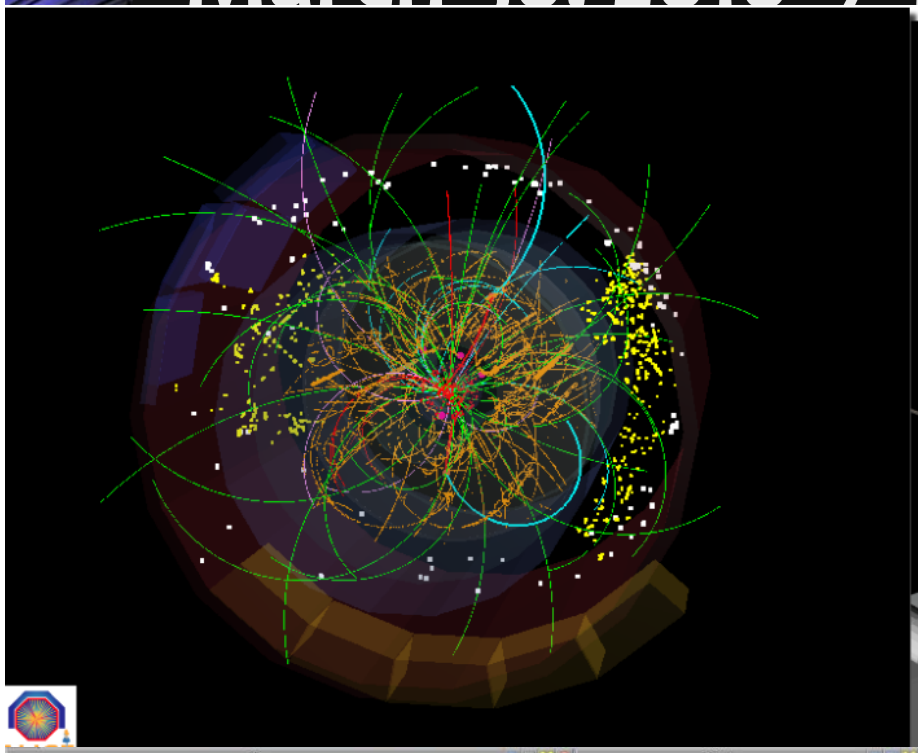
Status Report on the LHC Experiments and Computing

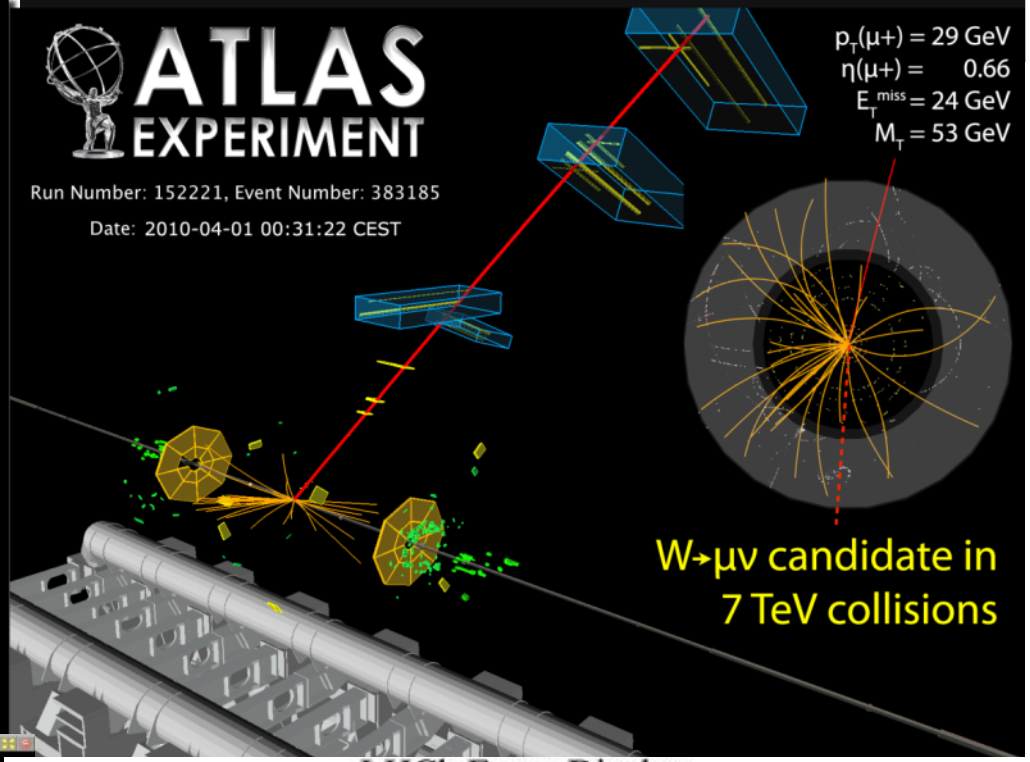
Council 155

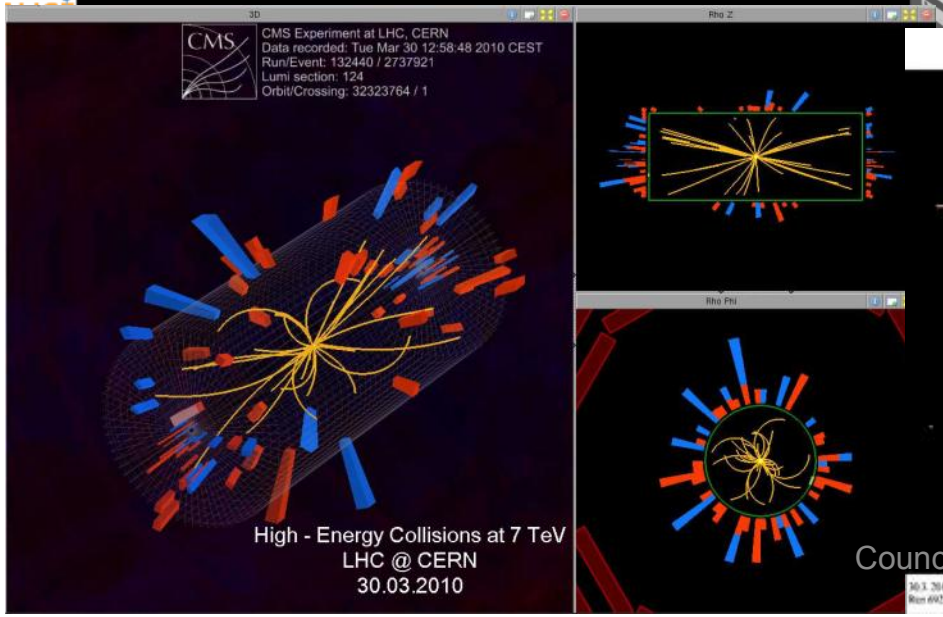
June 17, 2010

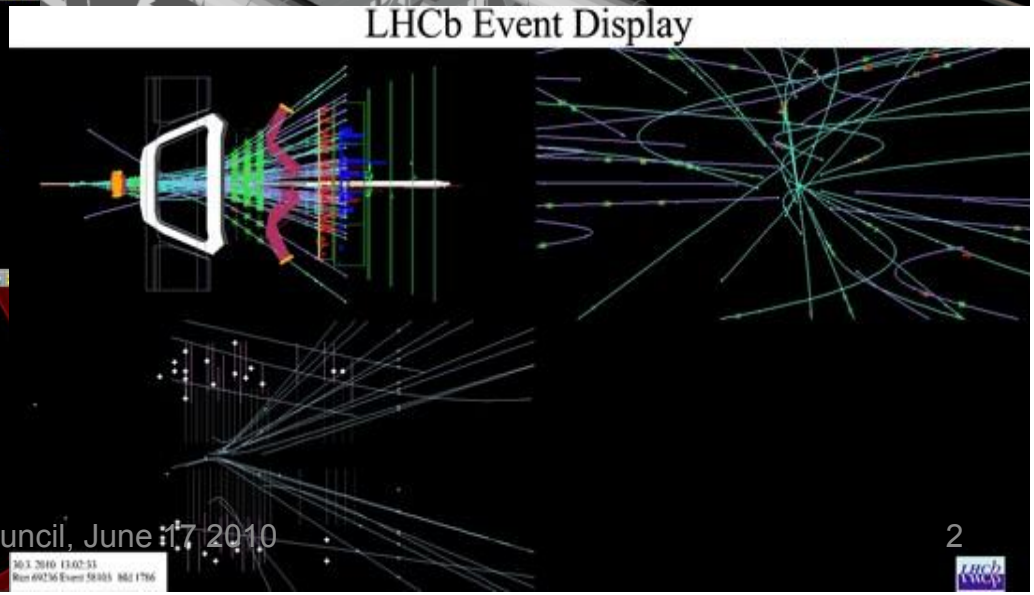
Sergio Bertolucci
CERN

March 30, 2010 7 TeV!

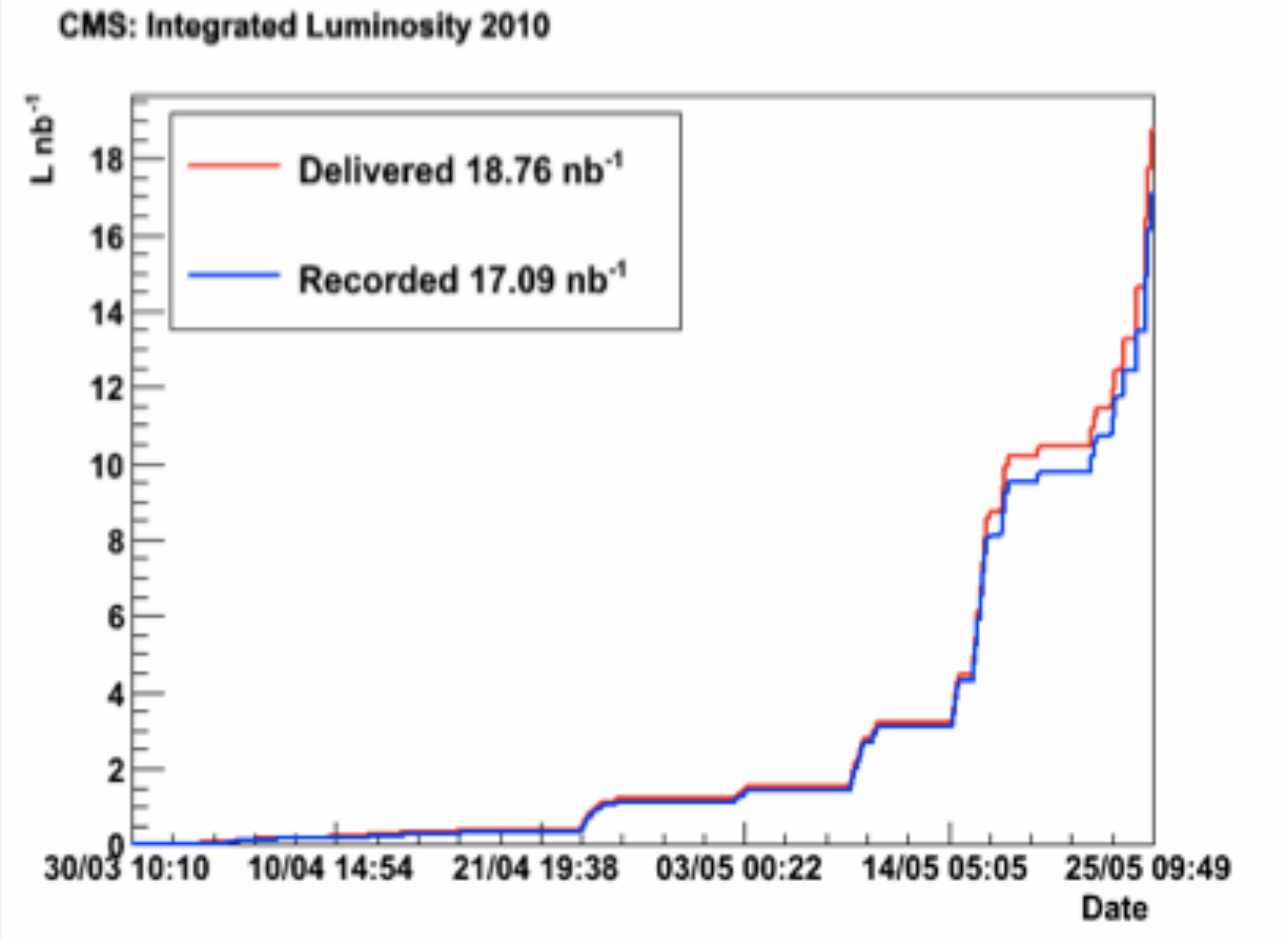








…and luminosity is growing!

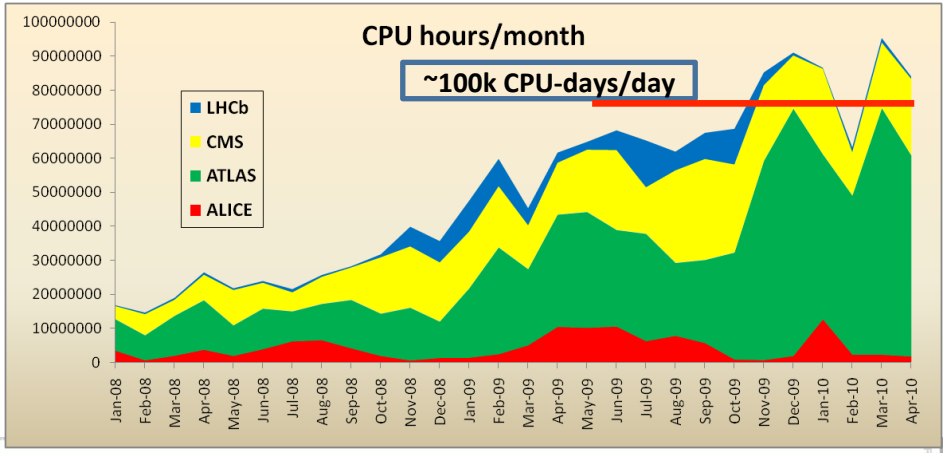


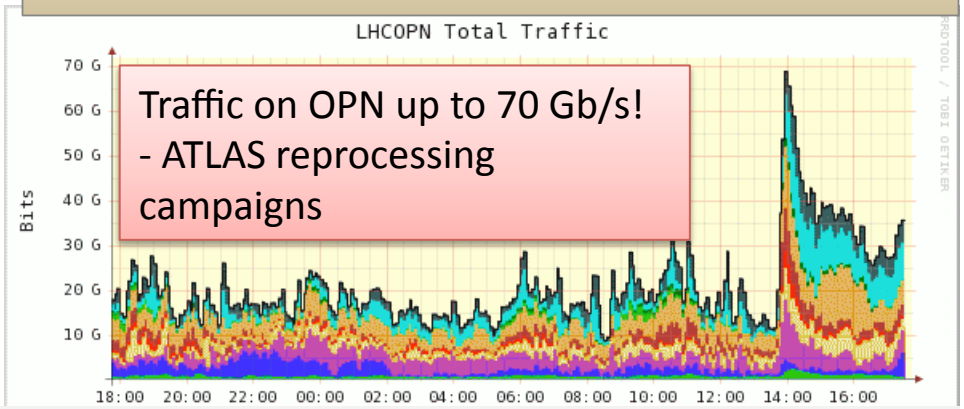
General considerations on experiments

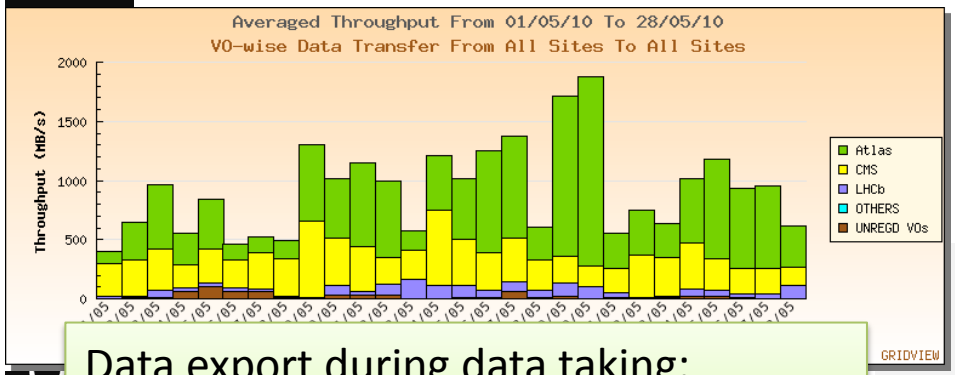
- Experiments demonstrating their readiness in the exploitation of the 7 TeV data…
- …ready to follow with more complex triggers the increase of luminosity.
- Experiments greedy for more L_{int} for the summer conferences.
- Analyses proceeding very rapidly and results being submitted for publication.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

WLCG Status – 1

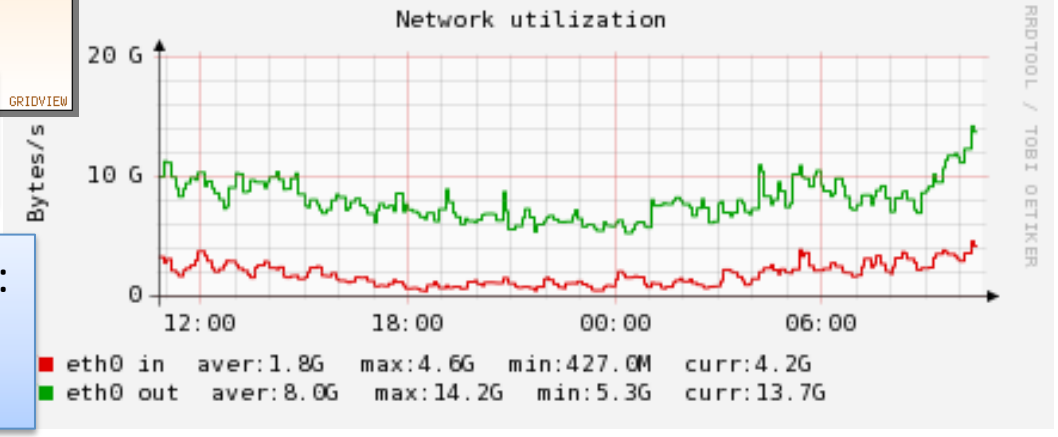
- WLCG running increasingly high workloads:
  - ~1 million jobs/day
    - Real data processing and re-processing
    - Physics analysis
    - Simulations
  - ~100 k CPU-days/day
- Unprecedented data rates







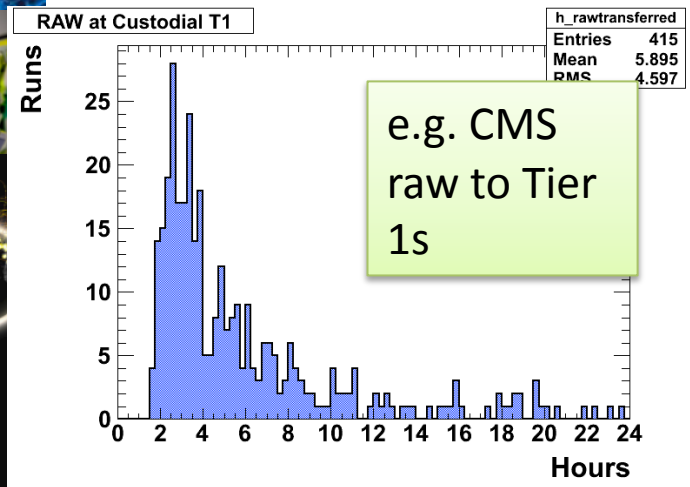
Data export during data taking:
- According to expectations on average

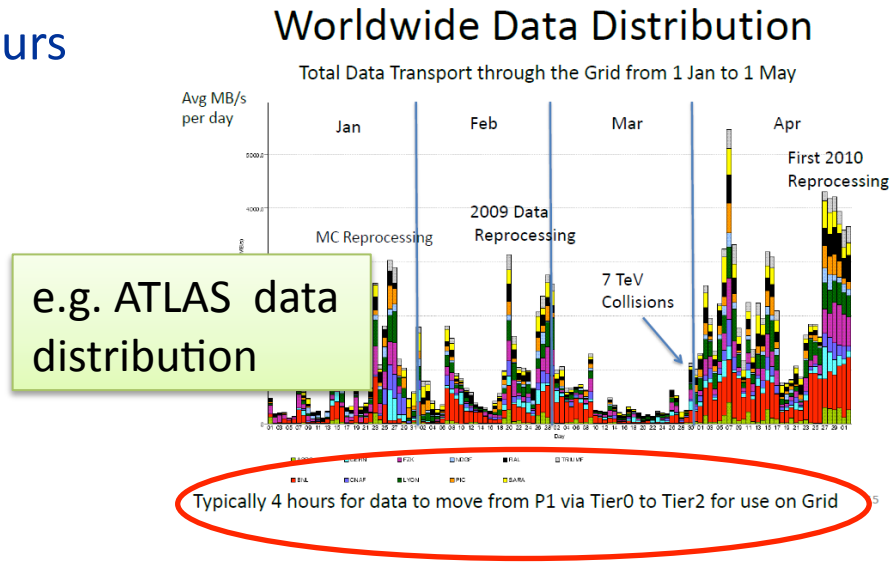


Castor traffic last month:
> 4 GB/s input
> 13 GB/s served

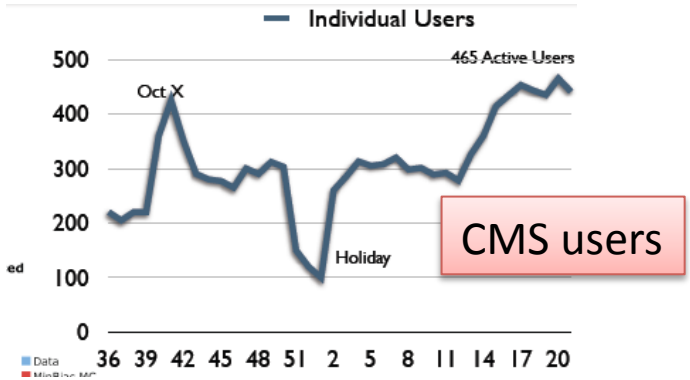
WLCG Status – 2

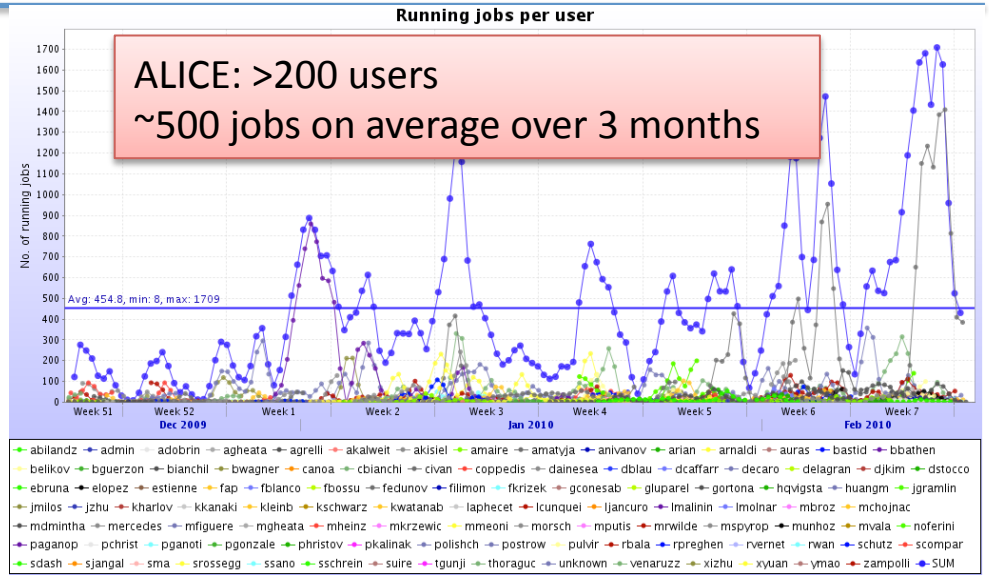
- Data reaches Tier 2s within hours





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





WLCG Worldwide LHC Computing Grid

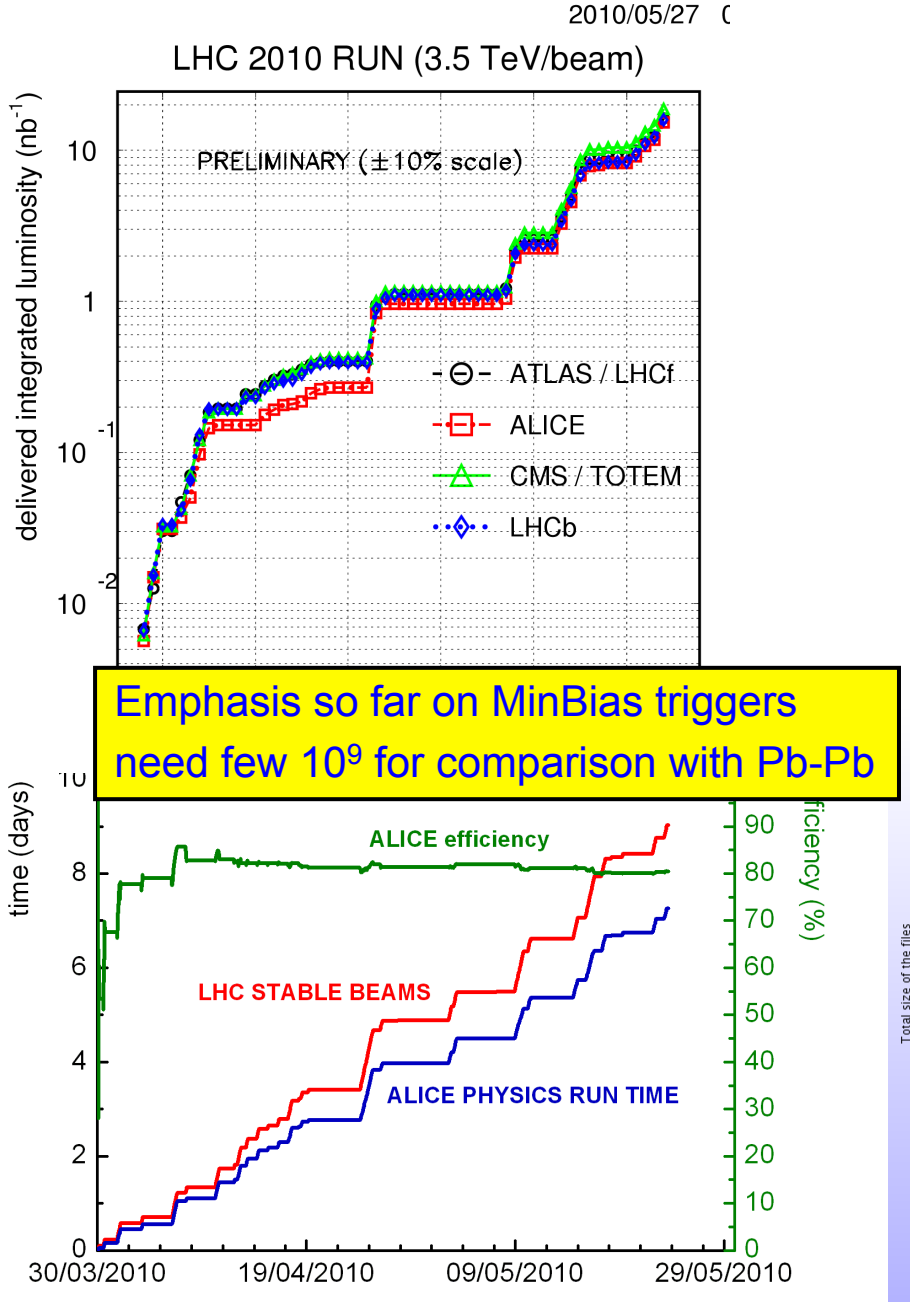
ALICE data loss

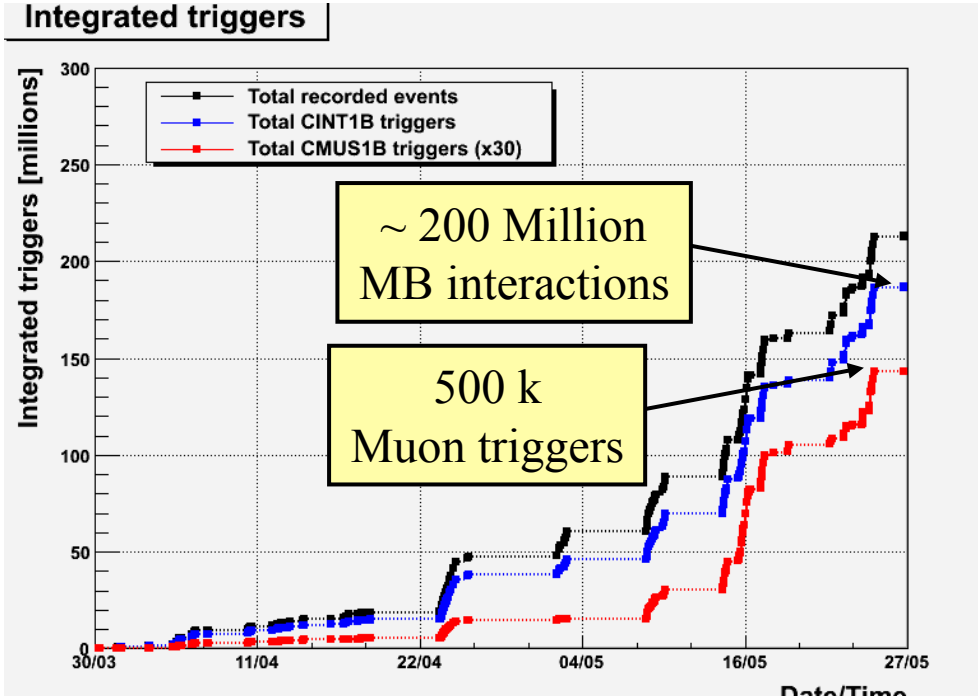
- A configuration error in Castor resulted in data being directed across all available tape pools instead of to the dedicated raw data pools
  - For ALICE, ATLAS, CMS this included a pool where the tapes were re-cycled after a certain time
- The result of this was that a number of files were lost on 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.

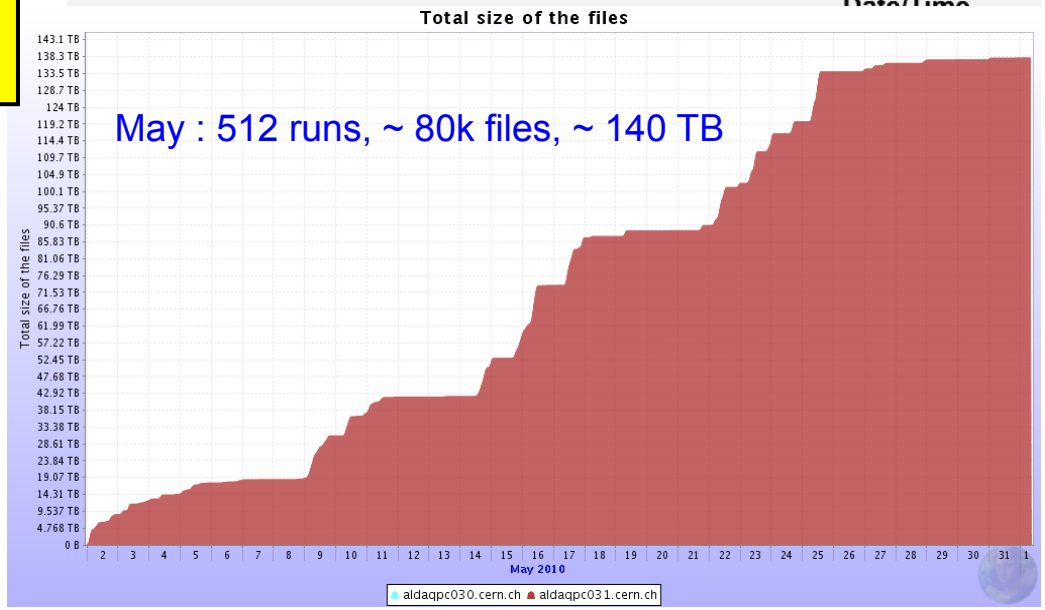
A few examples

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

Data Taking

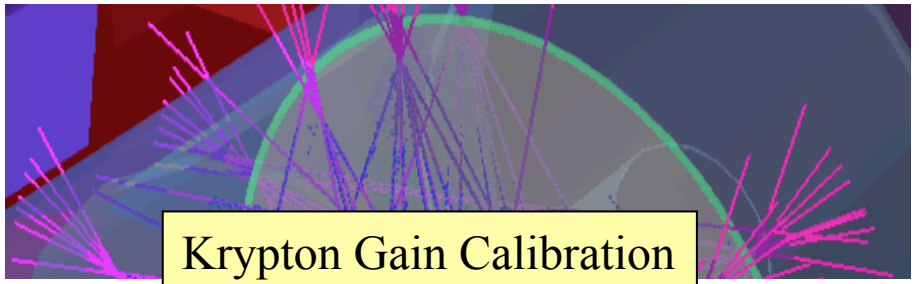

2010/05/27
LHC 2010 RUN (3.5 TeV/beam)
PRELIMINARY (±10% scale)
delivered integrated luminosity (nb-1)
ATLAS / LHCf
ALICE
CMS / TOTEM
LHCb
Emphasis so far on MinBias triggers
need few 10^9 for comparison with Pb-Pb
time (days)
ALICE efficiency
LHC STABLE BEAMS
ALICE PHYSICS RUN TIME
30/03/2010
19/04/2010
09/05/2010
29/05/2010


Integrated triggers
Integrated triggers [millions]
Total recorded events
Total CINT1B triggers
Total CMUS1B triggers (x30)
~ 200 Million
MB interactions
500 k
Muon triggers
30/03
11/04
22/04
04/05
16/05
27/05

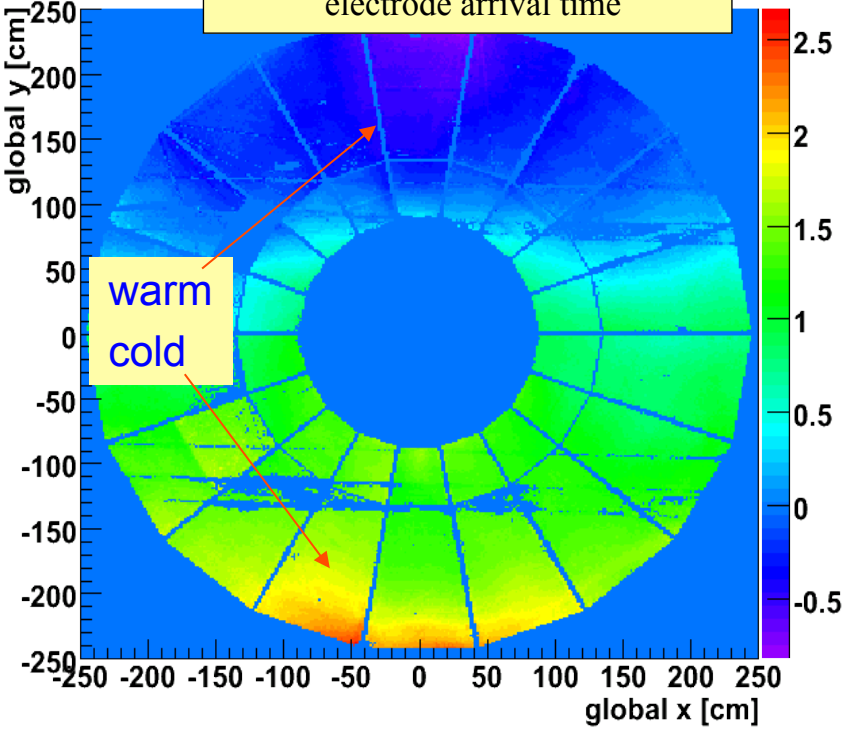

Total size of the files
May : 512 runs, ~ 80k files, ~ 140 TB
May 2010

Getting to know : Calibration (non)constants

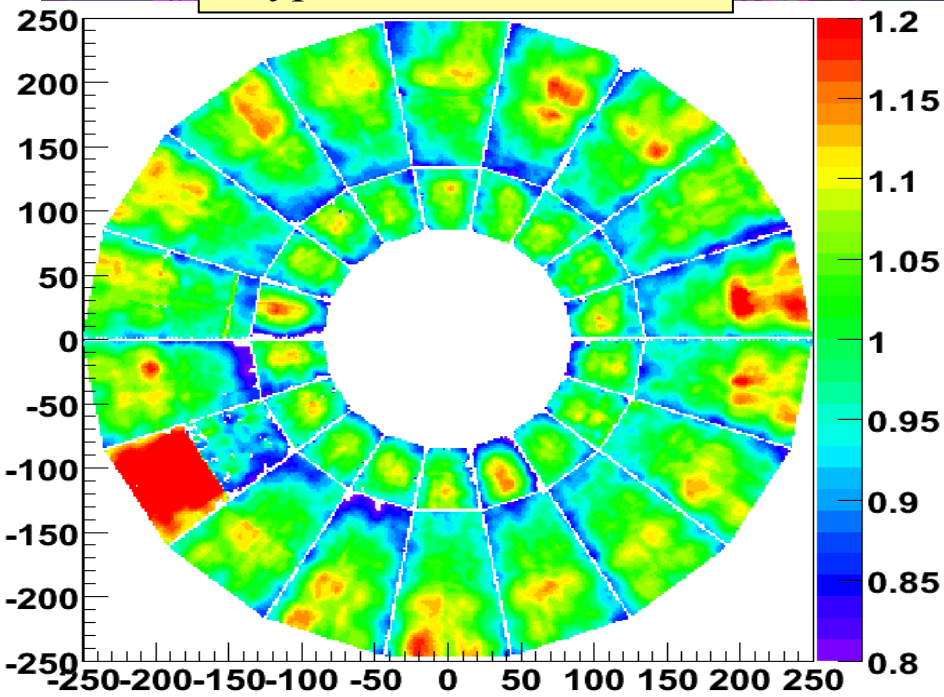
- TPC: concept simple, devil is in the details..
  - ⇨ v_drift = f(T, P, gas, ..), $\Delta v/v < 10^{-4}$, => 4 different methods used
  - ⇨ geometry, planarity (200μm/2m), ..
  - ⇨ Field distortions, ExB effect, $\omega\tau$, …
  - ⇨ pad-by-pad gain calibration (dE/dx < 5.5%



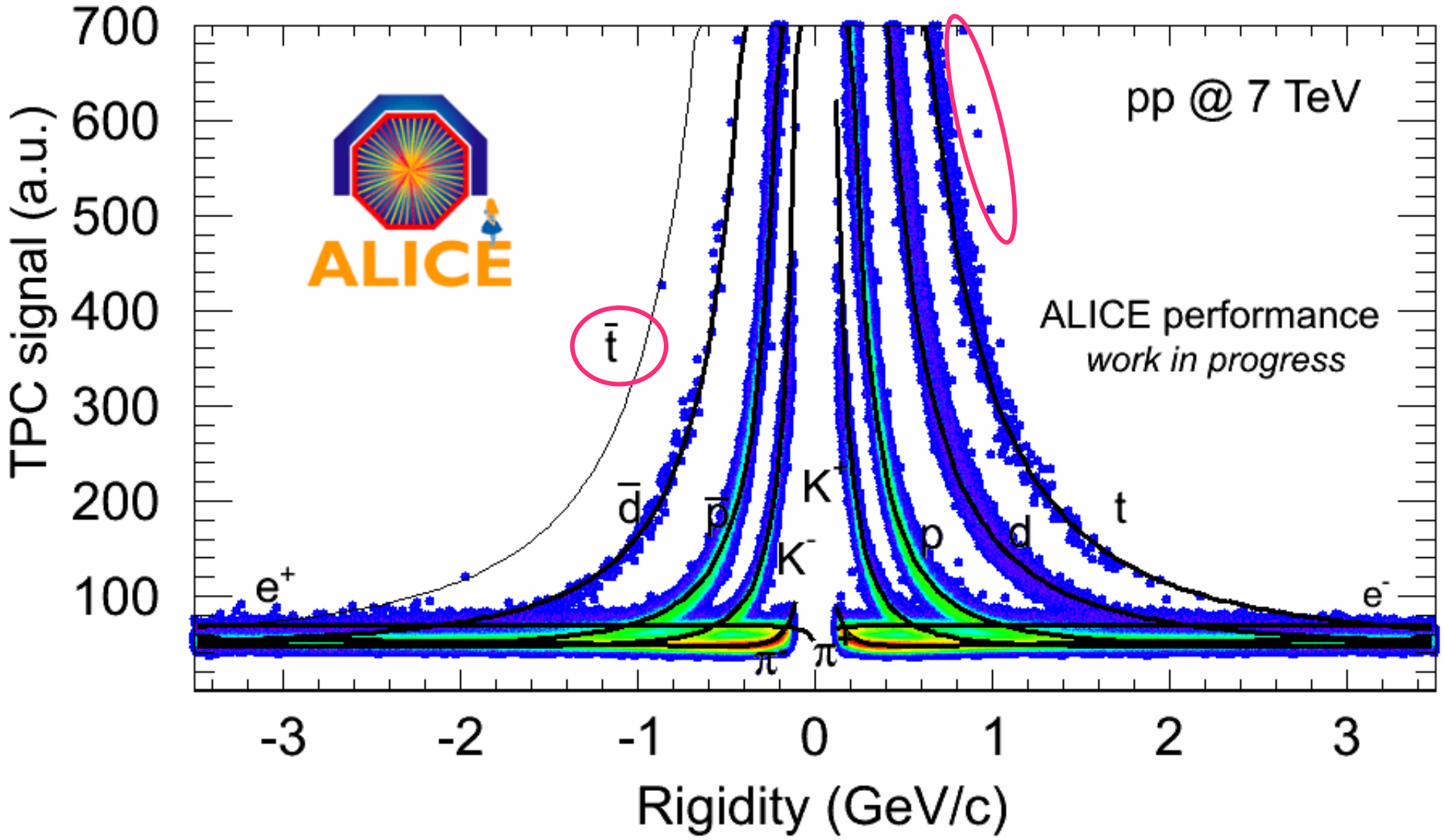
Laser Photo electrons from central electrode arrival time



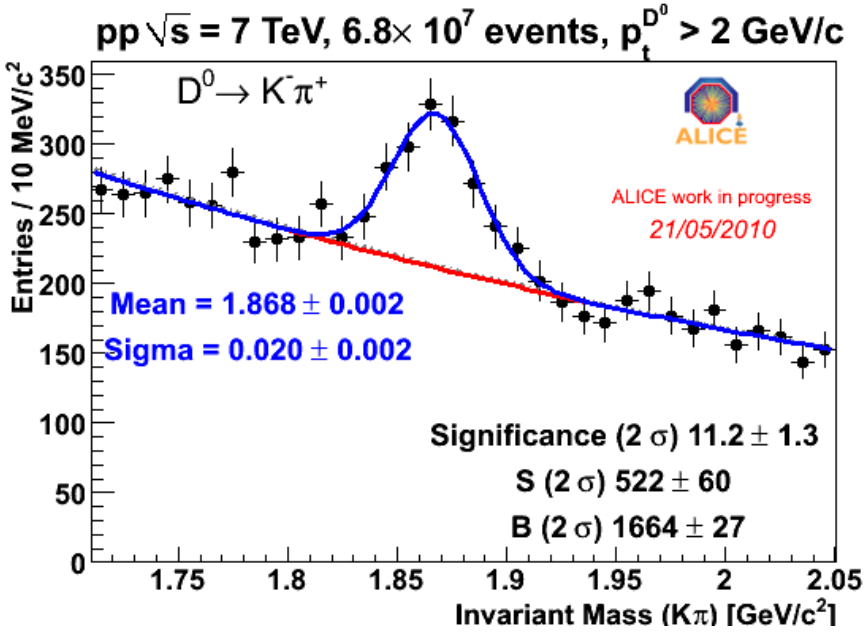
Krypton Gain Calibration

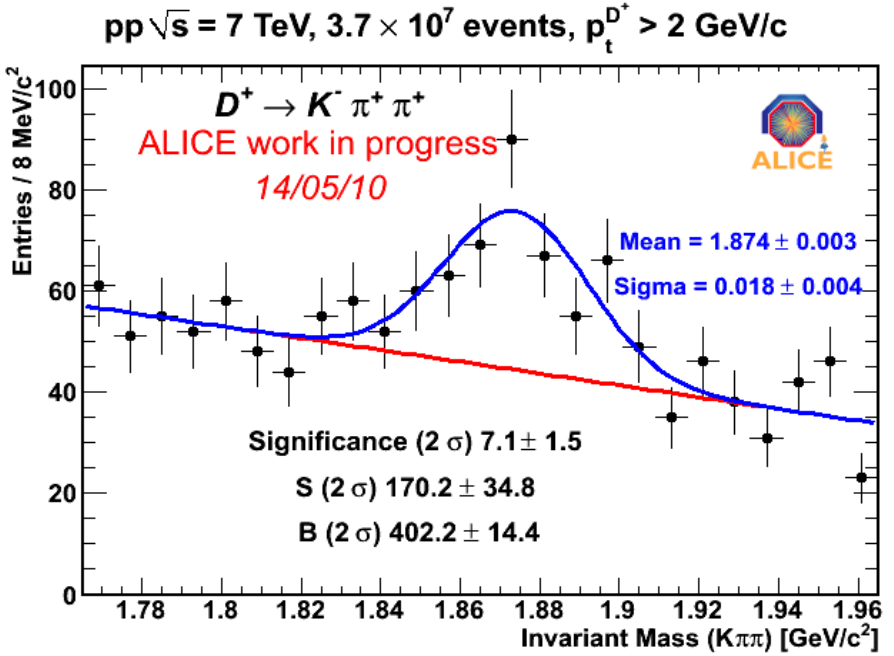


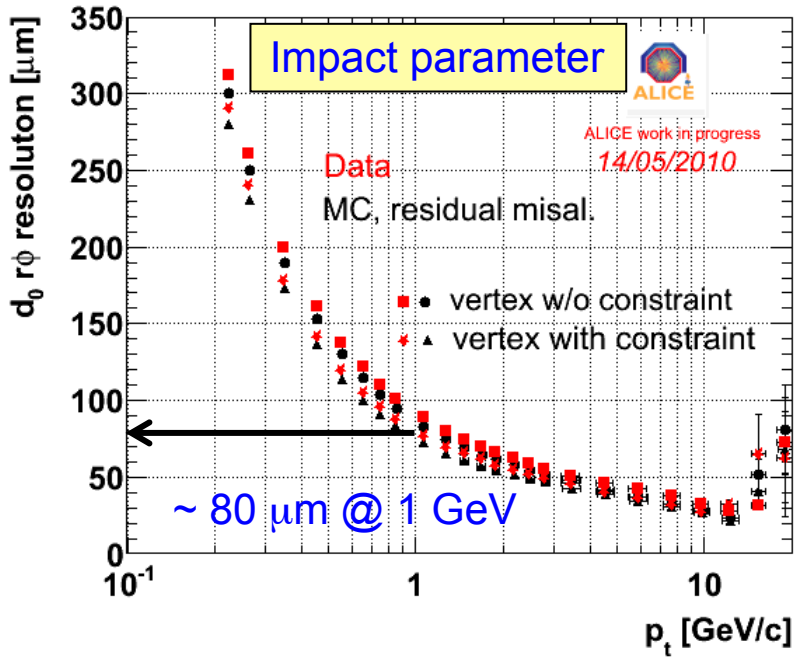
(Anti)Nuclei

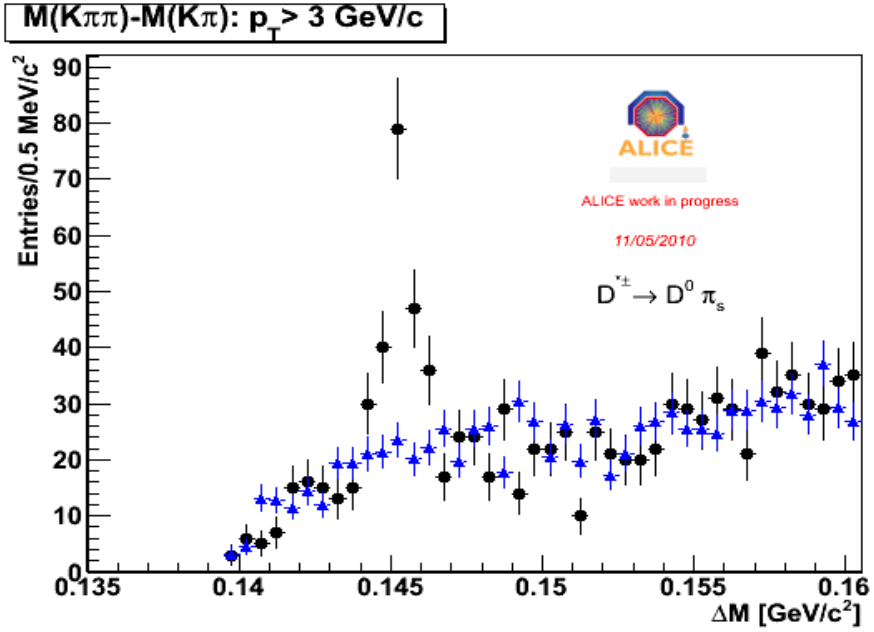

TPC signal (a.u.)
700
600
500
400
300
200
100
-3
-2
-1
0
1
2
3
Rigidity (GeV/c)
pp @ 7 TeV
ALICE performance
work in progress
ALICE
$\bar{t}$
$\bar{d}$
$\bar{p}$
K^+
K^-
p
d
t
e^+
e^-
π
π

Charm

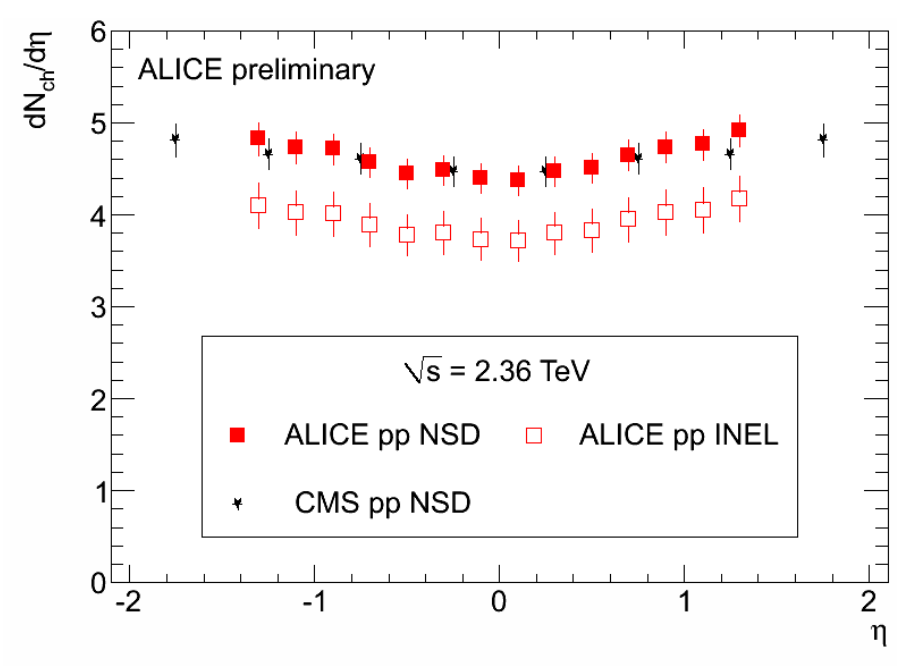

pp $\sqrt{s}$ = 7 TeV, 6.8× 10^7 events, $p_t^{D^0}$ > 2 GeV/c
$D^0 \rightarrow K^-\pi^+$
ALICE work in progress
21/05/2010
Mean = 1.868 ± 0.002
Sigma = 0.020 ± 0.002
Significance (2 σ) 11.2 ± 1.3
S (2 σ) 522 ± 60
B (2 σ) 1664 ± 27
Entries / 10 MeV/c²
Invariant Mass (Kπ) [GeV/c²]

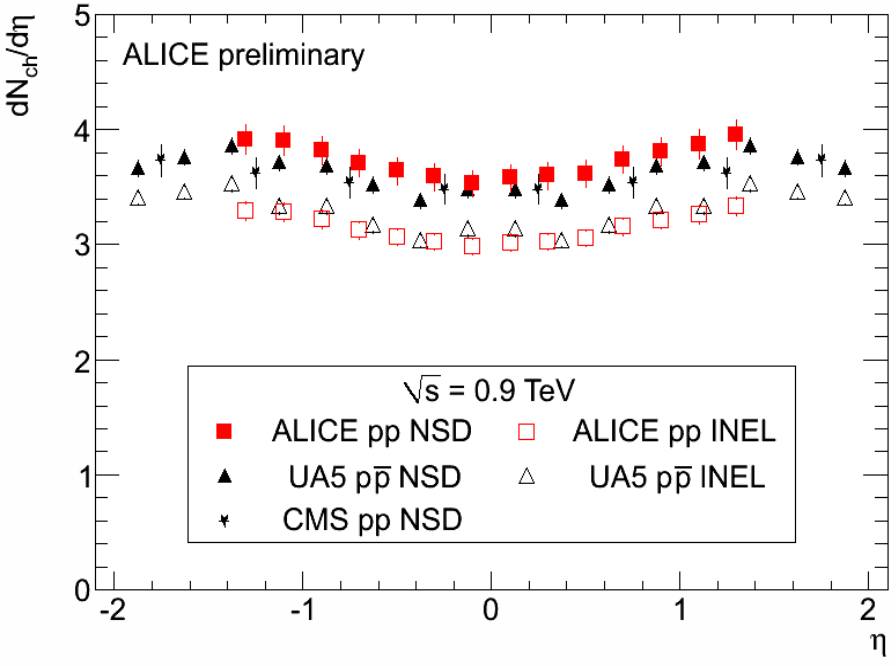

pp $\sqrt{s}$ = 7 TeV, 3.7 × 10^7 events, $p_t^{D^+}$ > 2 GeV/c
$D^+ \rightarrow K^- \pi^+ \pi^+$
ALICE work in progress
14/05/10
Mean = 1.874 ± 0.003
Sigma = 0.018 ± 0.004
Significance (2 σ) 7.1 ± 1.5
S (2 σ) 170.2 ± 34.8
B (2 σ) 402.2 ± 14.4
Entries / 8 MeV/c²
Invariant Mass (Kππ) [GeV/c²]


Impact parameter
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 work in progress
11/05/2010
$D^{*\pm} \rightarrow D^0 \pi_s$
Entries/0.5 MeV/c²
ΔM [GeV/c²]

Getting quantitative





Systematic error of 2-3% !

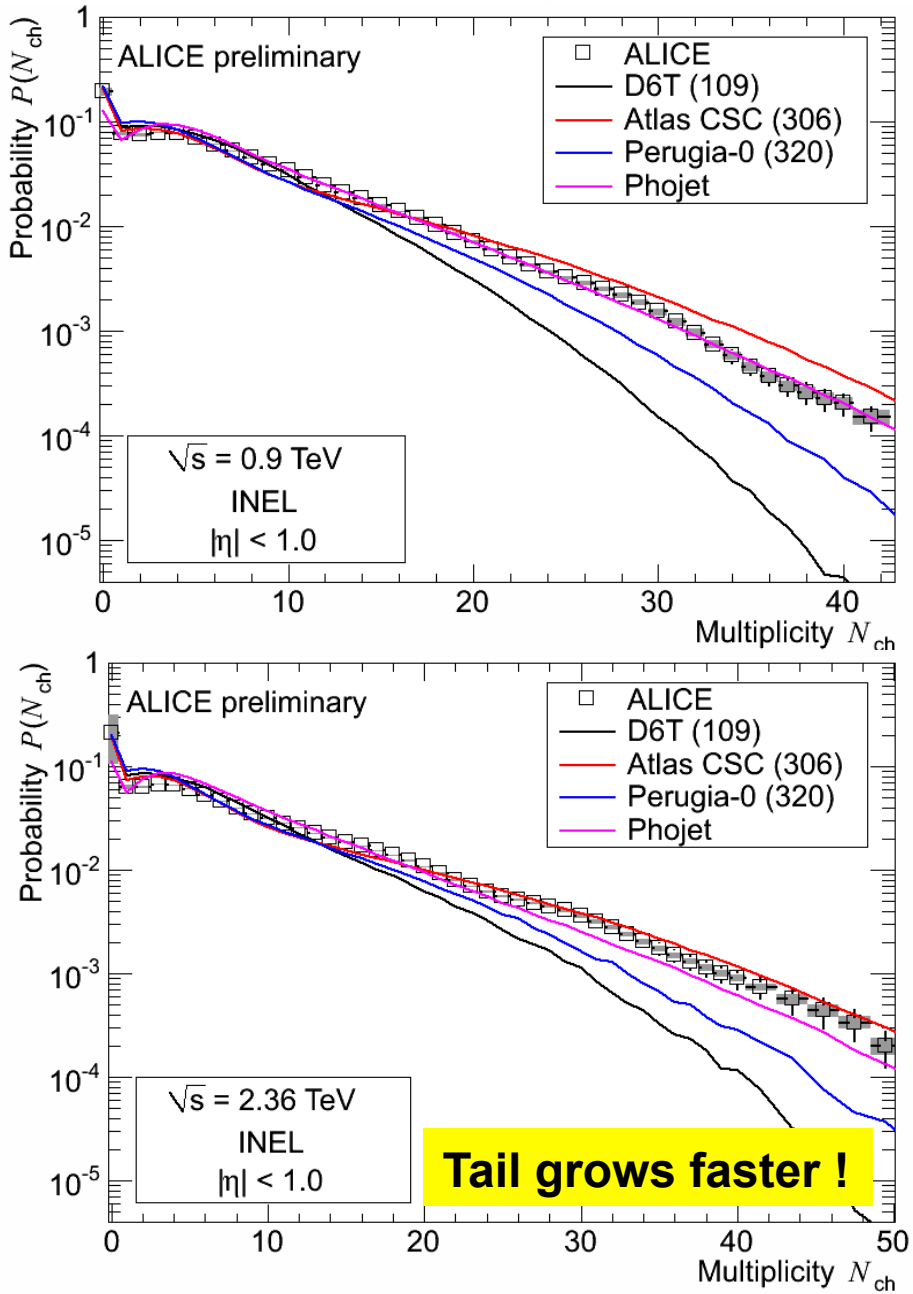
	NSD 2.36 TeV	NSD 900 GeV	INEL 900 GeV
ALICE preliminary	**4.43 ± 0.01 ± 0.16**	**3.58 ± 0.01 ± 0.12**	**3.02 ± 0.01 ± 0.07**
ALICE EPJC 65 111 (2010)		**3.51 ± 0.15 ± 0.25**	**3.10 ± 0.13 ± 0.22**
CMS JHEP 02 (2010) 041	**4.47 ± 0.04 ± 0.16**	**3.48 ± 0.02 ± 0.13**	
UA5 Z. Phys. C33 1 (1986)		**3.43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

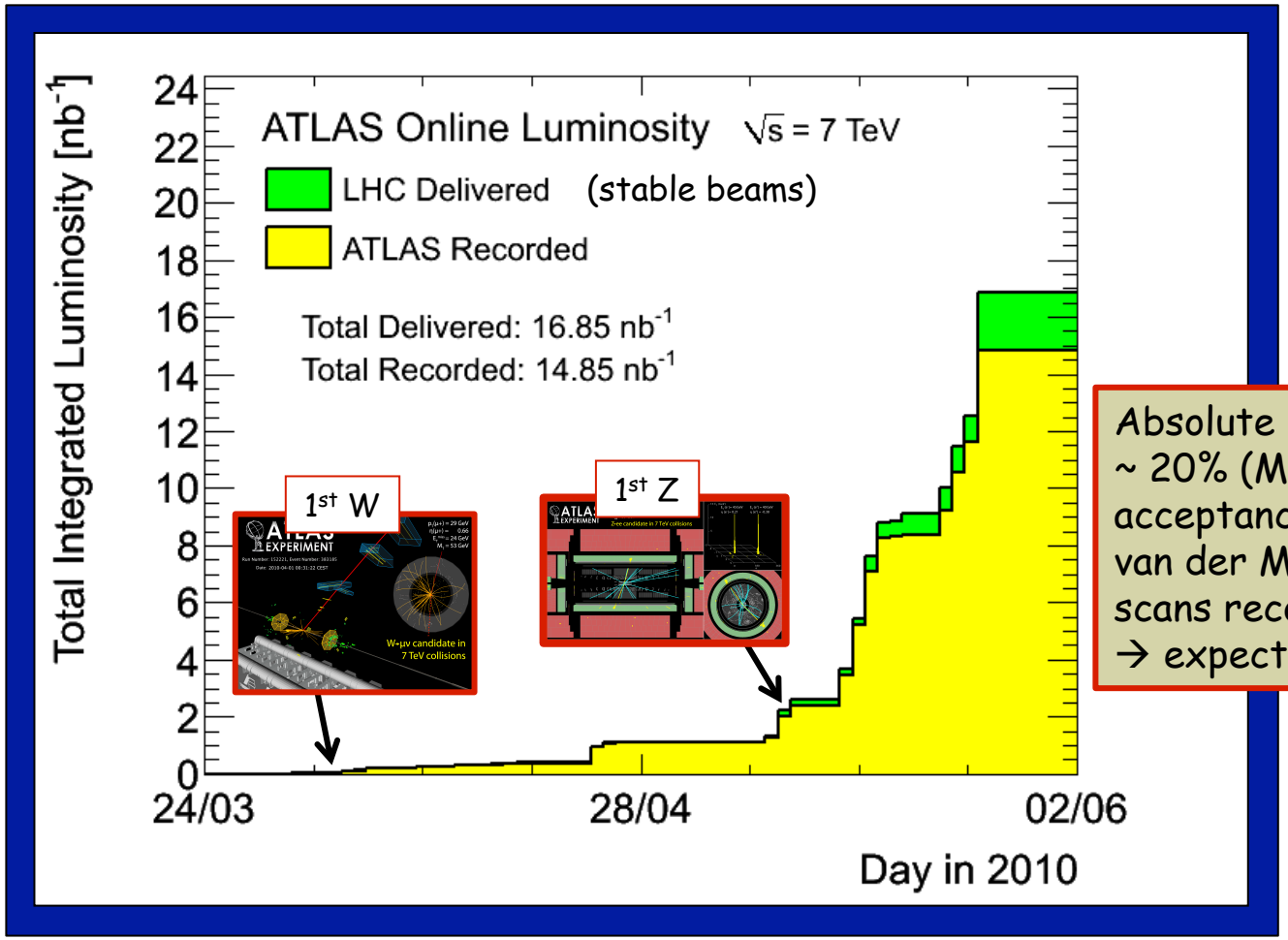
Larger increase of multiplicity at mid-rapidity than in MC generators

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 %

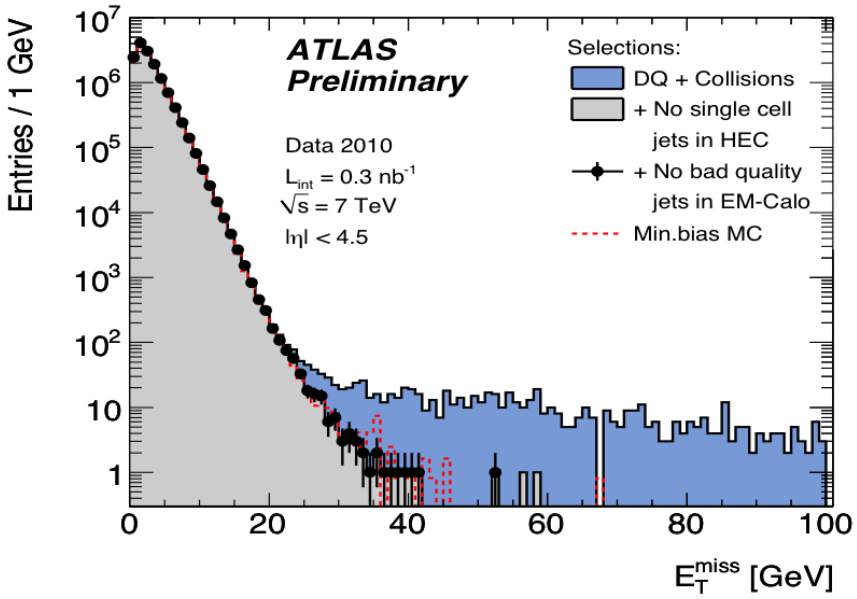
Results presented here are based on up to ~ 7.9 nb^{-1} of reprocessed data

Detector status

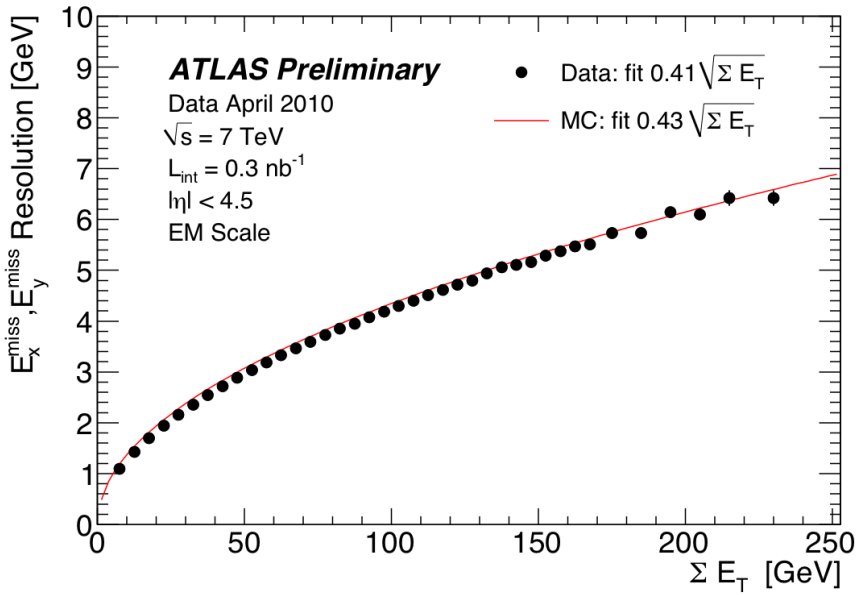
Subdetector	Number of Channels	Approximate Operational Fraction
Pixels	80 M	97.5%
SCT Silicon Strips	6.3 M	99.3%
TRT Transition Radiation Tracker	350 k	98.0%
LAr EM Calorimeter	170 k	98.5%
Tile calorimeter	9800	97.3%
Hadronic endcap LAr calorimeter	5600	99.9%
Forward LAr calorimeter	3500	100%
LVL1 Calo 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

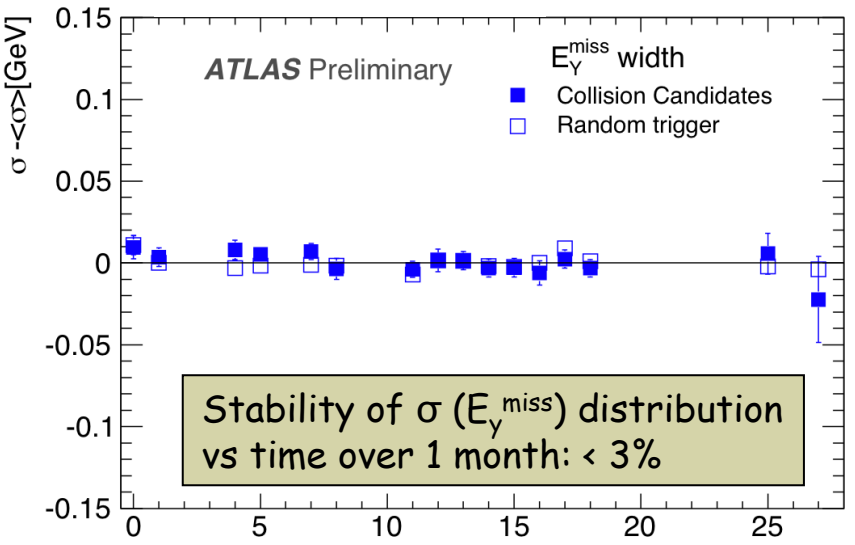


Measured over ~ full calorimeter coverage (360^0 in φ, |η| < 4.5, ~ 200k cells)

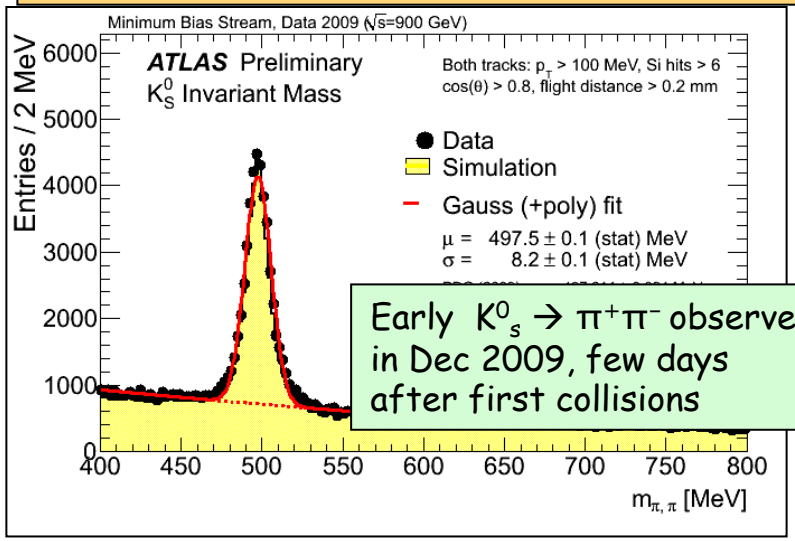


Event fraction removed by additional cleaning cuts: ~ 10^{-4}

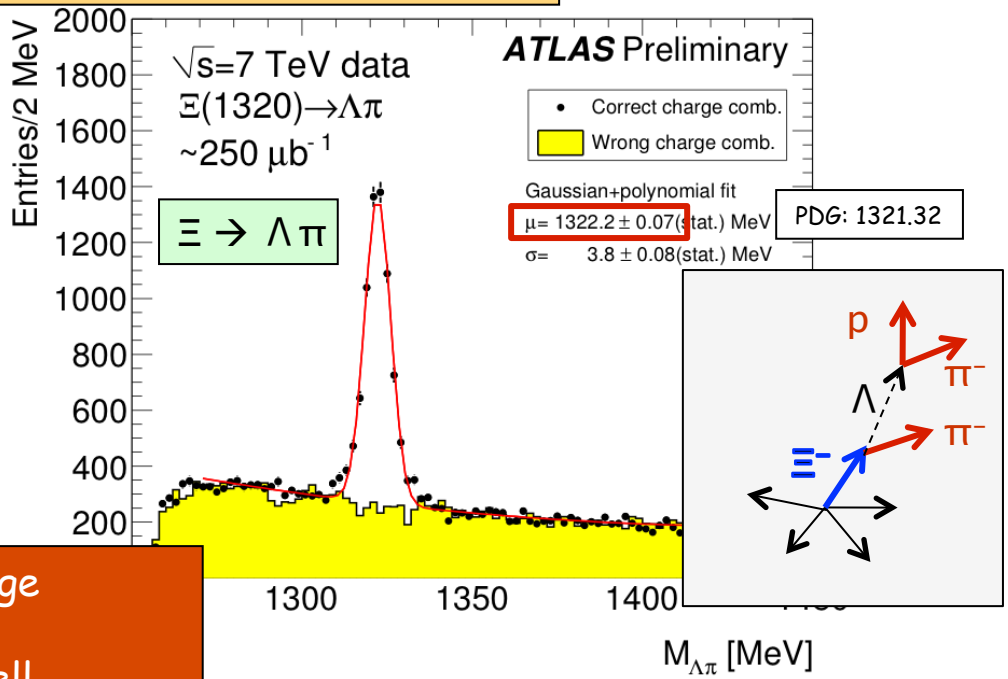
E_T^{miss} is sensitive to calorimeter performance (noise, coherent noise, dead cells, mis-calibrations, cracks, etc.), and cosmics and beam-related backgrounds



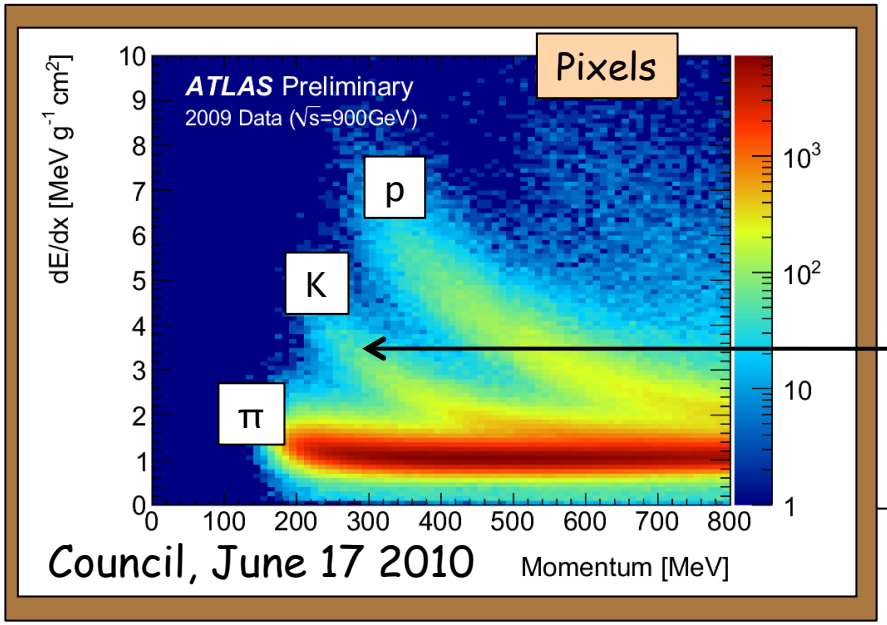
Tracking : from early observation of peaks to cascade decays

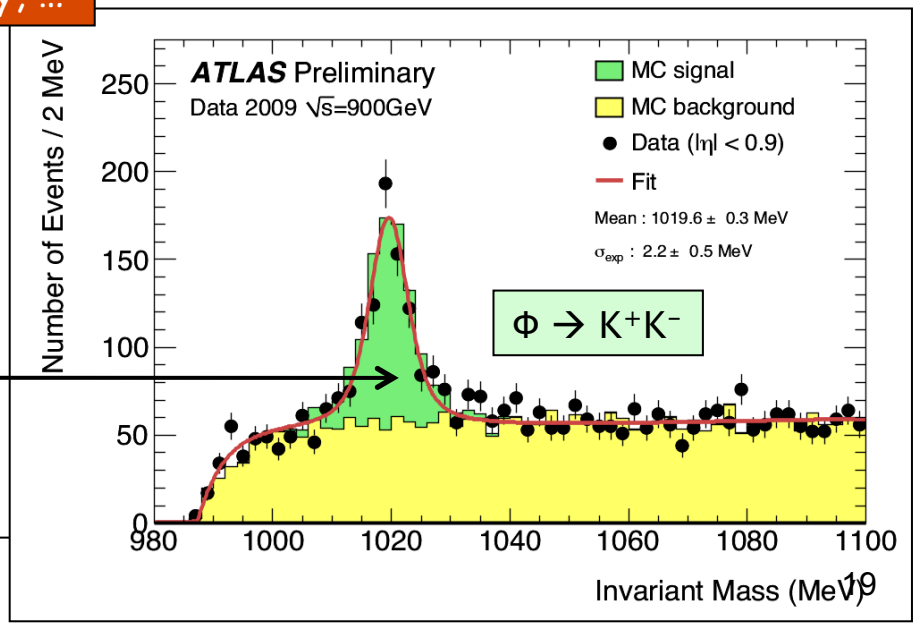


Early $K^0_s \rightarrow \pi^+\pi^-$ observed in Dec 2009, few days after first collisions

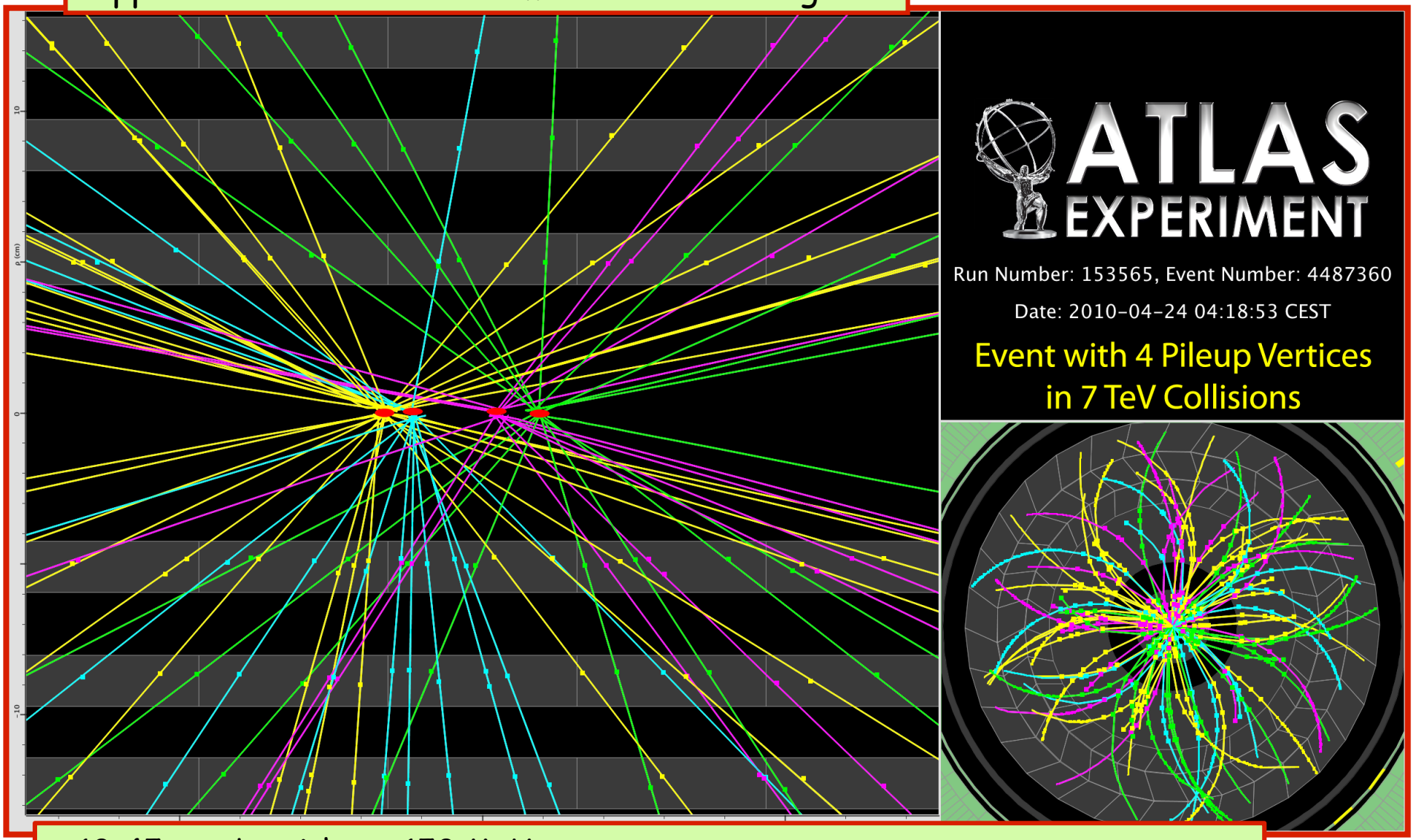


Momentum scale known to few permil in this range
Resolution as expected (multiple scattering)
Complex algorithms (cascades, b-tag, …) work well
Working on material, alignment, data-driven efficiency, …





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

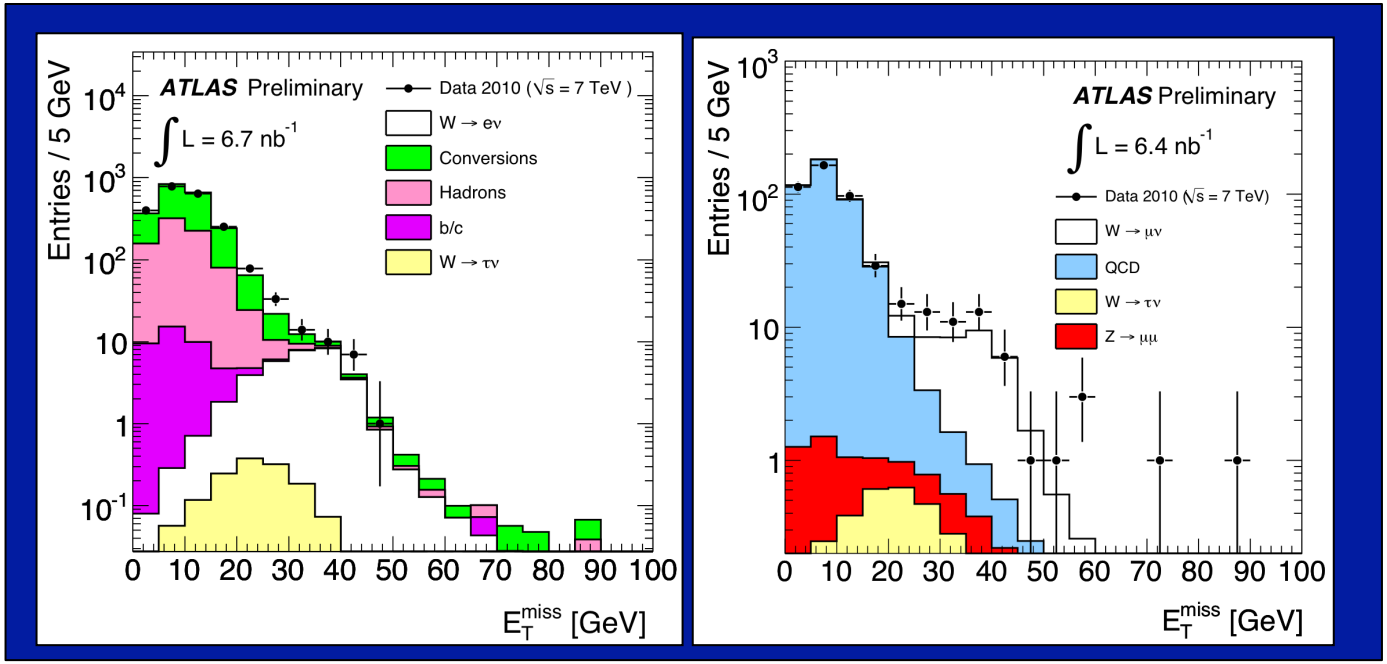
-- W → μν:

p_T (μ)> 15 GeV

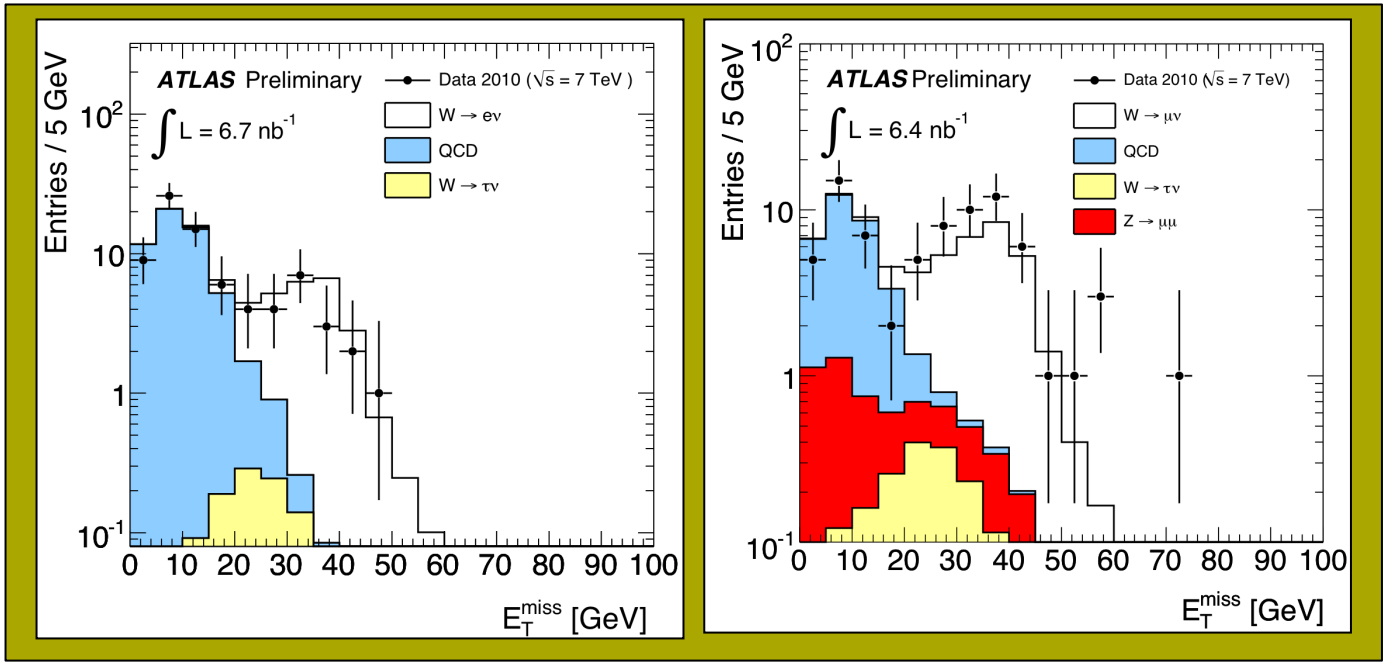
$|\Delta p_T(\text{ID-MS})|$ < 15 GeV

$|Z_\mu - Z_{vtx}|$<1 cm

MC: normalised to data (total number of events)



After all cuts but E_T^{miss} and m_T

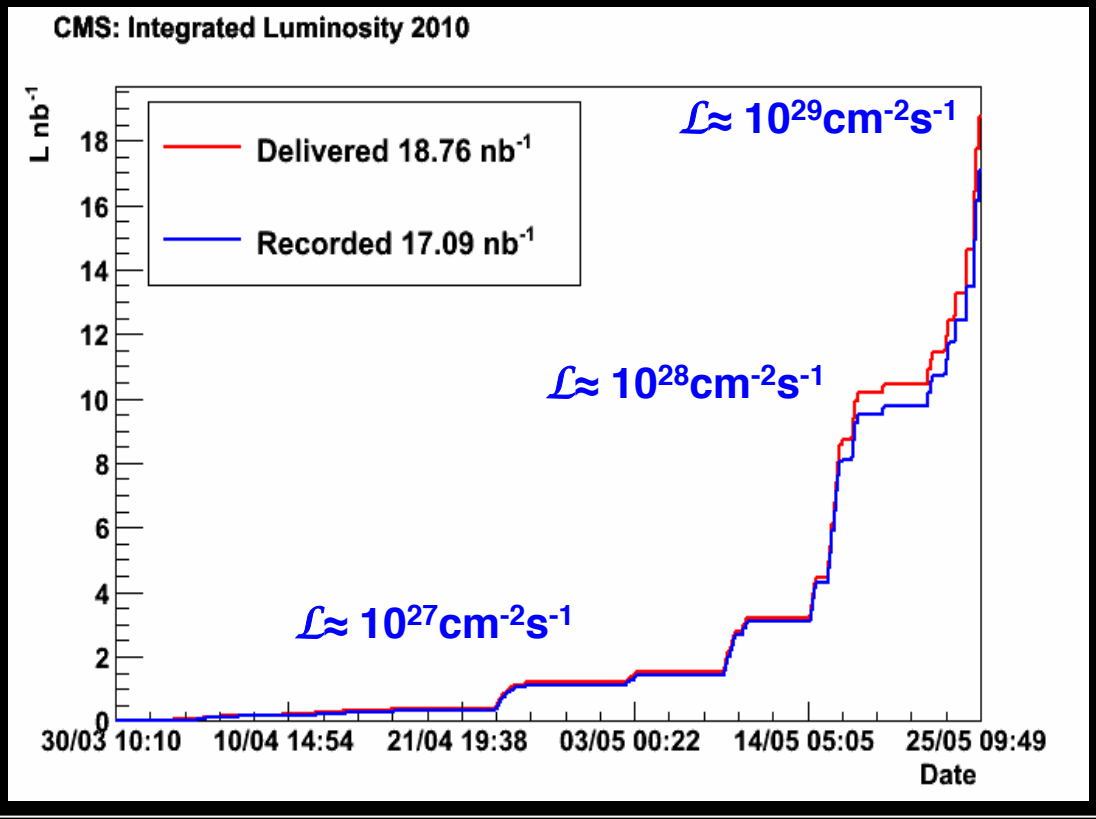


Final candidates inspected in detail → timing, lepton reconstruction quality, event topology …

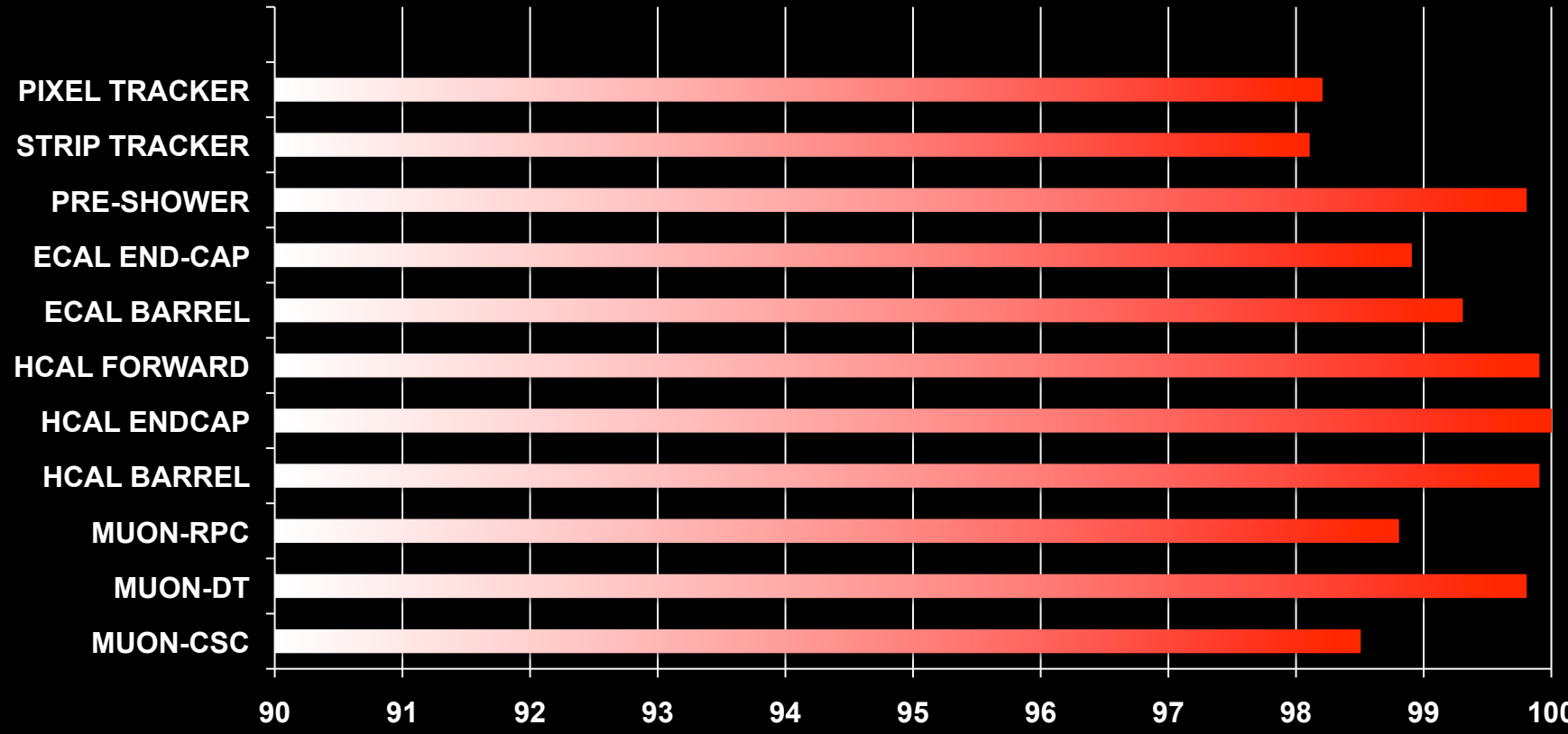
CMS

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.



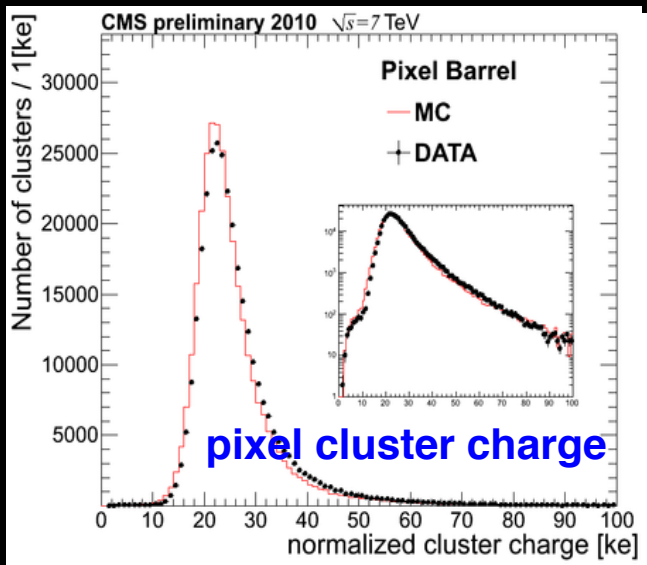
Sub-detectors operational status

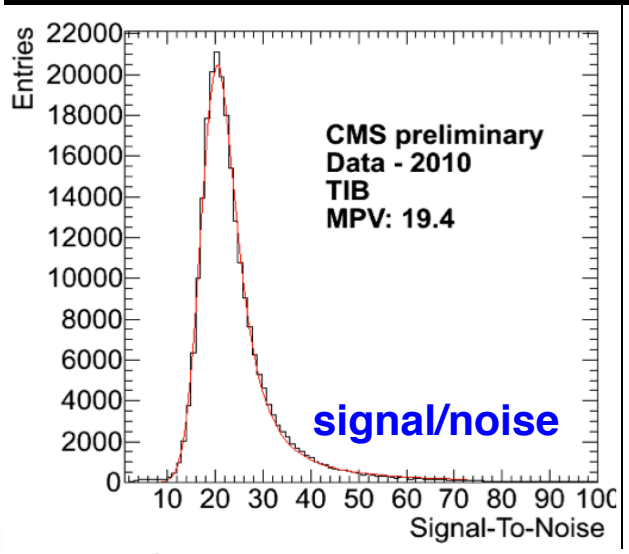


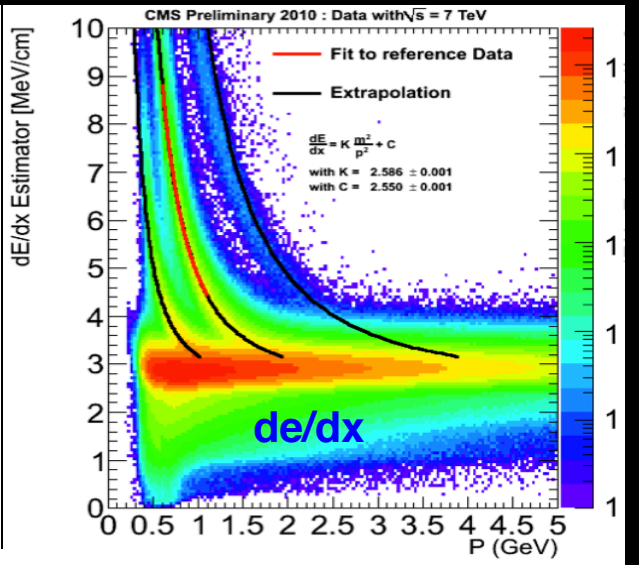
	MUON-CSC	MUON-DT	MUON-RPC	HCAL BARREL	HCAL ENDCAP	HCAL FORWARD	ECAL BARREL	ECAL END-CAP	PRE-SHOWER	STRIP TRACKER	PIXEL TRACKER	
Series1	98.5	99.8	98.8	99.9	100	99.9	99.3	98.9	99.8	98.1	98.2	

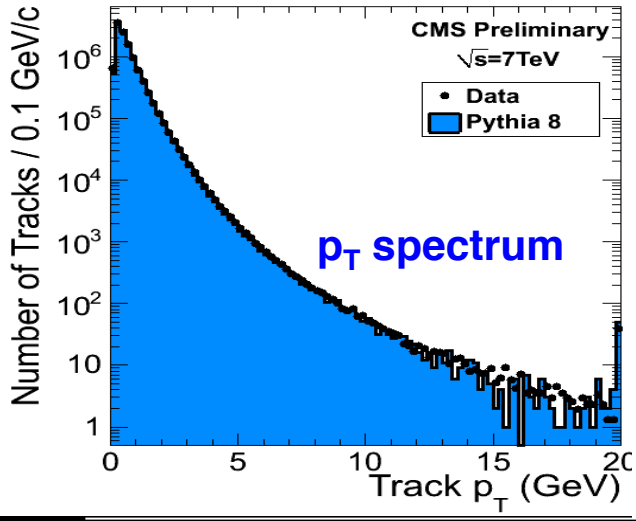
Tracker Performance

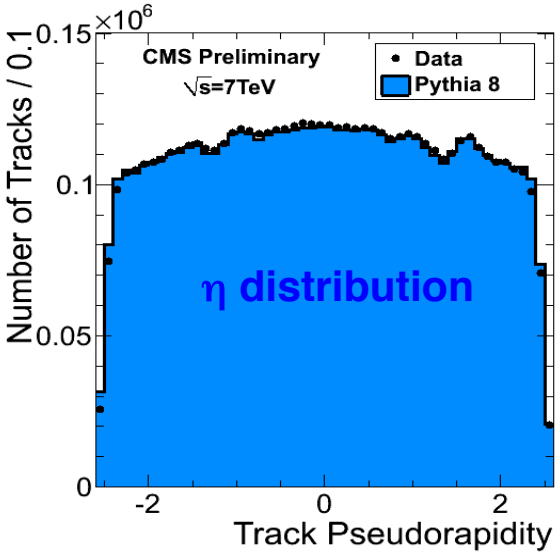
(see talks from L. DeMaria. V. Radicci. A. Bonato)

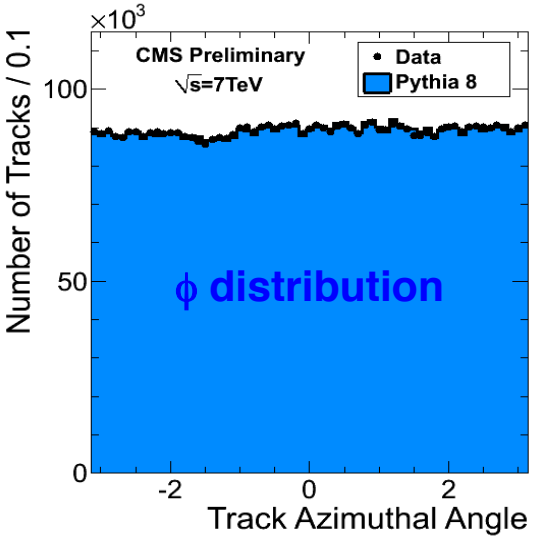






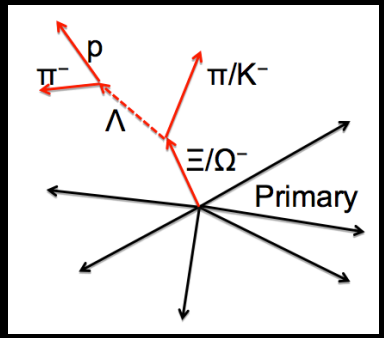




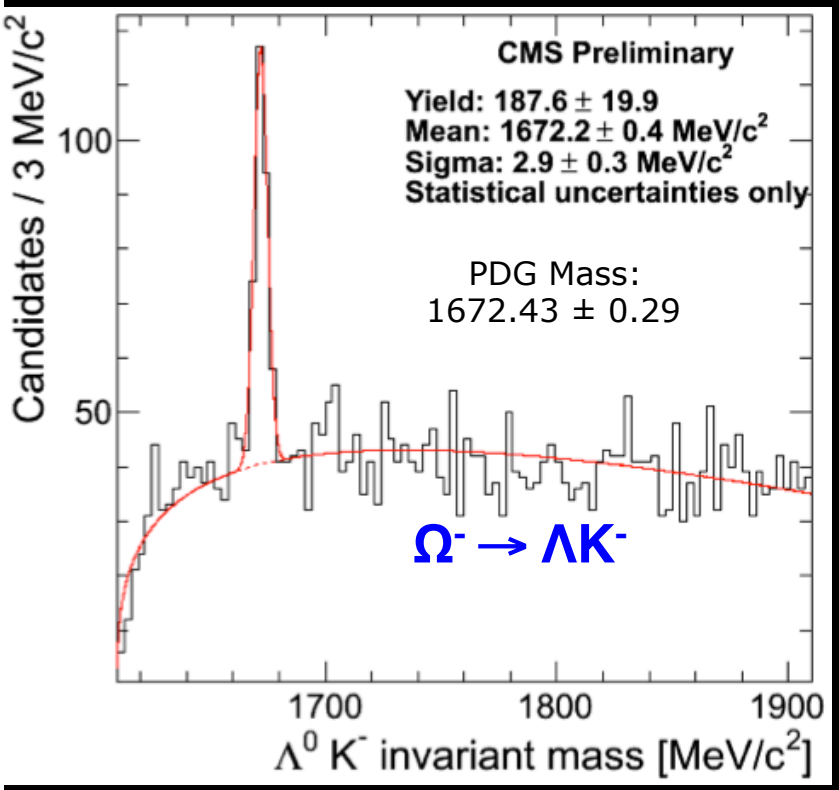


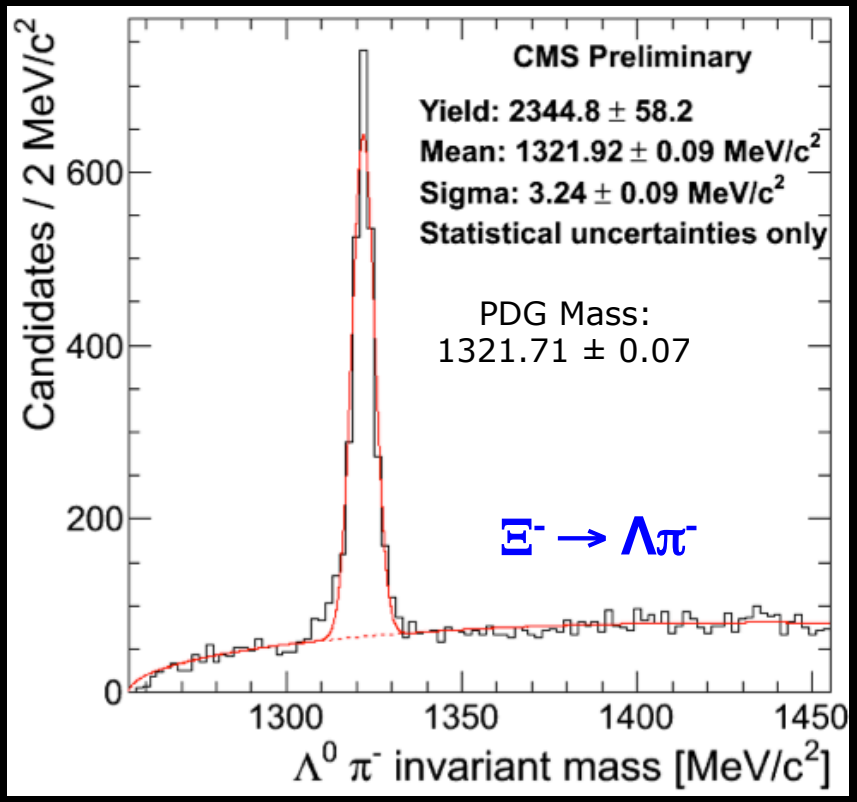
Low mass resonances

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

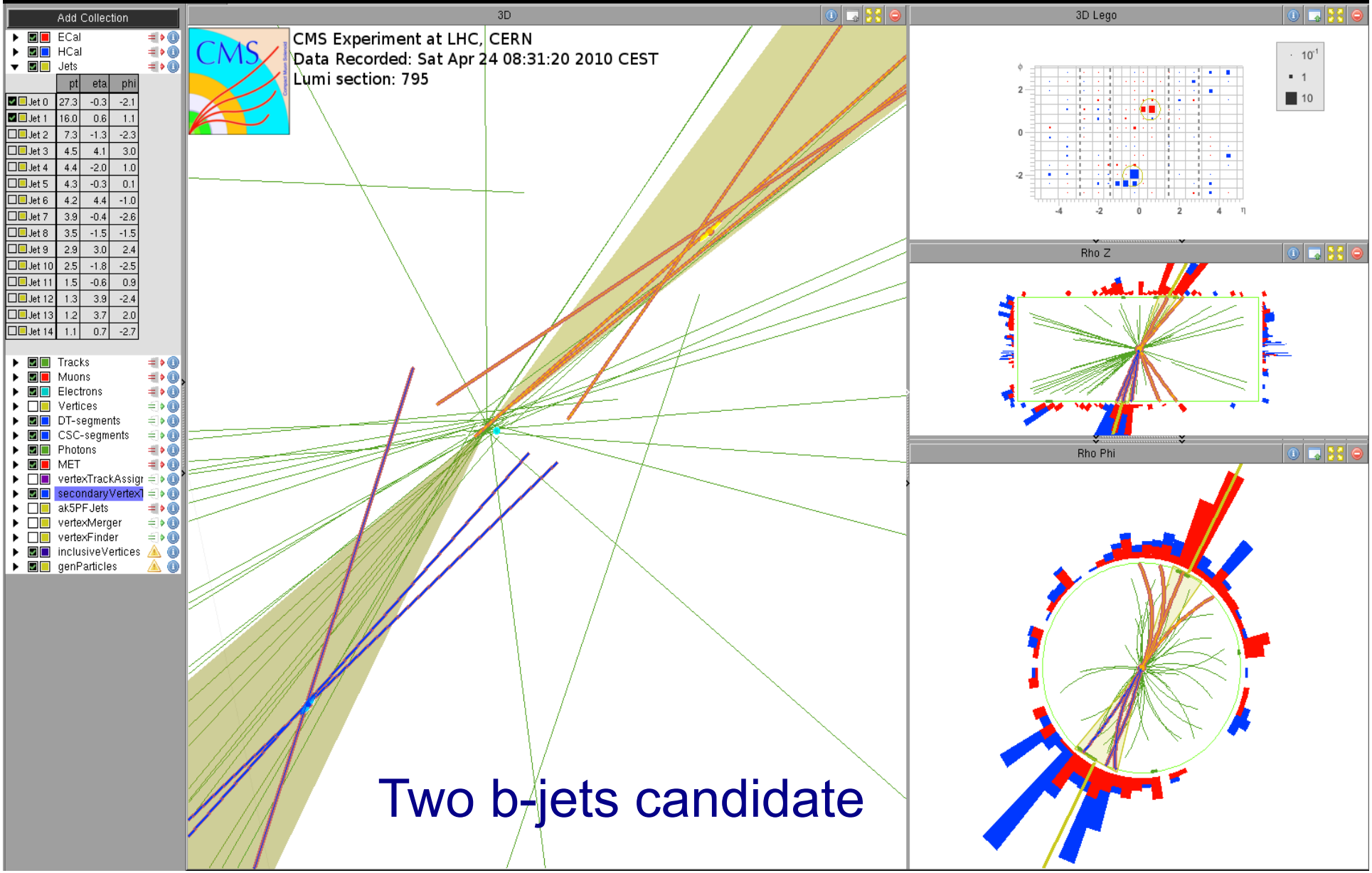


Invariant mass distribution for different combinations ($\Omega^{\pm} \rightarrow \Lambda K^{\pm}$ or $\Xi^{\pm} \rightarrow \Lambda\pi^{\pm}$) fit to a common vertex.

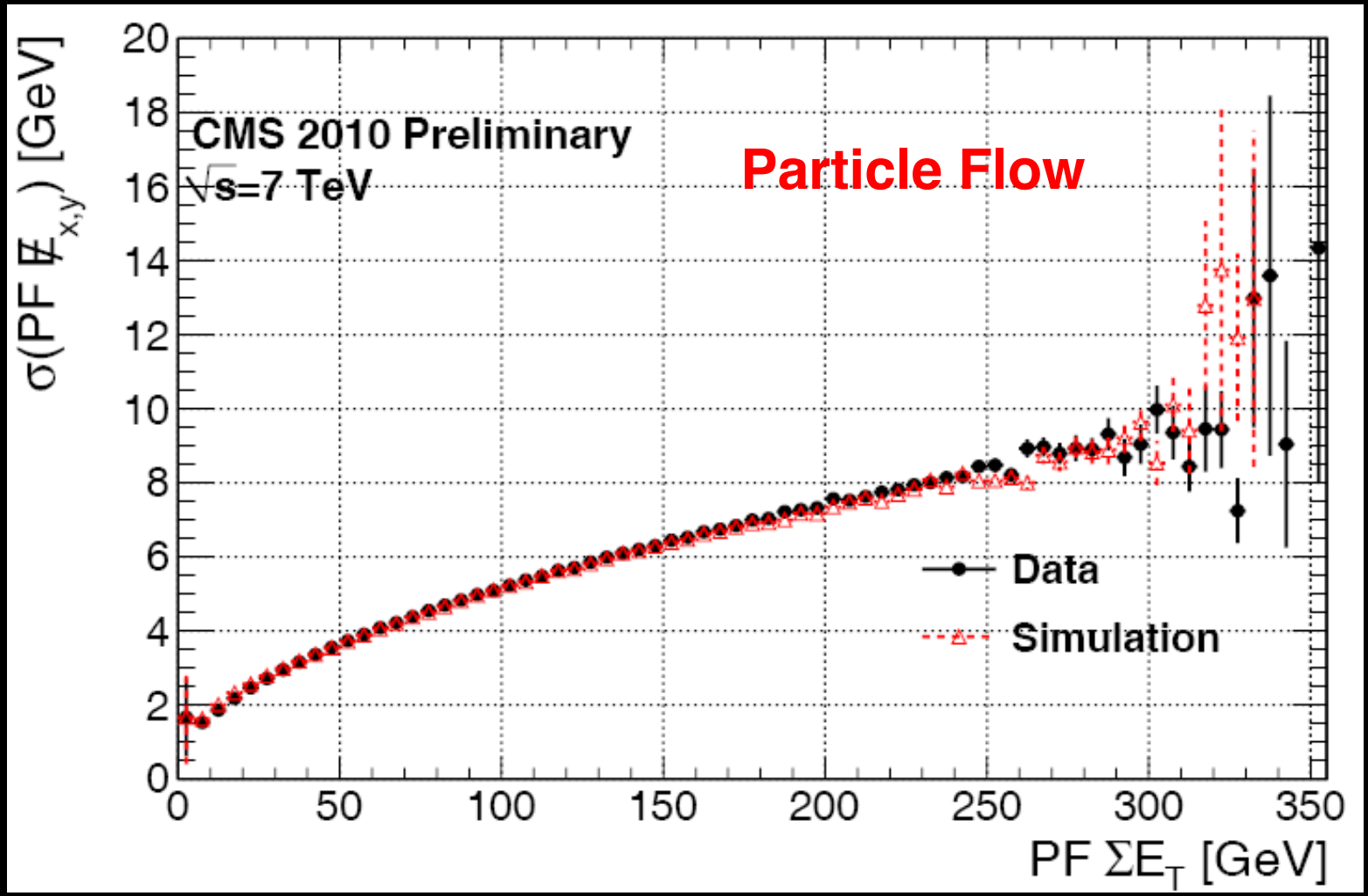




Ready for b physics (and b-tagging in general)



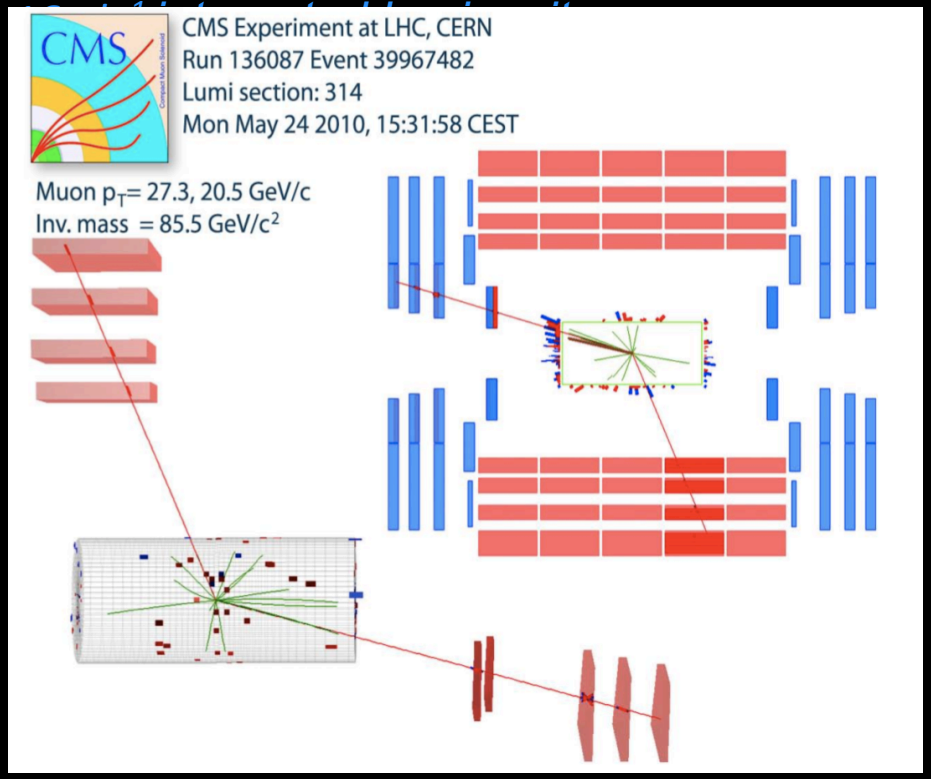
MET resolution vs Sum

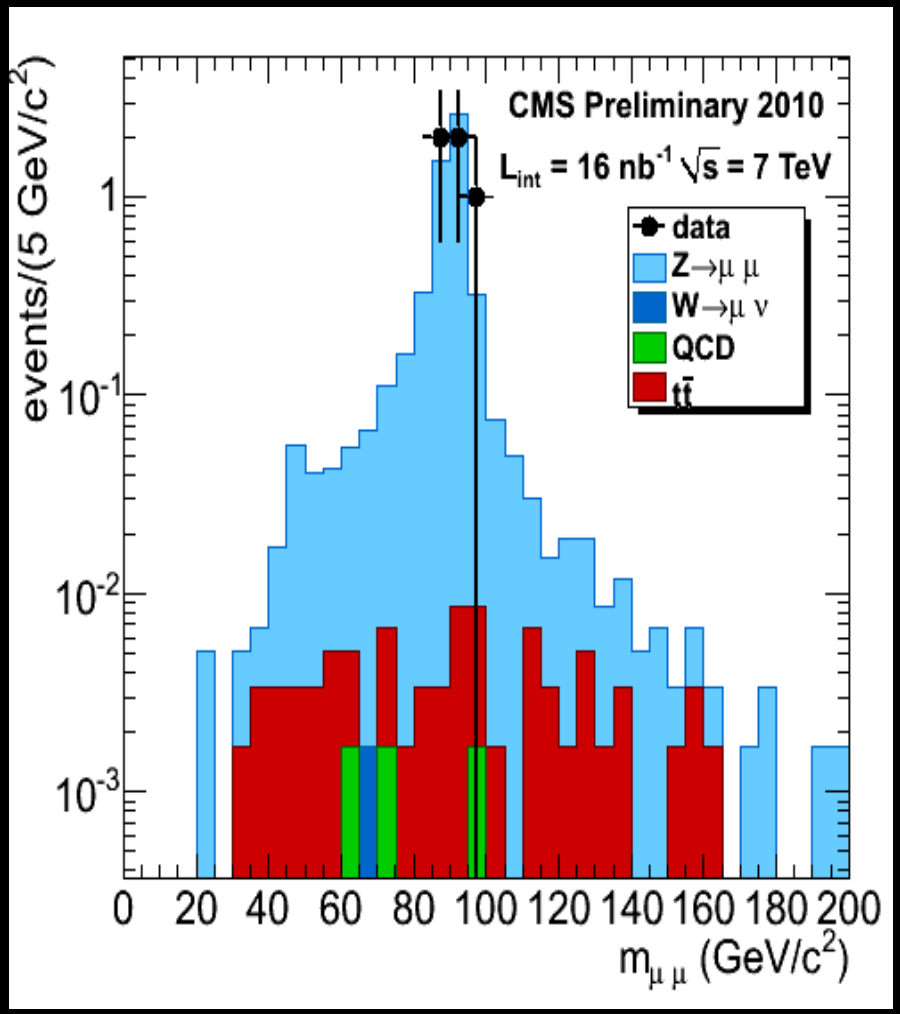


$Z \rightarrow \mu^+\mu^-$ observation

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

Monte Carlo : *cross section normalized to*



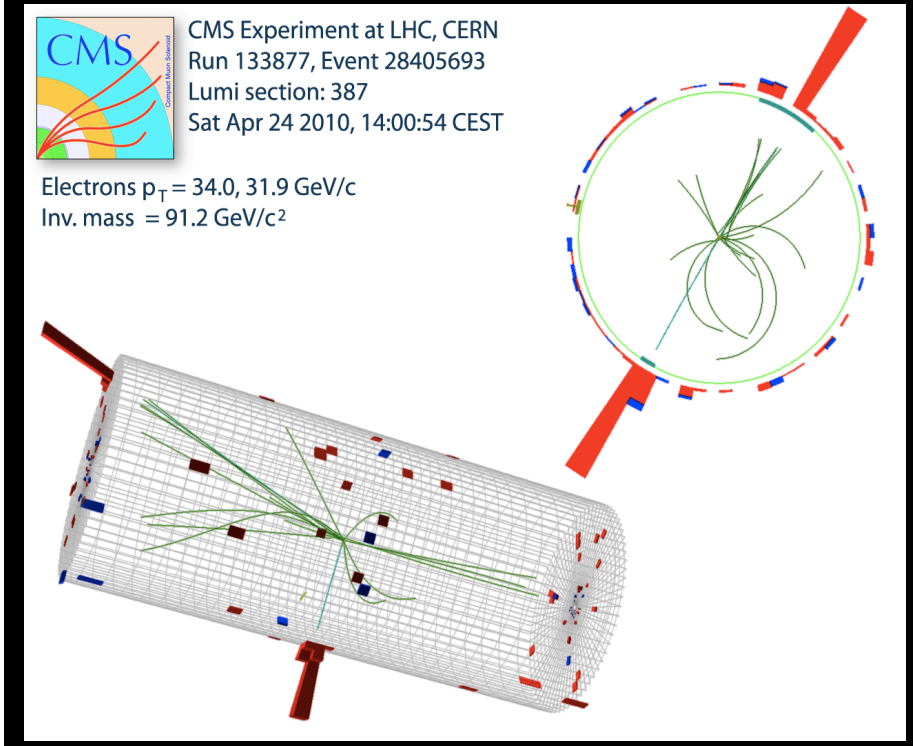


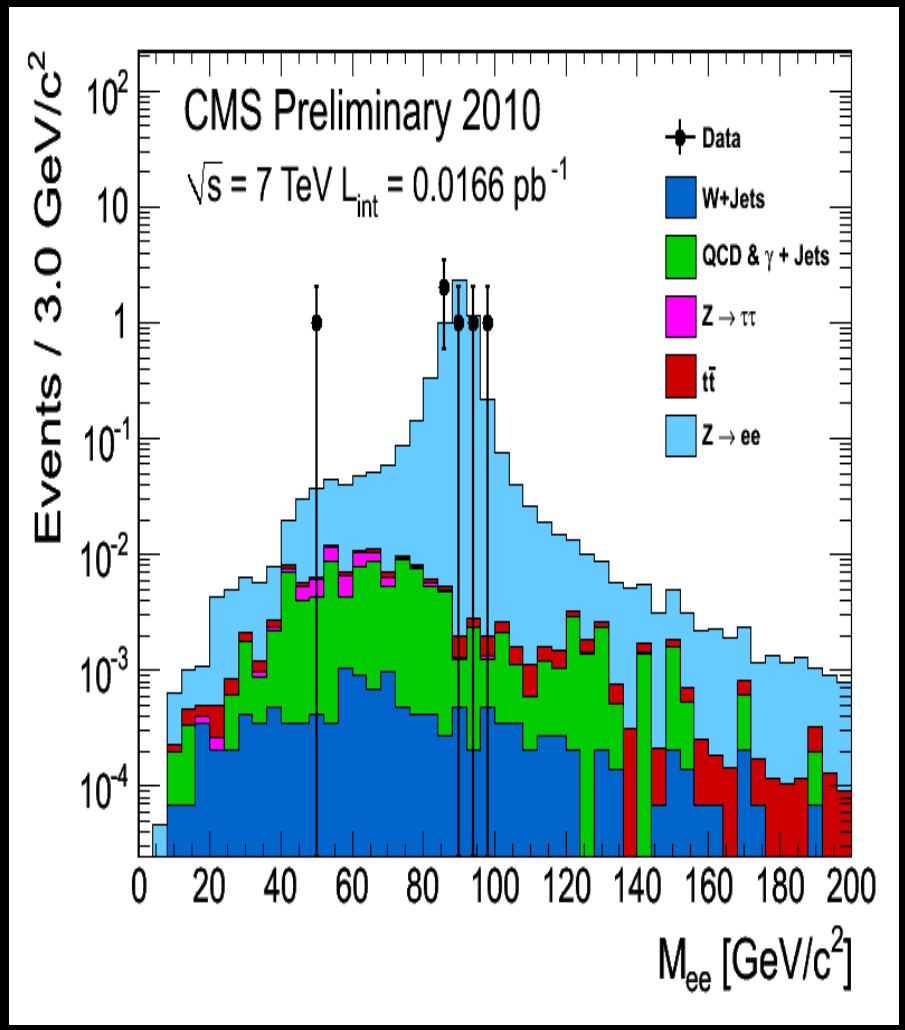
5 $Z \rightarrow \mu^+\mu^-$ candidates

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

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

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



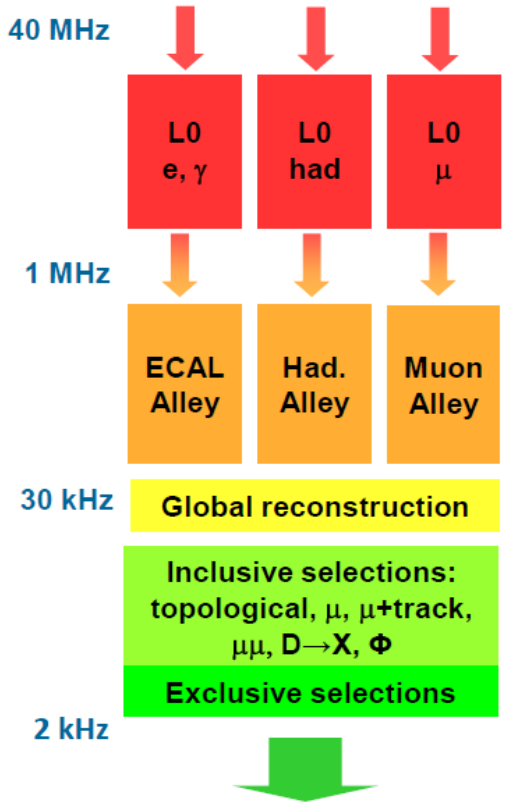


5 $Z \rightarrow e^+e^-$ candidates

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



Level-0

2010 approach

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

HLT1

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

HLT2

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%.

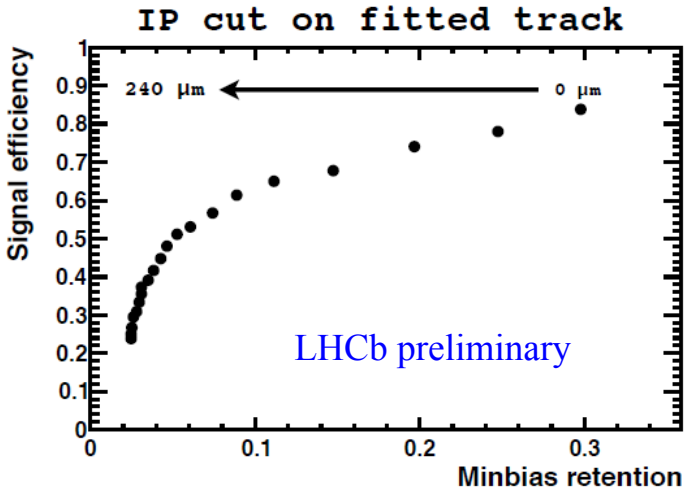
Trigger Efficiencies

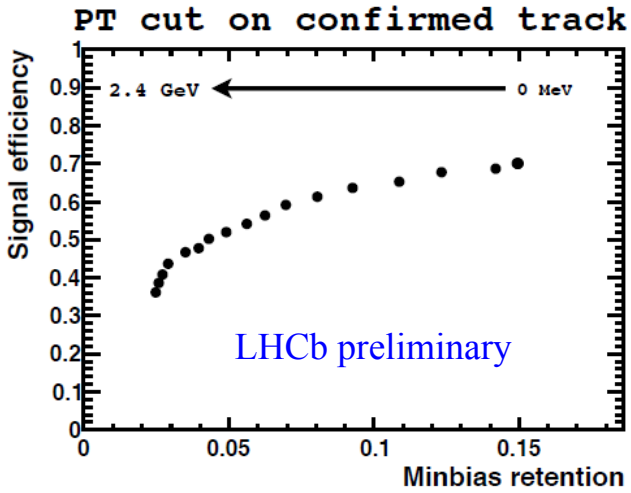
Take D*, $D^0 \to K\pi$ signal collected in minimum bias events
&
Evaluate L0*HLT1 performance with 2010 low luminosity trigger settings

good agreement with MC

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

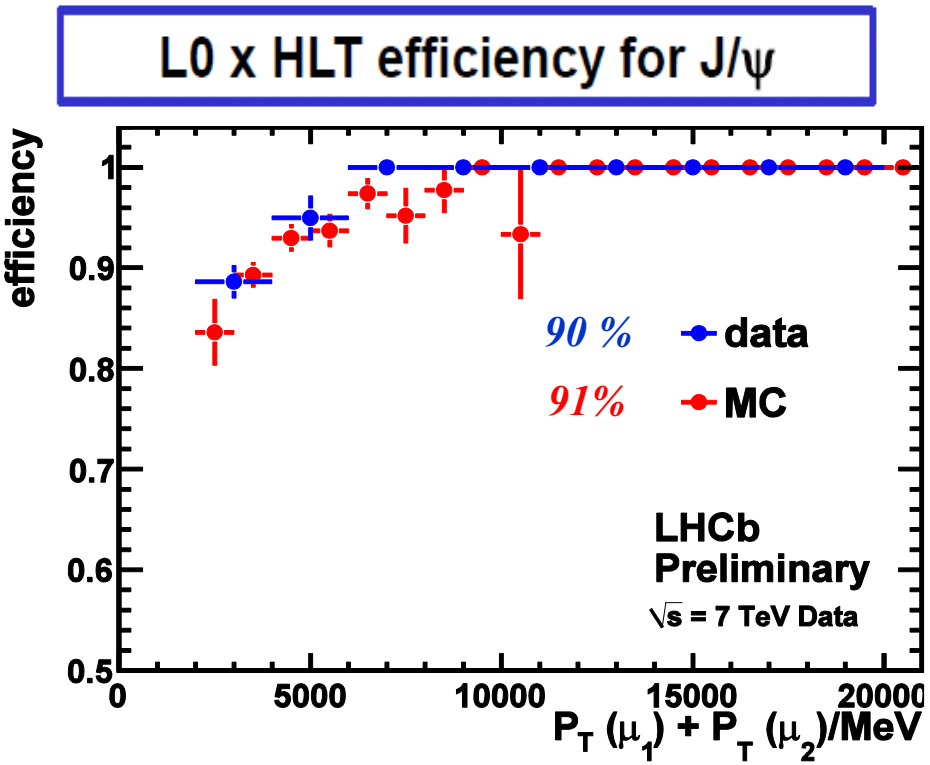
Performance of single-hadron HLT1 line on data

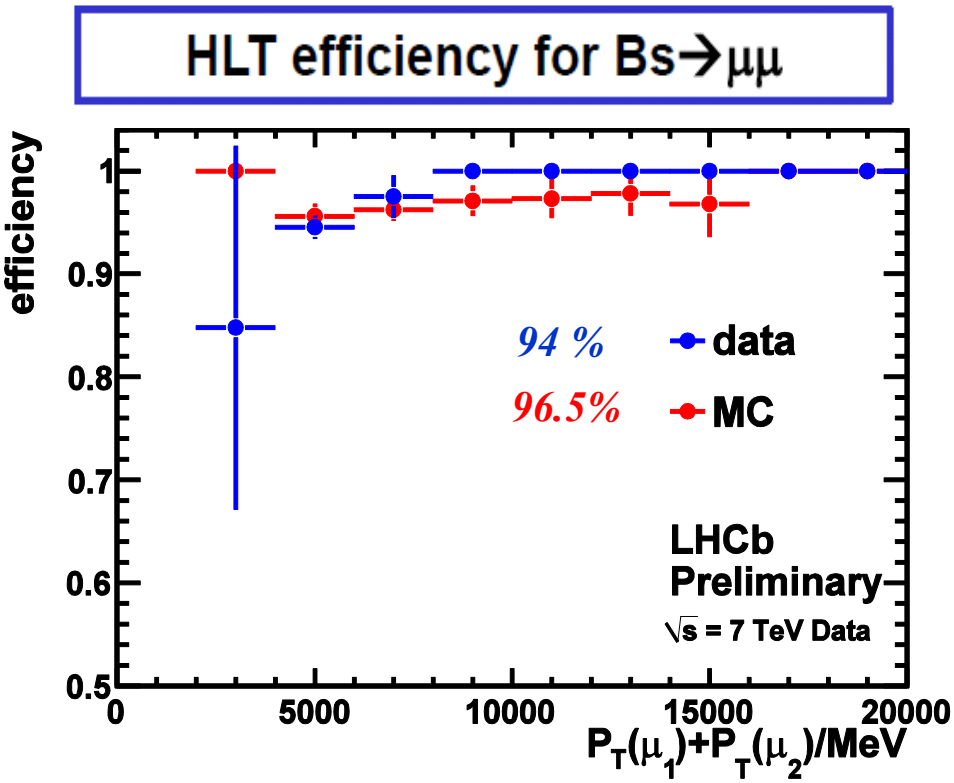




Trigger Efficiencies

- *Measure performance of L0*HLT1 (using lifetime unbiased HLT1 lines) for J/ψ→μμ*
- *Transport results to harder p_t spectrum of B_s→μμ*





Data agree well with MC

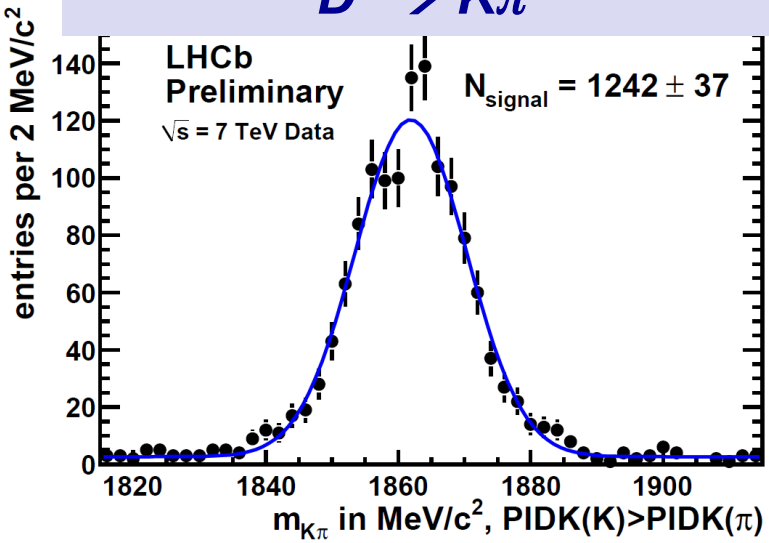
LHCb trigger concept has been proven with data !!!

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

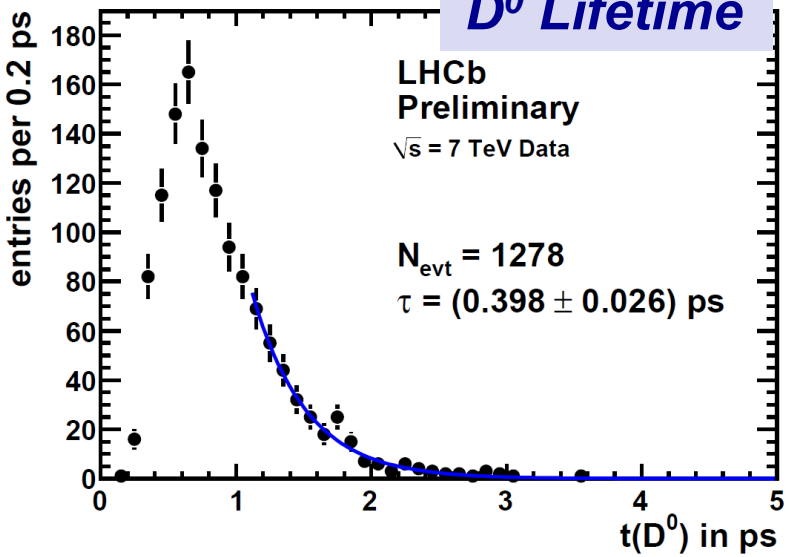
Proper Lifetime

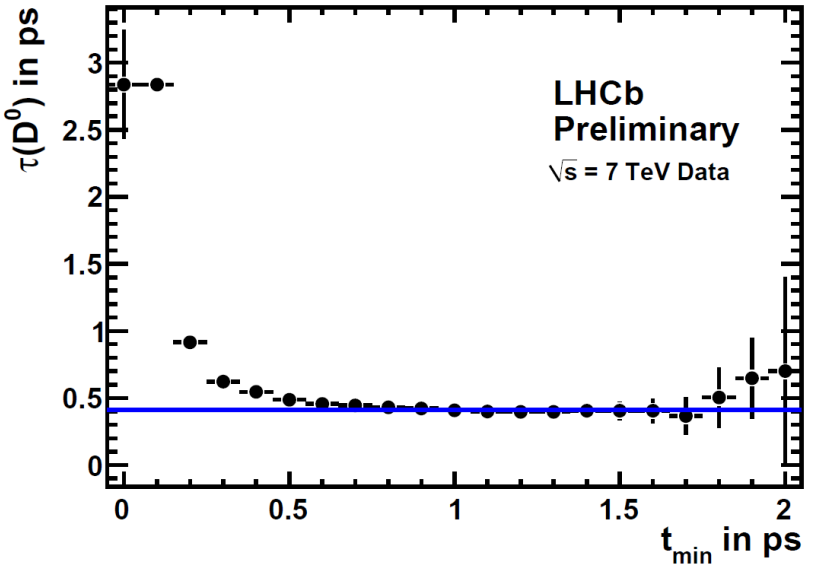
(use sample of D^0 for calibration; D^0 lives 3.5 times shorter than B^0)

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



D^0 Lifetime





LHCb Lifetime fit gives:

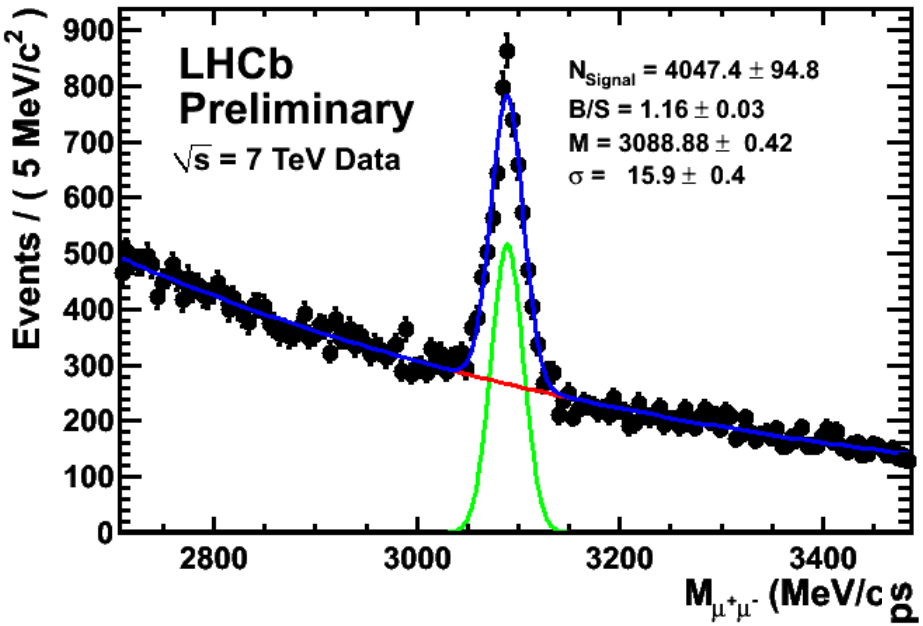
$\tau(D^0) = (0.398 \pm 0.026)$ ps

In good agreement with PDG:

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

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

J/psi effective lifetime

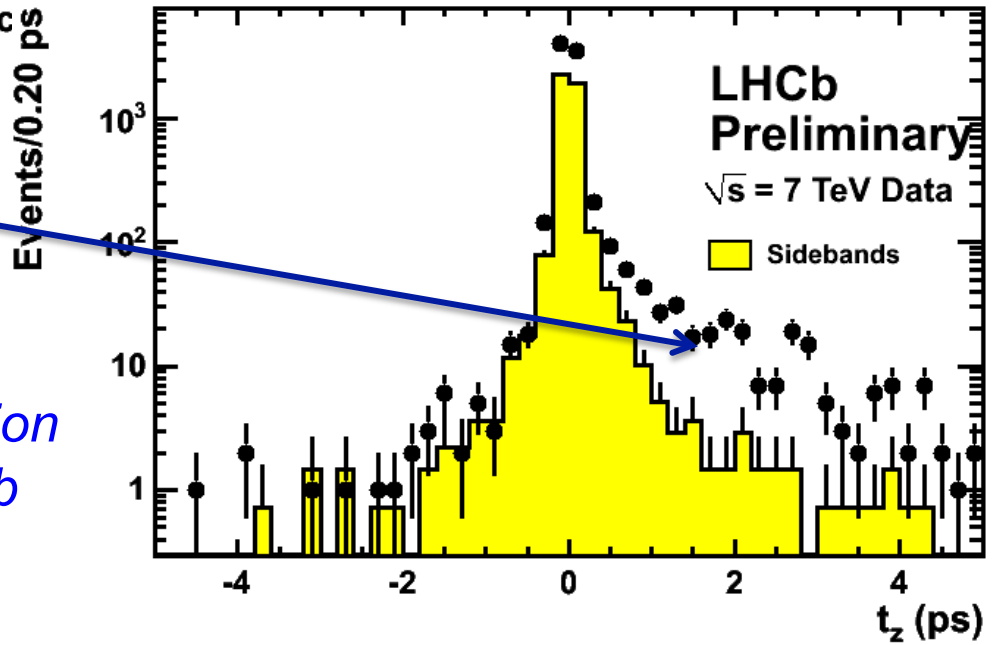


A total of 4000 J/ψ → μμ decays reconstructed

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 √s = 7 TeV

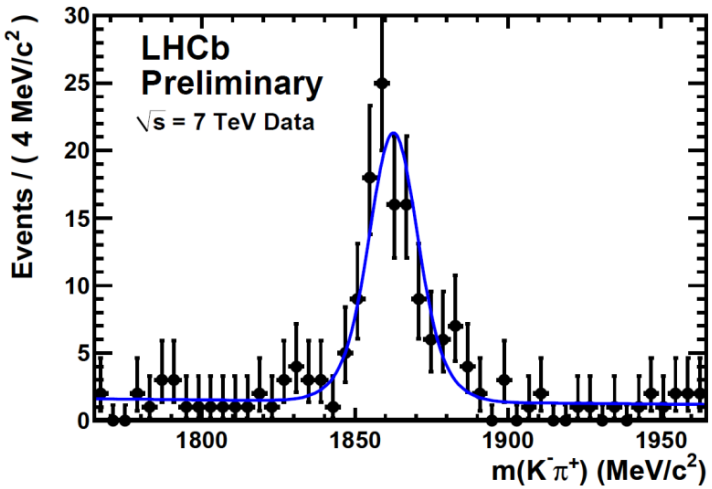
Signal window & normalized sideband



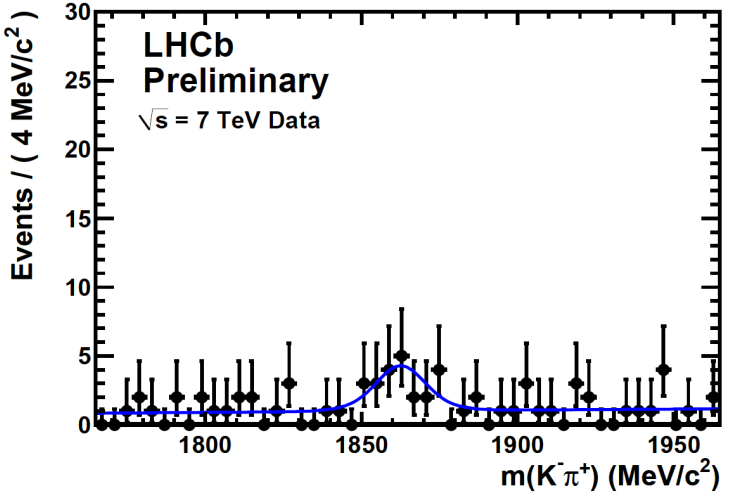
$B^0 \rightarrow D^0 \mu\nu$ with $D^0 \rightarrow K\pi$

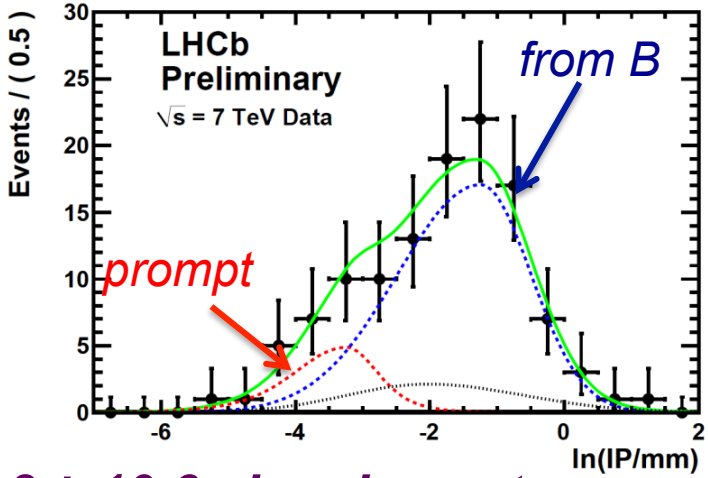
Correlate D^0 with the muon of the right (wrong) sign

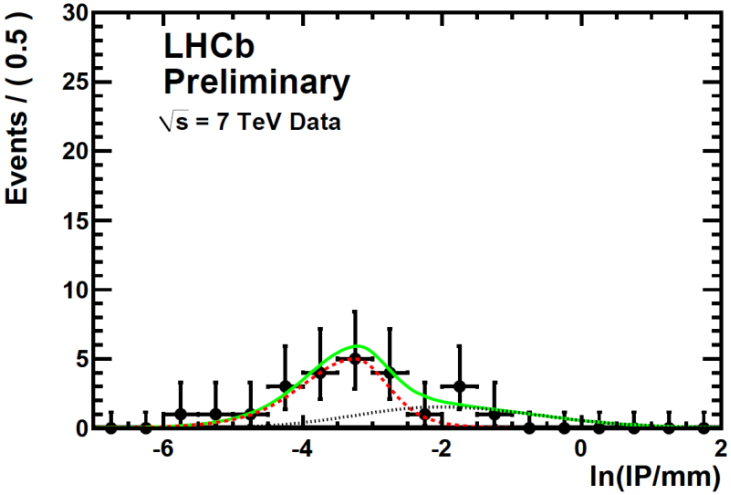
Right sign



Wrong sign



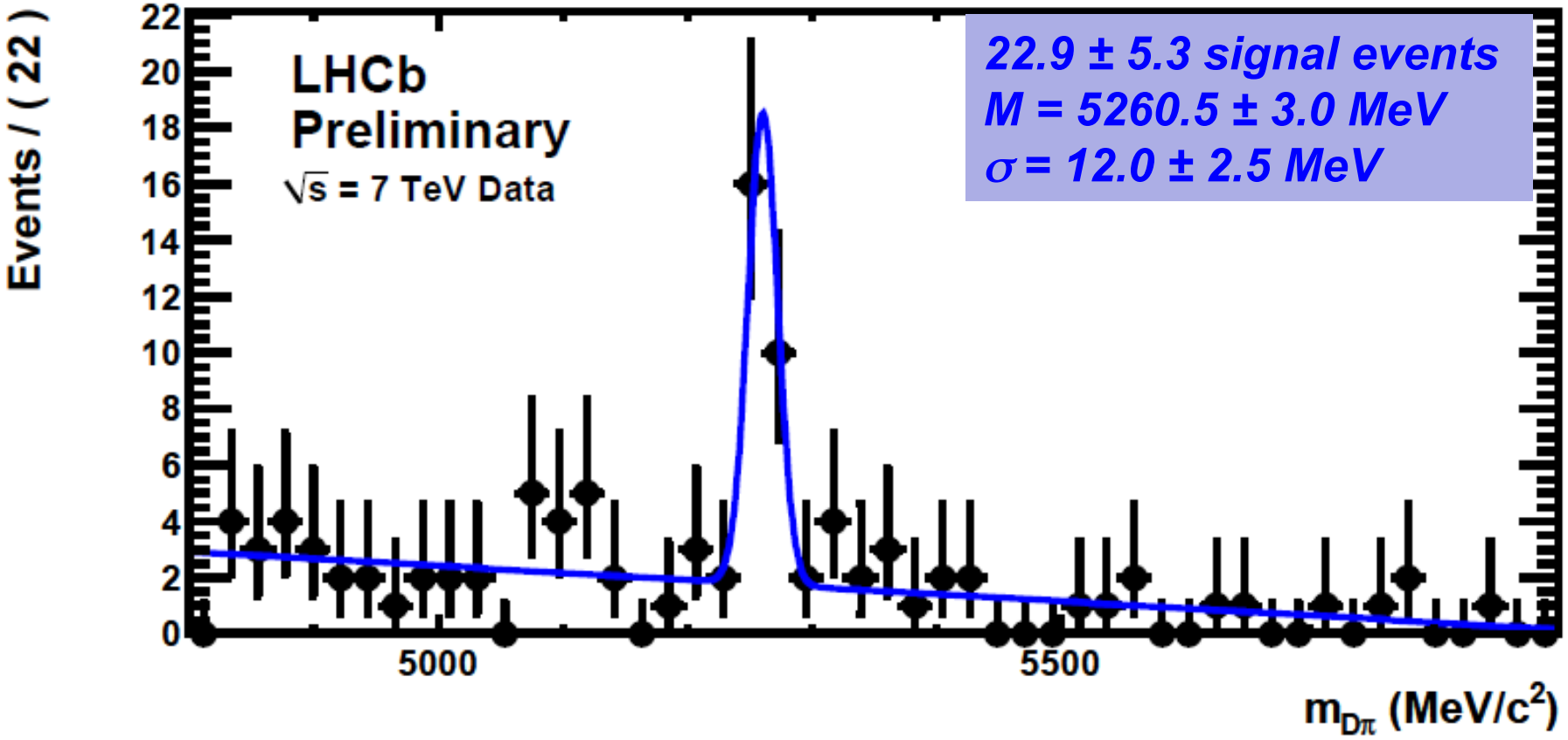




85.3 ± 10.6 signal events with D from B

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

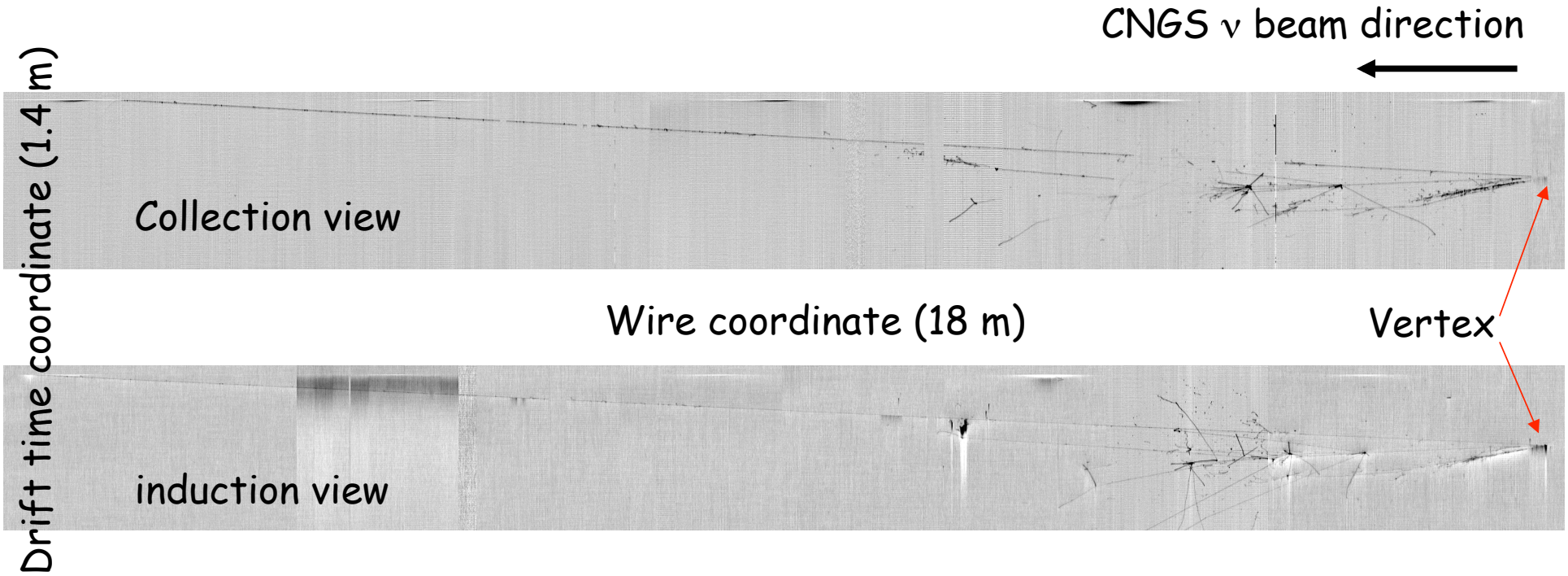
LHC experiments summary

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

Not only LHC…..

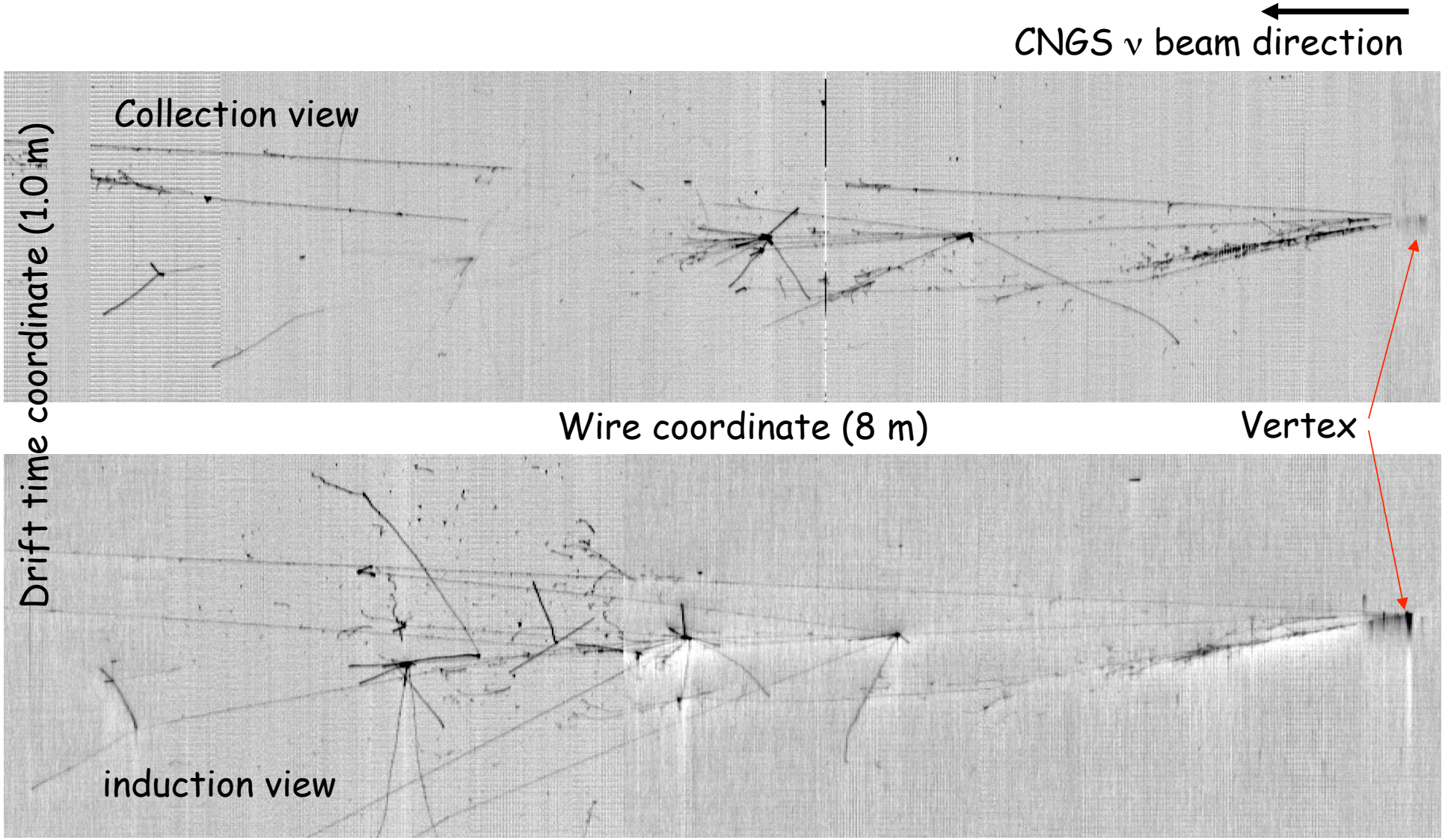
ICARUS @ CNGS

The first CNGS neutrino interaction in ICARUS T600

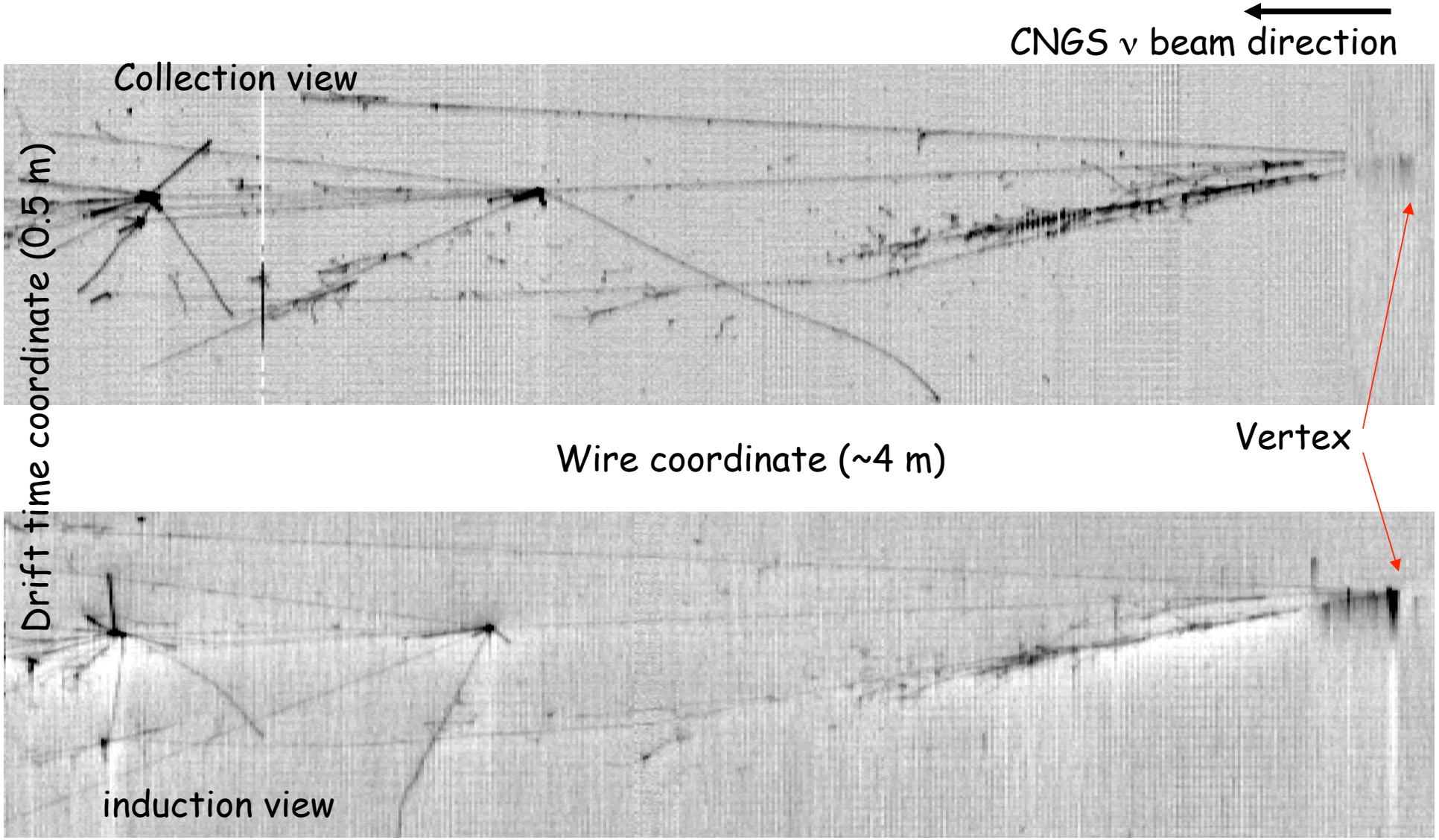


- Leading muon (crossing horizontally the whole cryostat)
- Two charged particle tracks undergoing hadronic interactions
- Two γ converting at 14 and 16 cm from vertex (π^0?)
- Vertex not fully visible in collection view, due to locally wrong wire biasing

The first CNGS neutrino interaction in ICARUS T600

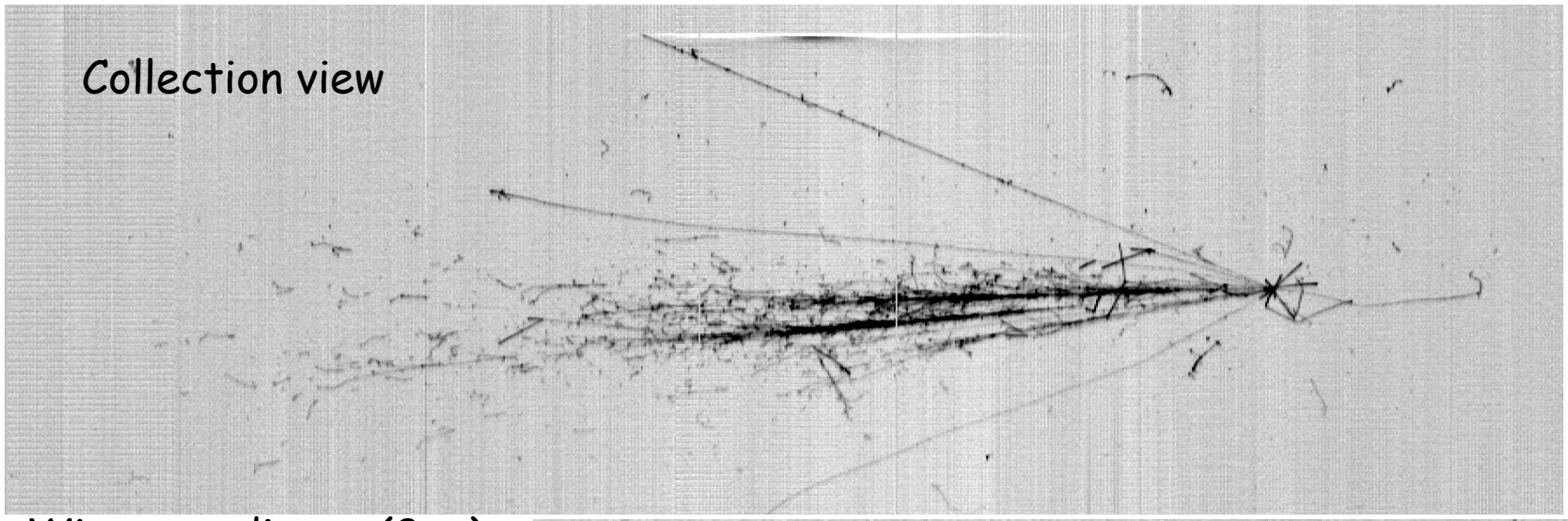


The first CNGS neutrino interaction in ICARUS T600



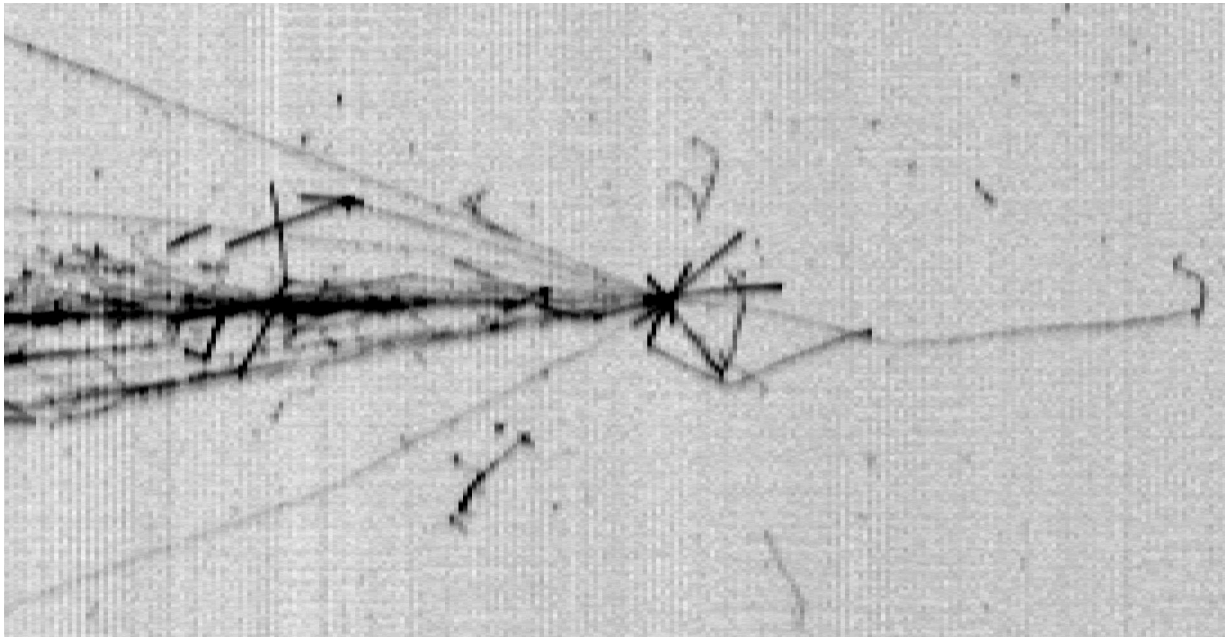
The second CNGS neutrino interaction in ICARUS T600

CNGS ν beam direction



Drift time coordinate (1.4 m)

Wire coordinate (8 m)

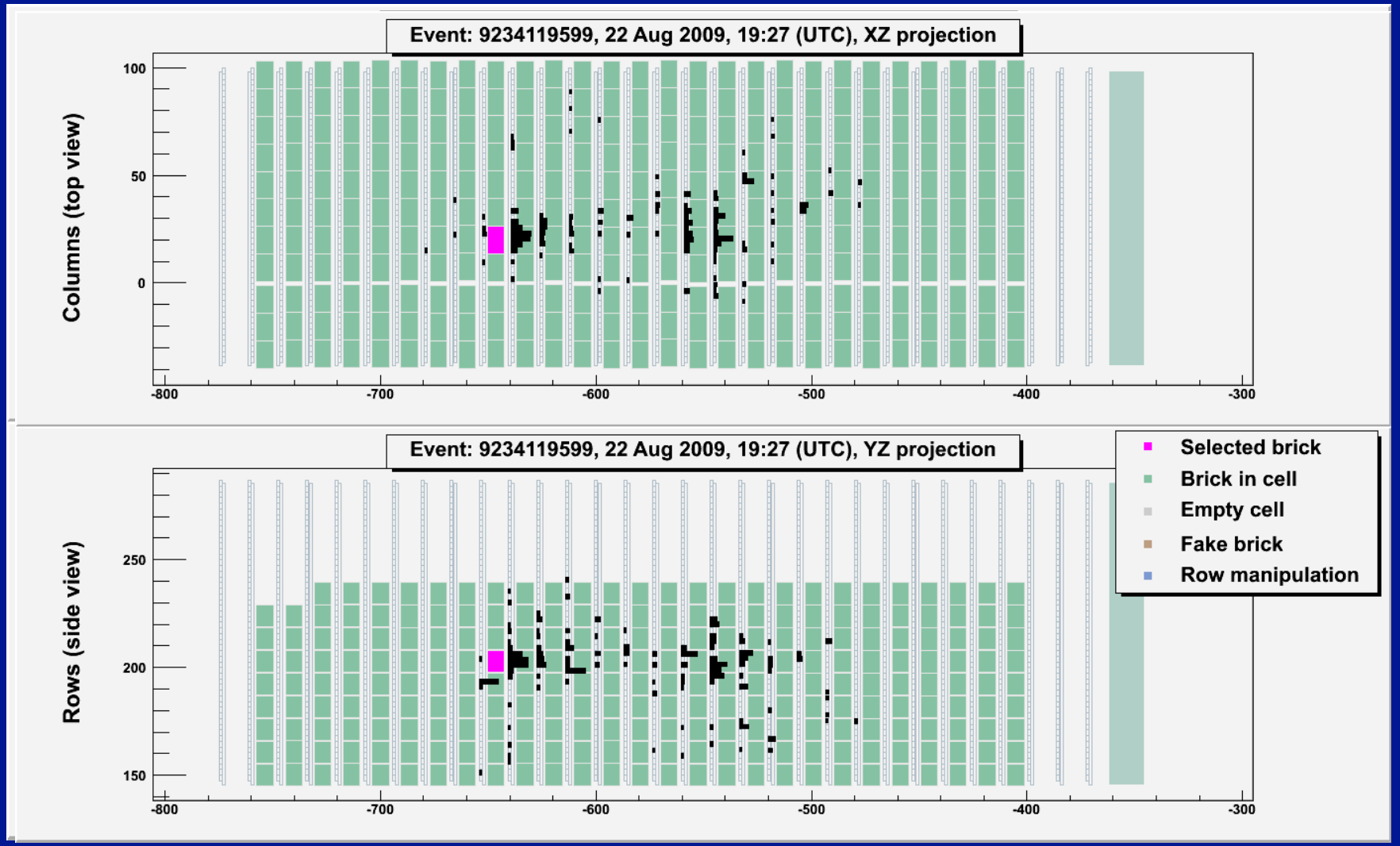


Not only LHC…..

…. and

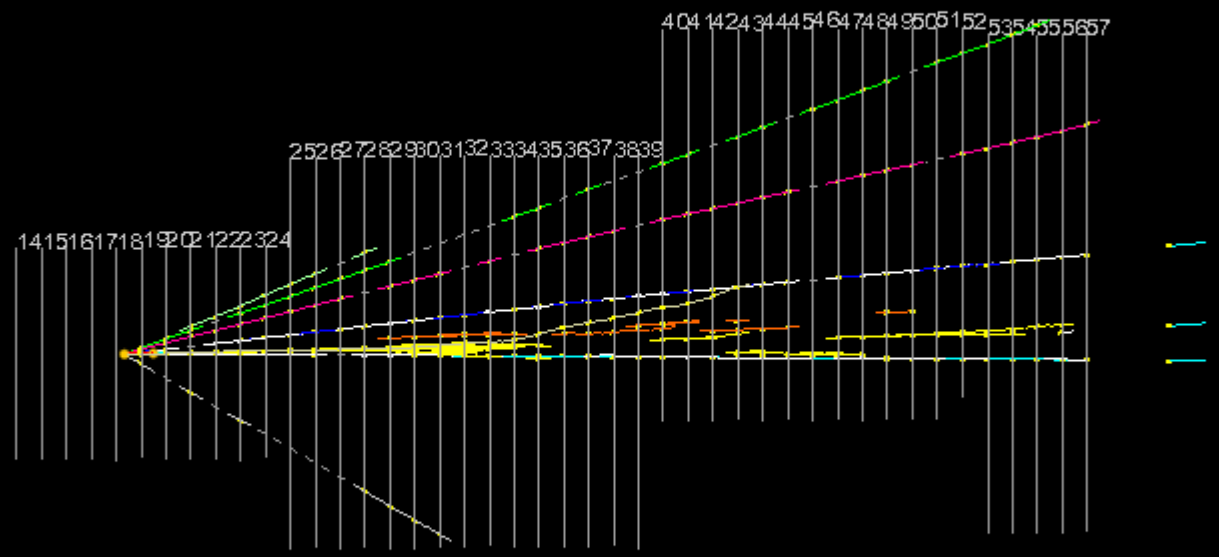
OPERA first τ candidate

Muonless event 9234119599, taken on 22 August 2009, 19:27 (UTC) (as seen by the electronic detectors)

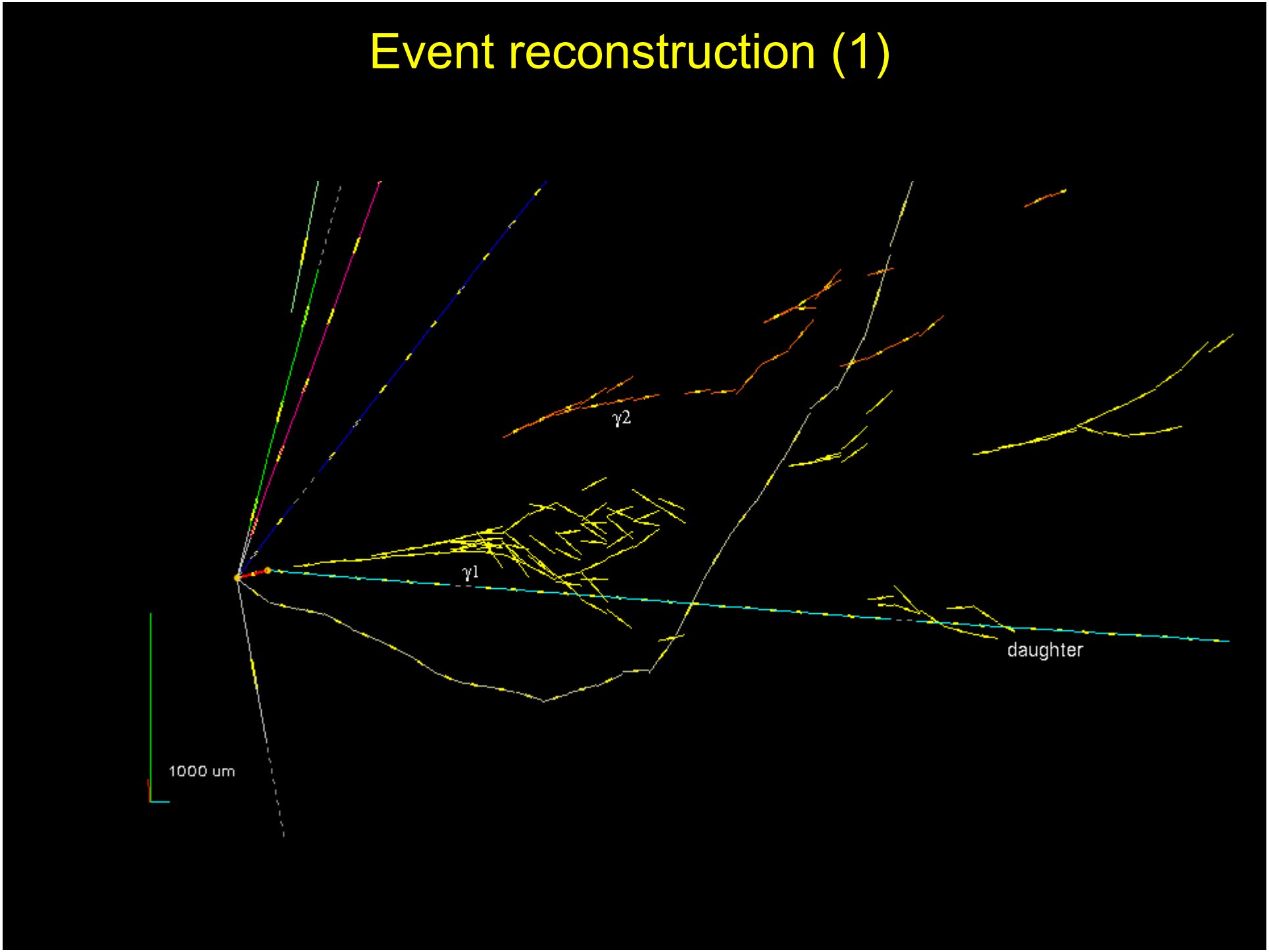


From CS to vertex location

Large area scanning
Full reconstruction of vertices and gammas

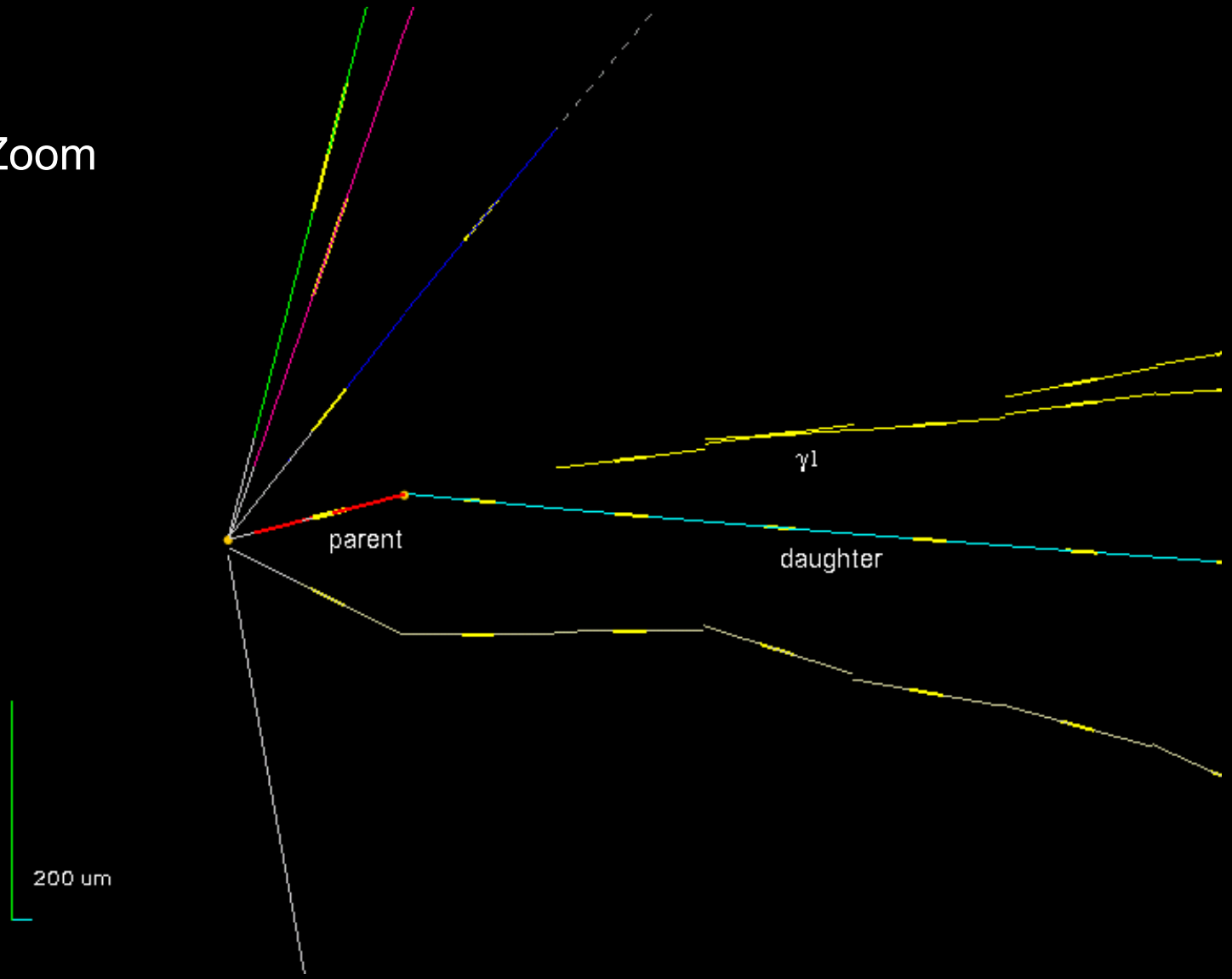


Event reconstruction (1)

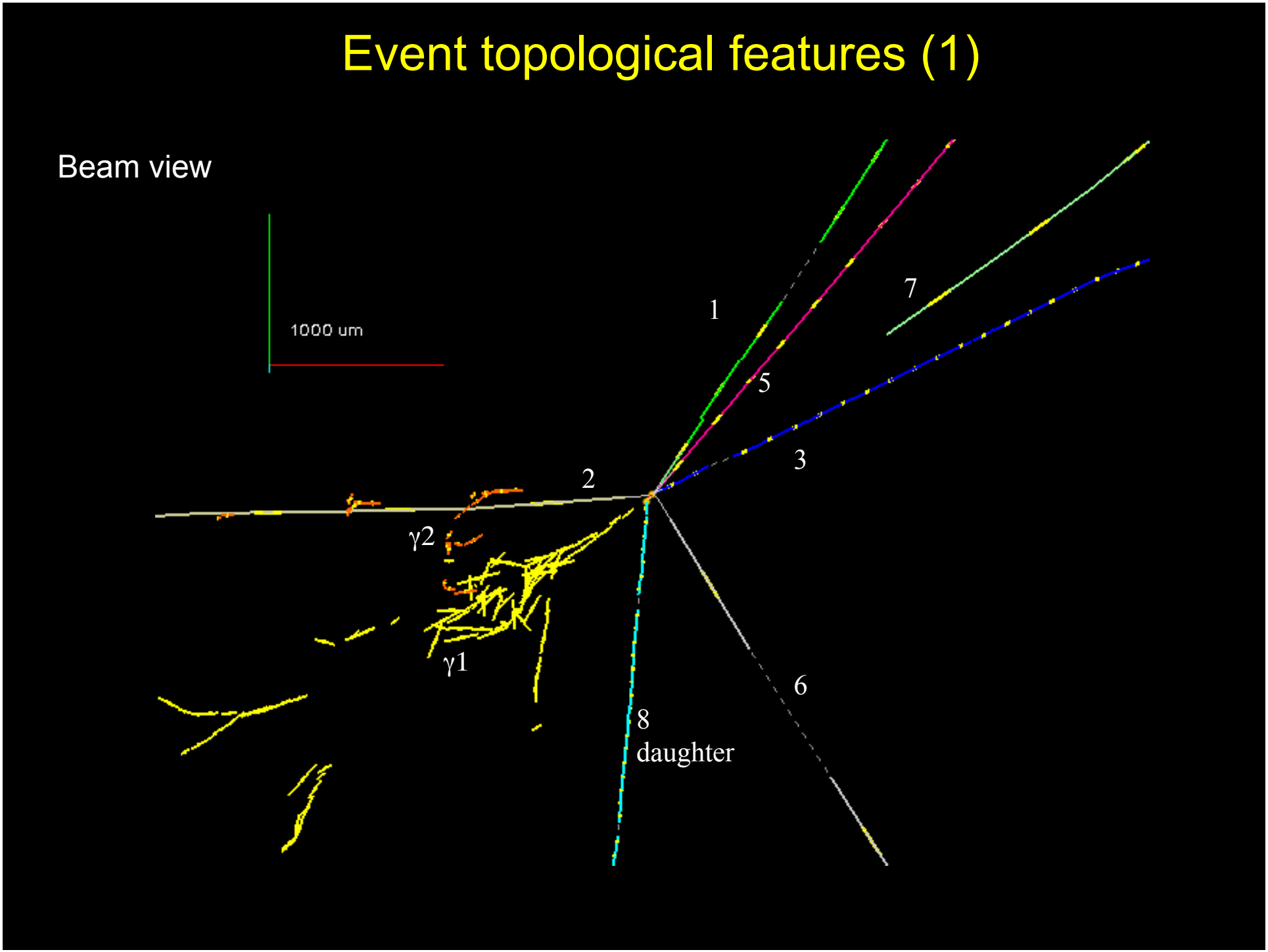


Event reconstruction (2)

Zoom

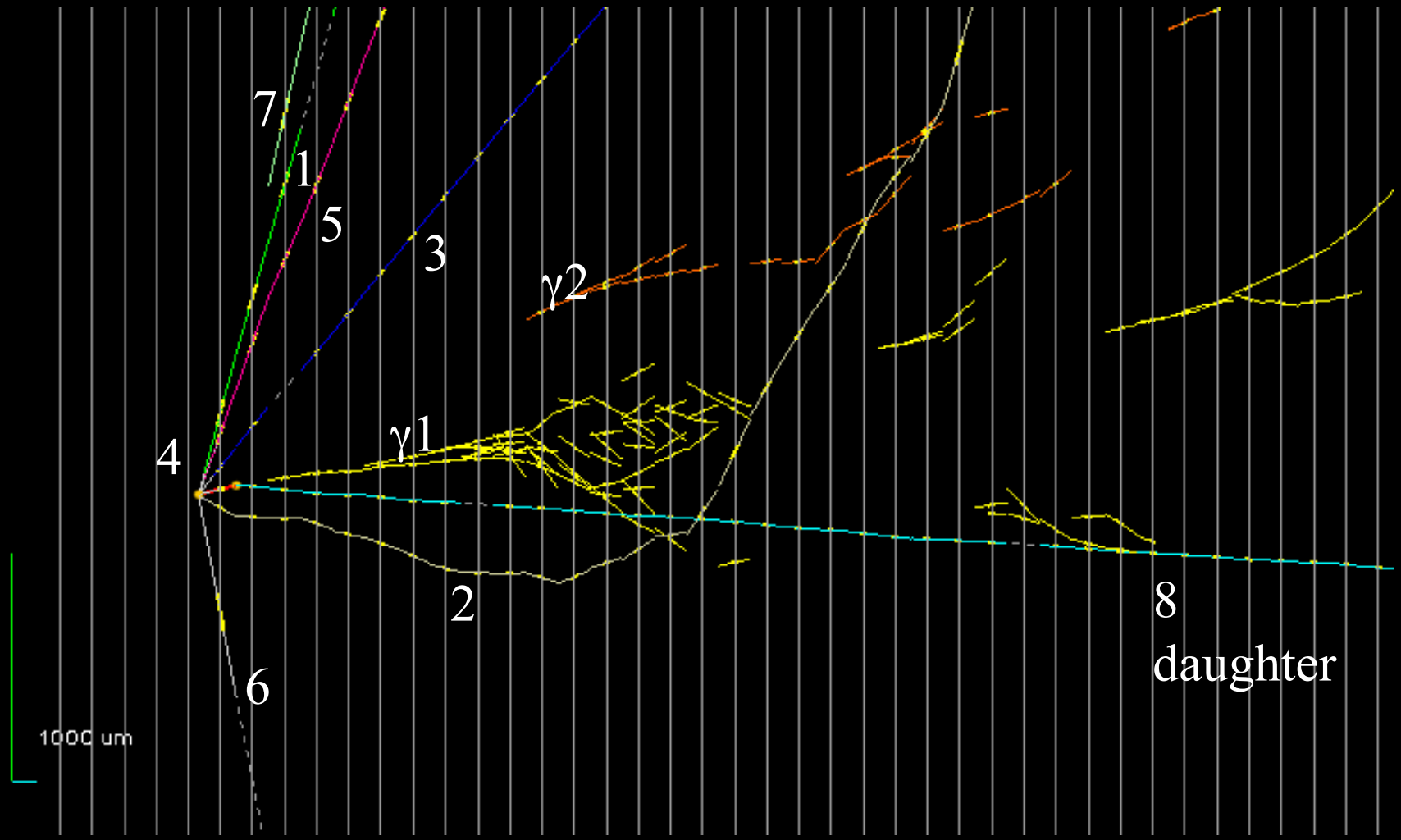


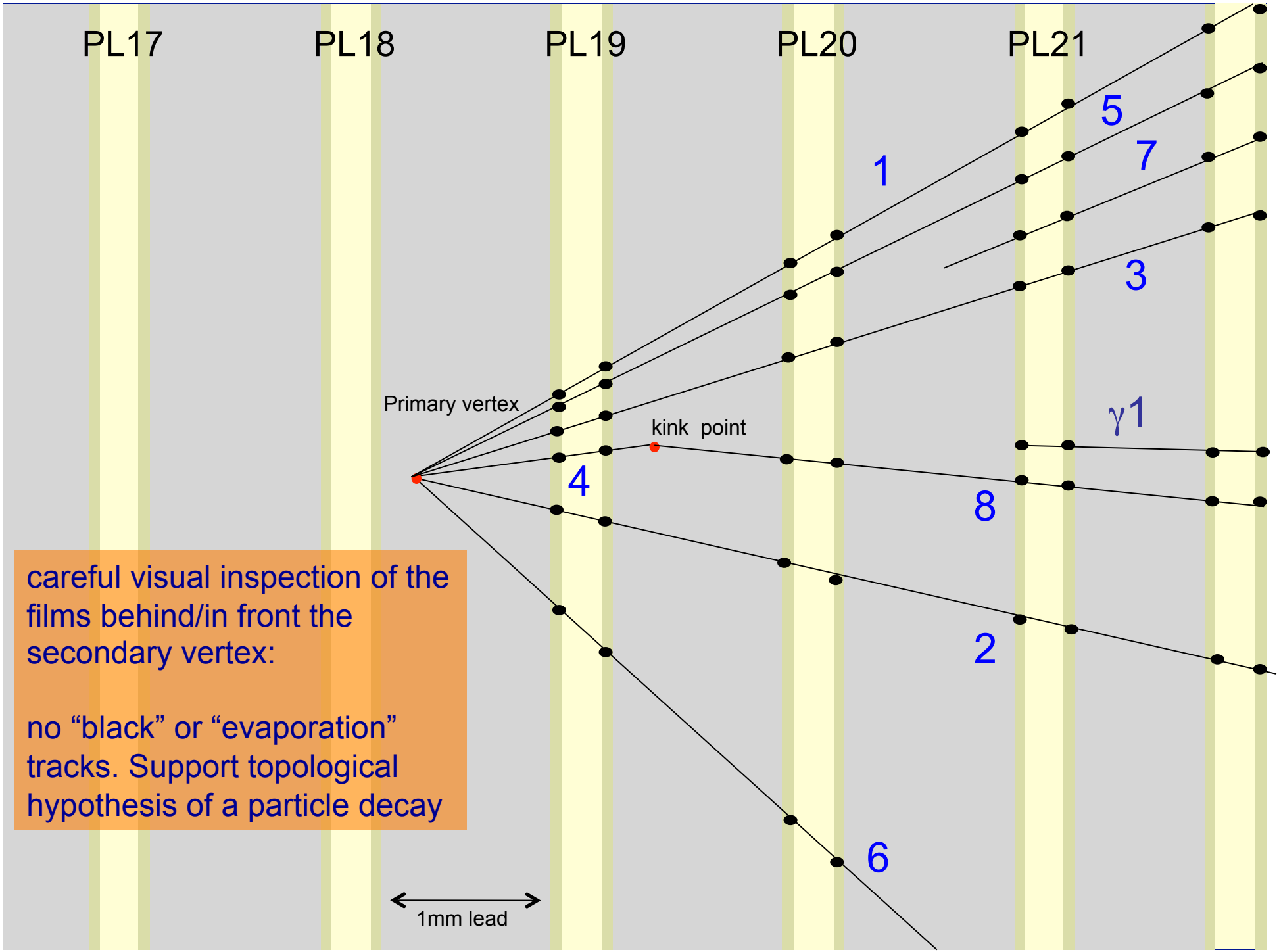
Event topological features (1)



Event topological features (2)

Side view





careful visual inspection of the films behind/in front the secondary vertex:

no “black” or “evaporation” tracks. Support topological hypothesis of a particle decay