.7?
LHC	1.7-2.3?	1.7-2.3?	1.7-2.3?

Possible Improvements in Existing Injector Chain: Summary

- Increase PSB (PS injection) energy to 2 GeV
  - Possibility to generate LHC bunches of up to 2.7×10^{11} p (or even up to 3×10^{11} p) with 25 ns spacing.
- Time line for implementation of new PSB extraction energy:
  - Three to four years (design and construction of new hardware)
  - One to two shutdowns (hardware installation)

Insertion Upgrade Plans

- IT Upgrade "phase 1"
  - Goal: reliable operation at $2x10^{34}cm^{-2}s^{-1}$, intensity < ultimate and > nominal

    Very similar to "ultimate"
  - ? Same resources for splice consolidation

Tough Questions:

1. Will the phase 1 upgrade produce an increase in useful integrated luminosity?
   - Installation time and recomissioning a new machine afterwards
2. Do we have the resources to complete on a time scale which is reasonable with respect to phase 2?

Task force set up immediately after Chamonix (Lucio Rossi) 4-5 weeks to answer above questions (mid-end March). Task force will then define the parameters for sLHC

Future Upgrade Scenarios “Phase 2”

- Luminosity Optimization and Levelling
  - For LHC high luminosities, the luminosity lifetime becomes comparable with the turn round time.. Low efficiency
  - Preliminary estimates show that the useful integrated luminosity is greater with
    - a peak luminosity of 5-6x10^{34} cm^{-2} s^{-1} and luminosity levelling
    - than with 10^{35} and a luminosity lifetime of a few hours
  - Luminosity Levelling by
    - Beta*, crossing angle, crab cavities, and bunch length

Detector people have also said that their detector upgrade would be much more complicated and expensive for a peak luminosity of 10^{35} due to

- Pile up events
- Radiation effects

Some additional Remarks

- Collimation (highest priority after the splice repair)
- Radiation to Electronics

- We also need to study
  - How to give LHCb $5x10^{33}cm^{-2}s^{-1}$
  - Higher luminosity with lead collisions (ALICE)

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**