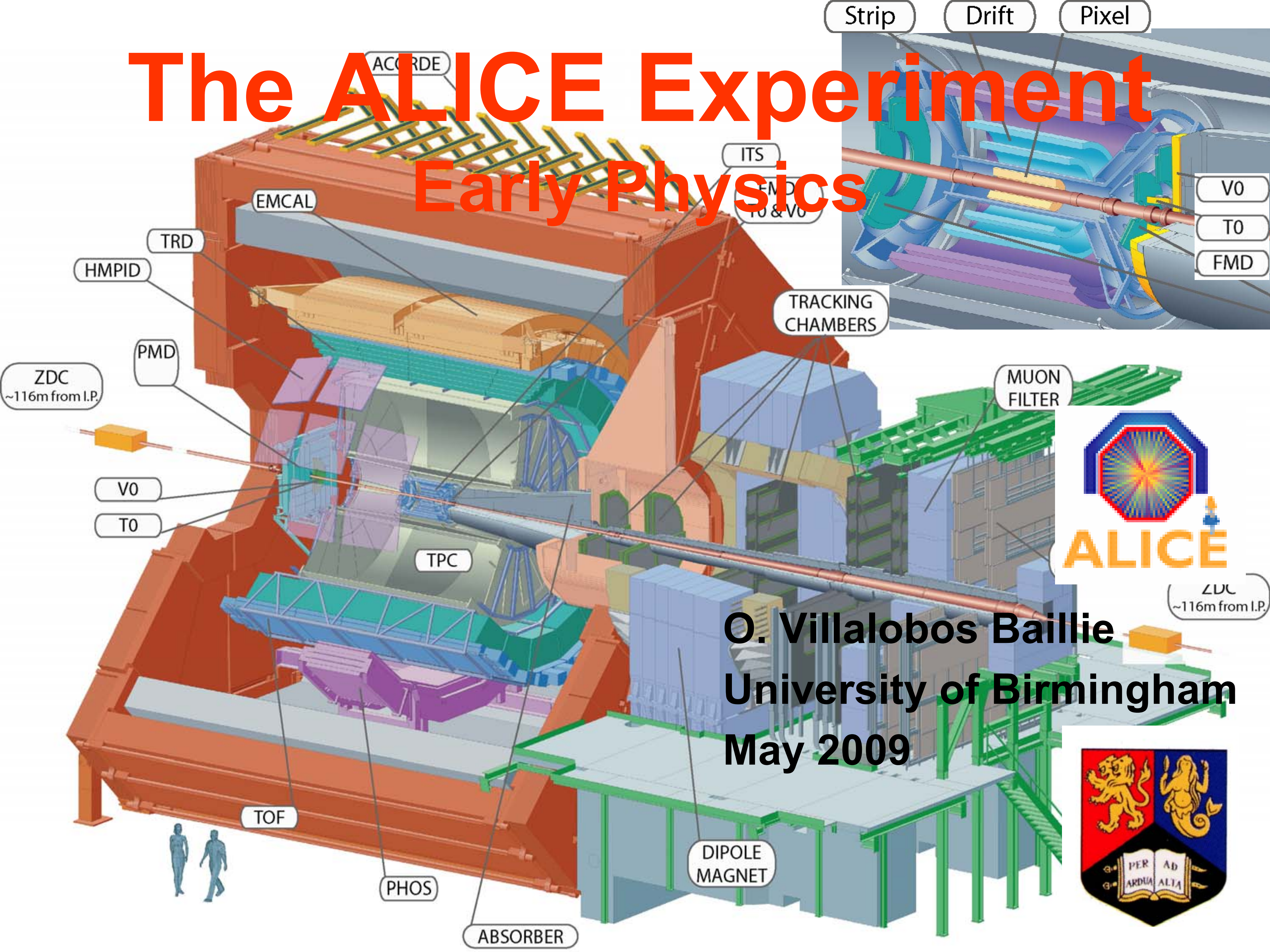
The ALICE Experiment

Early Physics



O. Villalobos Baillie
University of Birmingham

May 2009

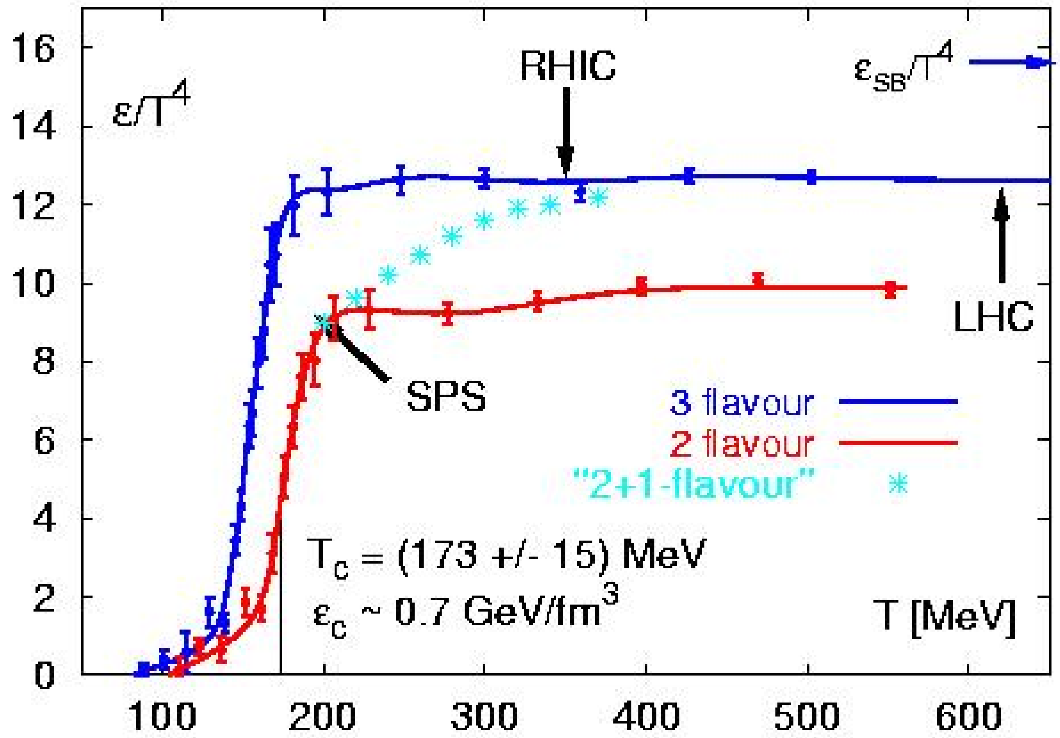
Plan of Talk

- The LHC energy regime
- Introduction to the ALICE detector
- Performance examples from 2008
- “First Physics” programme in pp
- Pb-Pb programme
- Summary

- **AA Collisions**
  - Study nature of phase transition to Quark-Gluon Plasma (QGP)
  - Study properties of QGP
  - Study chiral symmetry restoration
- **pp Collisions**
  - Reference for AA
  - Study specific physics phenomena for which ALICE is well suited

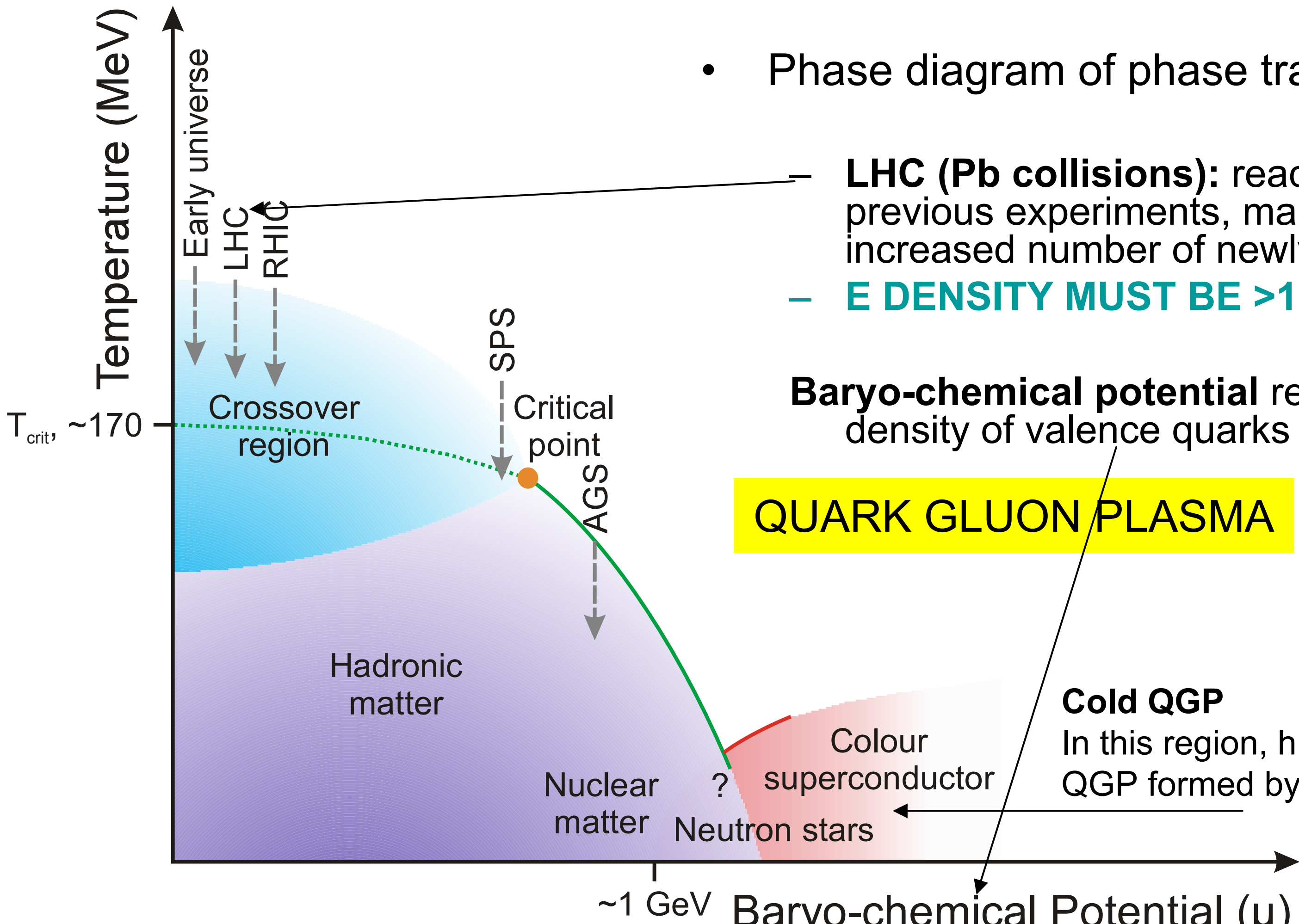
Phases of Strongly Interacting Matter

Lattice QCD, $\mu_B = 0$



Both statistical and lattice QCD predict that nuclear matter will undergo a phase transition at a temperature of, $T \sim 170$ MeV and energy density, $\varepsilon \sim 1$ GeV/fm^3.

Quark Gluon Plasma (QGP)



- Phase diagram of phase transition to QGP.
  - **LHC (Pb collisions):** reaches higher energy than previous experiments, makes hotter collision and increased number of newly produced partons.
  - **E DENSITY MUST BE >1 GeV/fm^{-3} to form QGP**

Baryo-chemical potential relates to the local net density of valence quarks

QUARK GLUON PLASMA

Cold QGP
In this region, high baryo-chemical potential, QGP formed by compressing nuclear matter

ALICE will look at Pb collisions to observe QGP “signatures”

Why Heavy Ions at the LHC?

... factor ~30 jump in $\sqrt{s}$ ...

$\varepsilon_{LHC} > \varepsilon_{RHIC} > \varepsilon_{SPS}$

$V_{f\,LHC} > V_{f\,RHIC} > V_{f\,SPS}$

$\tau_{LHC} > \tau_{RHIC} > \tau_{SPS}$

Central collisions	SPS	RHIC	LHC
$s^{1/2}$(GeV)	17	200	5500
dN_{ch}/dy	500	850	2–8 x10^3
ε (GeV/fm^3)	2.5	4–5	15–40
V_f(fm^3)	10^3	7x10^3	2x10^4
τ_{QGP} (fm/c)	<1	1.5–4.0	4–10
τ_0 (fm/c)	~1	~0.5	<0.2

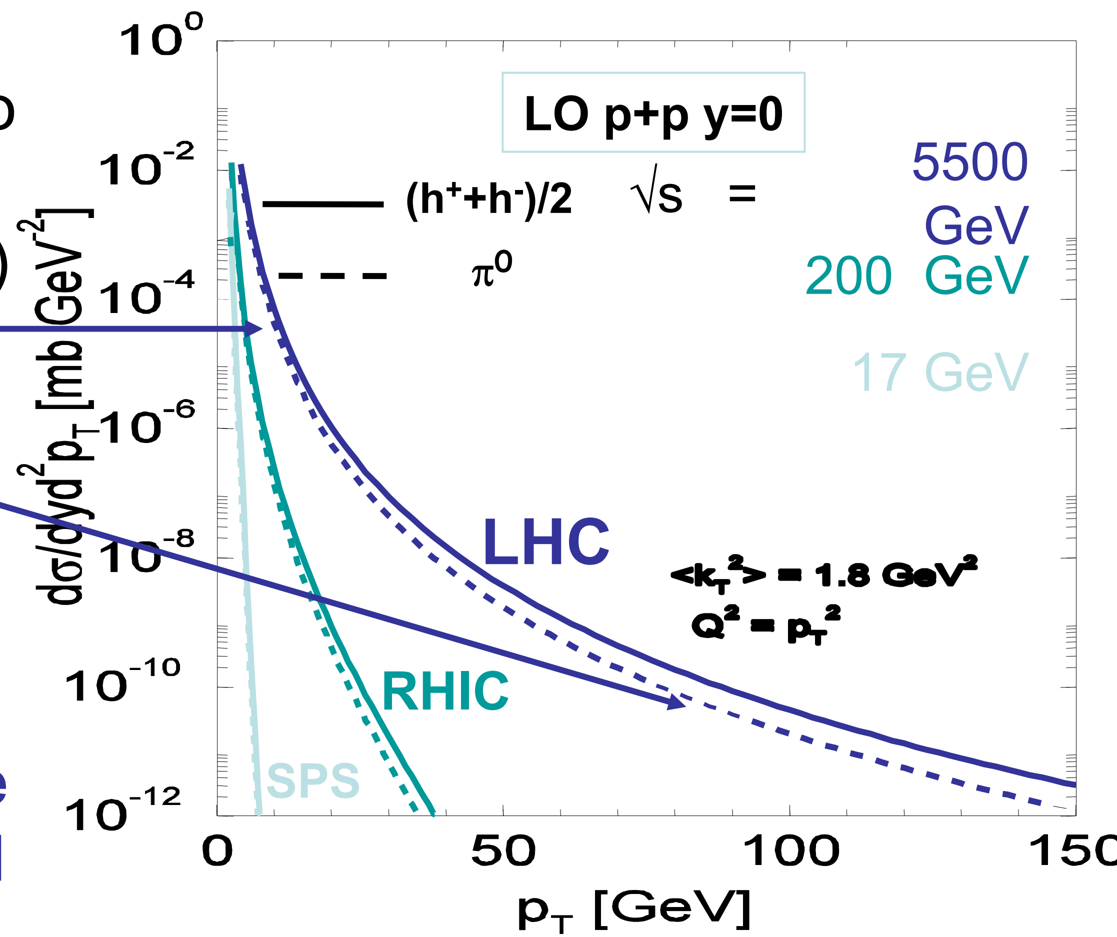
J. Schukraft QM2001:

" hotter - bigger -longer lived "

Novel aspects at ALICE

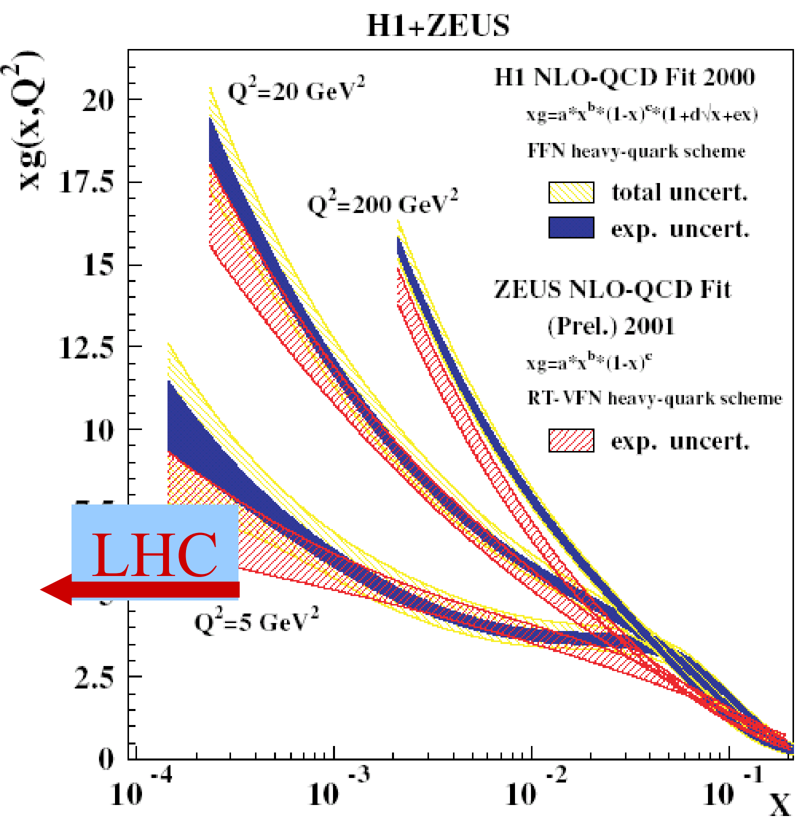
Qualitatively new regime

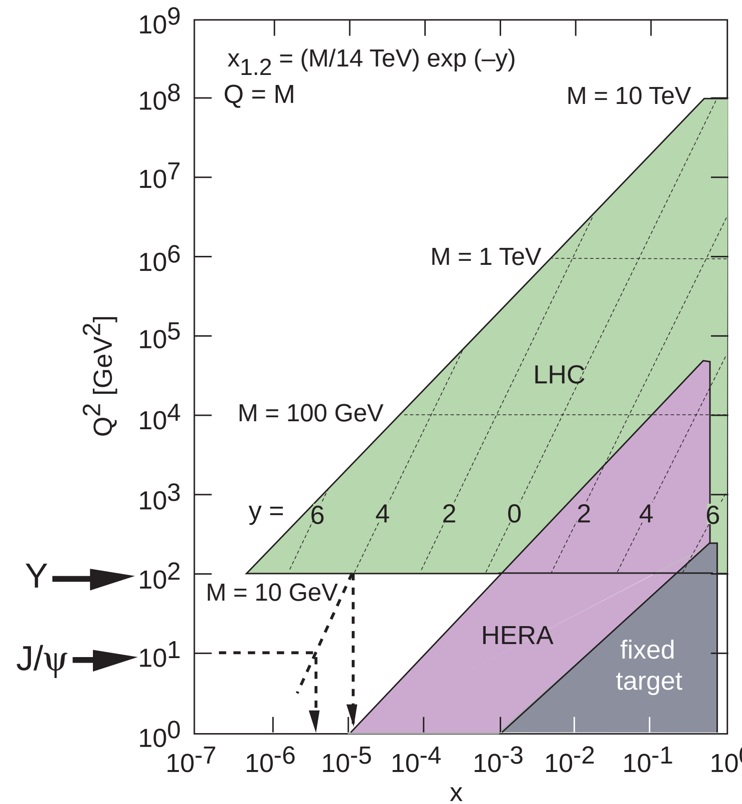
- Hard processes contribute significantly to the total AA cross-section ($\sigma^{hard}/\sigma^{tot}$ = 98%)
  - Bulk properties dominated by hard processes
  - Very hard probes are abundantly produced



New regime accessible at LHC

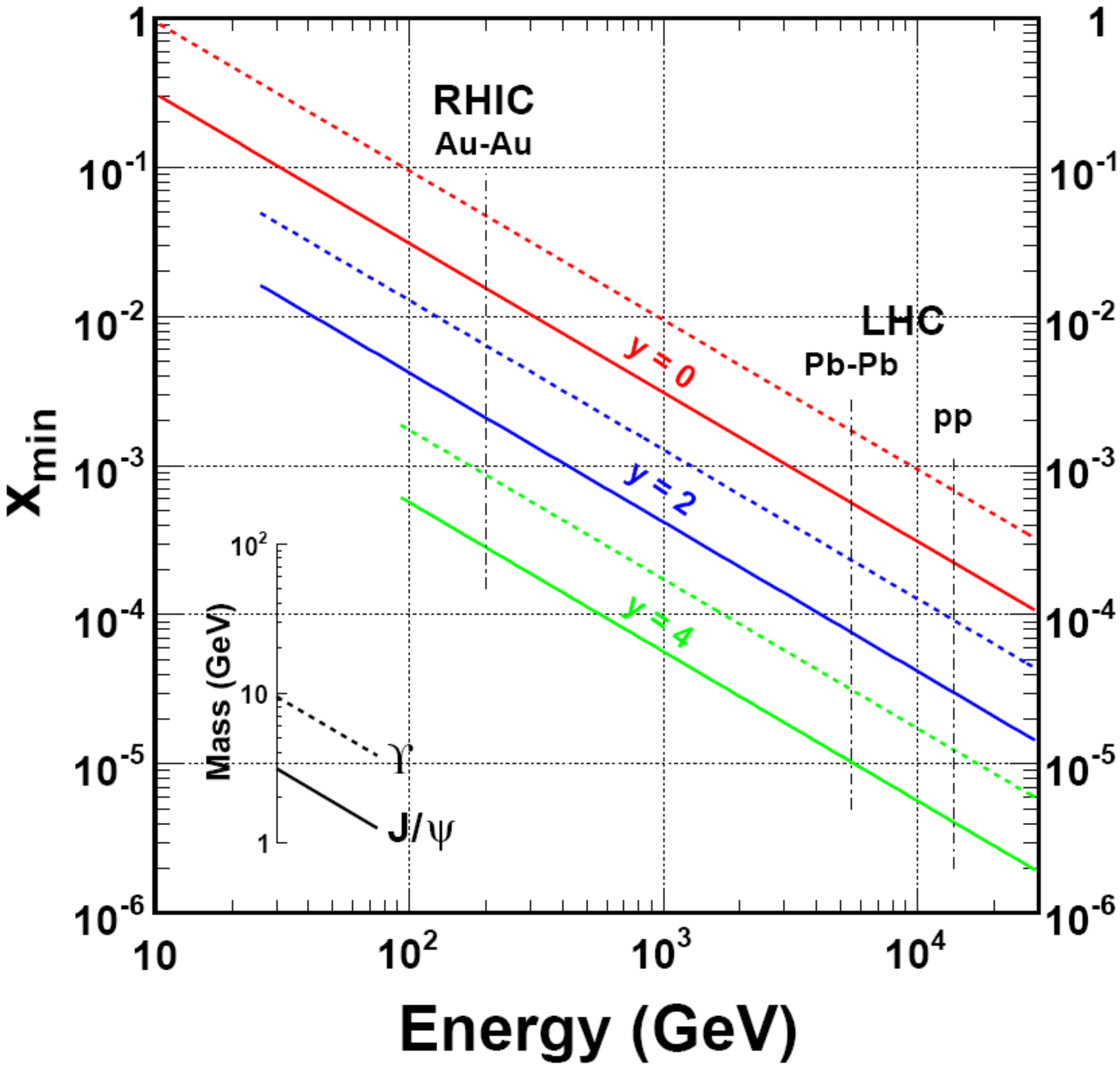
- As low x (~Q^2/s) values are reached, **both the parton density and the parton transverse sizes increase**, there must be a regime (at $q^2 < Q_s^2$) where partons overlap. When this happens, the increase in the number of small x partons becomes limited by gluon fusion.





What is new at LHC is that this overlap should occur for relatively high p_T partons ~ 1 GeV/c (Kharzeev $Q_s^2 \sim 0.7$ GeV²), where the effect must be visible

New low-x regime



From RHIC to LHC

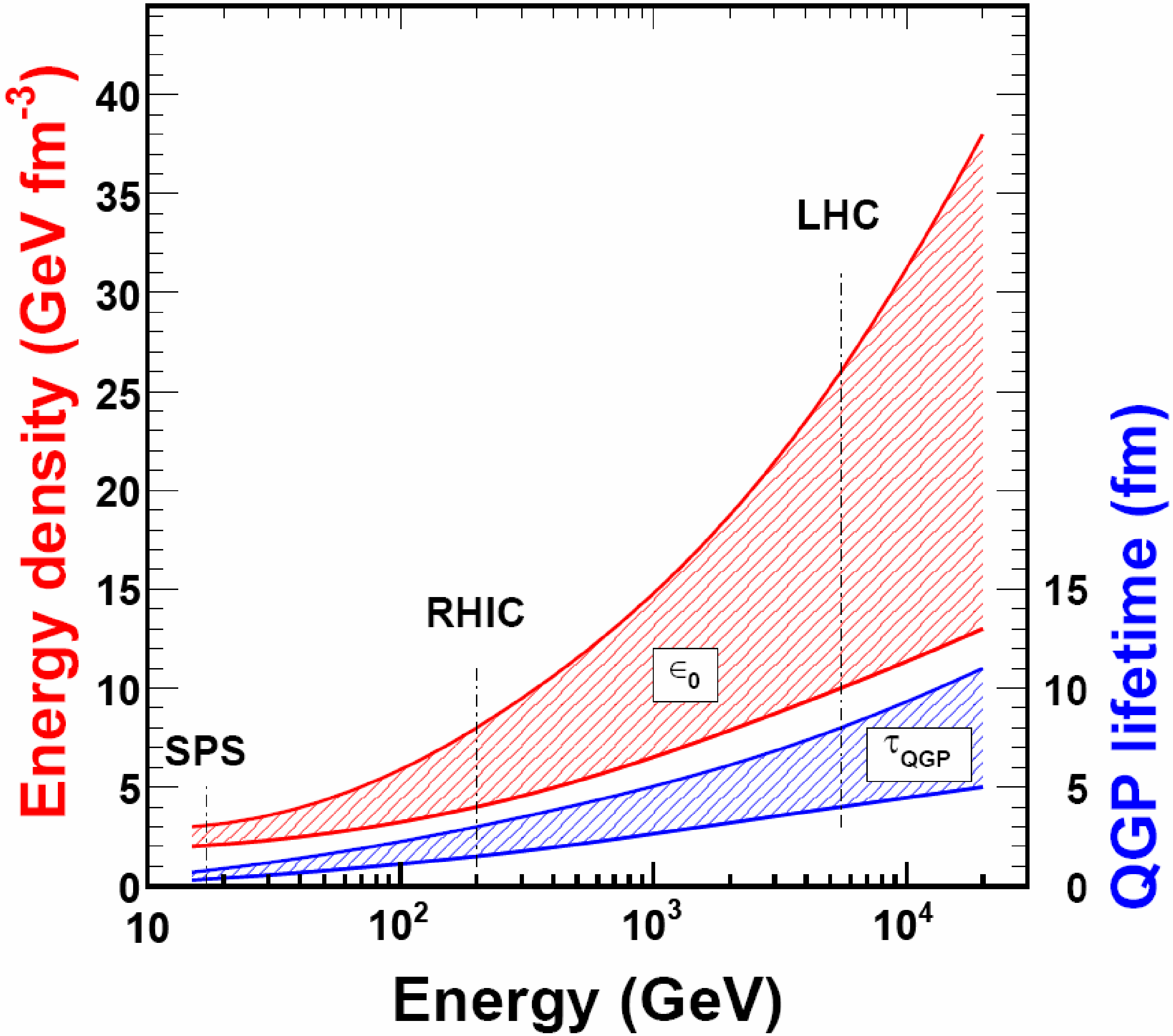
x_{min} ↘ ~ 10^{-2}

- factor 1/30 due to energy
- factor 1/3 larger rapidity

With J/ψ at rapidity 4

- Pb-Pb collisions $x_{min} \sim 10^{-5}$
- pp collisions $x_{min} \sim 3\times10^{-6}$

Energy density



From RHIC to LHC

$\varepsilon_0 = dN/dy <E_\perp>/\tau_0 \, 4\pi R^2$
– increase by factor 2–3

QGP lifetime
– increase by factor 2–3

LHC as Ion Collider

- Running conditions for 'typical' Alice year:

Collision system	$\sqrt{s_{NN}}$ (TeV)	L_0 ($cm^{-2}s^{-1}$)	$\langle L\rangle/L_0$ (%)	Run time (s/year)	σ_{inel} (b)
pp	14.0	10^{31*}		10^7	0.07
PbPb	5.5	10^{27}	70-50	10^{6} **	7.7

- + other collision systems: pA, lighter ions (Sn, Kr, Ar, O)
- & energies (pp @ 5.5 TeV)

* L_{max} (ALICE) = 10^{31} $cm^{-2}s^{-1}$
** $\int L\,dt$ (ALICE) ~ 0.7 nb^{-1}/year

ALICE Collaboration

~ 1000 Members

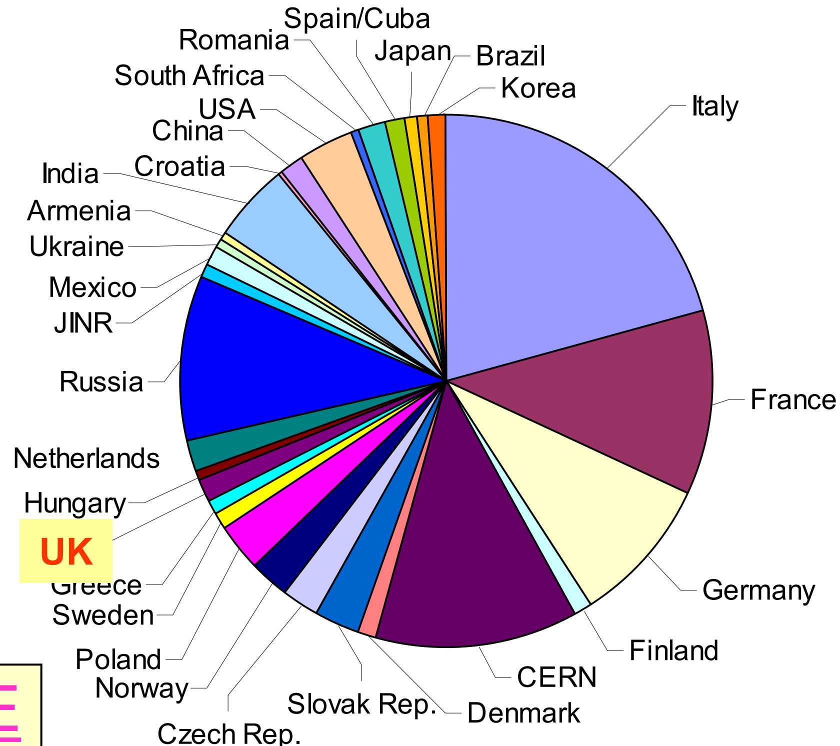
(63% from CERN MS)

~30 Countries

~100 Institutes

~150 MCHF capital cost

(+ inherited magnet)



A brief history of ALICE

1990-1996: Design

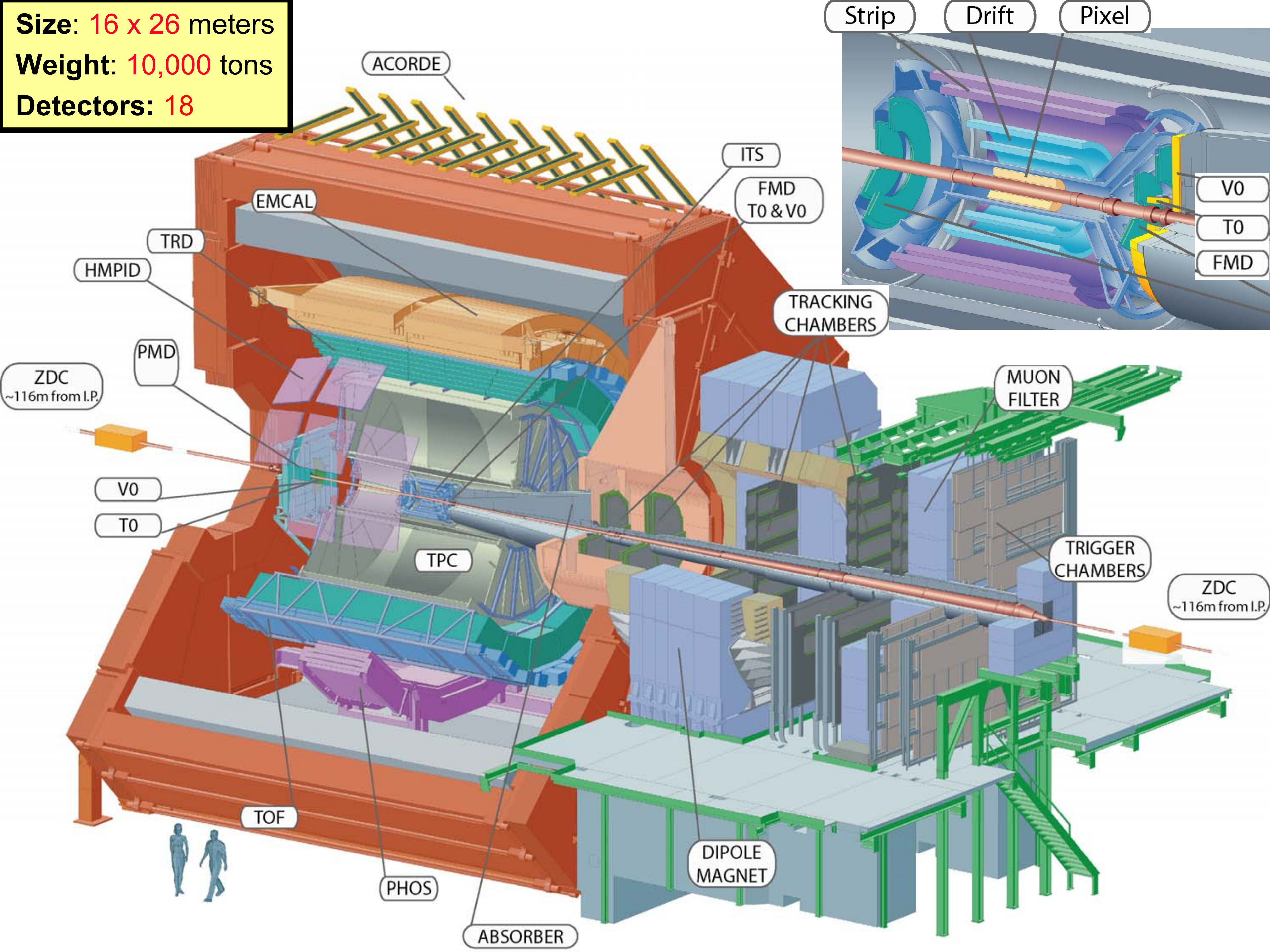
1992-2002: R&D

2000-2010: Construction

2002-2007: Installation

2008 -> : Commissioning

Size: 16 x 26 meters
Weight: 10,000 tons
Detectors: 18



ALICE R&D

1990-1998: Strong, well organized, well funded R&D activity

- Inner Tracking System (ITS)
  - Silicon Pixels (RD19)
  - Silicon Drift (INFN/SDI)
  - Silicon Strips (double sided)
  - low mass, high density interconnects
  - low mass support/cooling
- TPC
  - gas mixtures (RD32)
  - new r/o plane structures
  - advanced digital electronics
  - low mass field cage
- em calorimeter
  - new scint. crystals (RD18)
- PID
  - Pestov Spark counters
  - Parallel Plate Chambers
  - Multigap RPC's (LAA)
  - low cost PM's
  - CsI RICH (RD26)
- DAQ & Computing
  - scalable architectures with COTS
  - high perf. storage media
  - GRID computing
- misc
  - micro-channel plates
  - rad hard quartz fiber calo.
  - VLSI electronics

RHIC

RHIC

RHIC

RHIC

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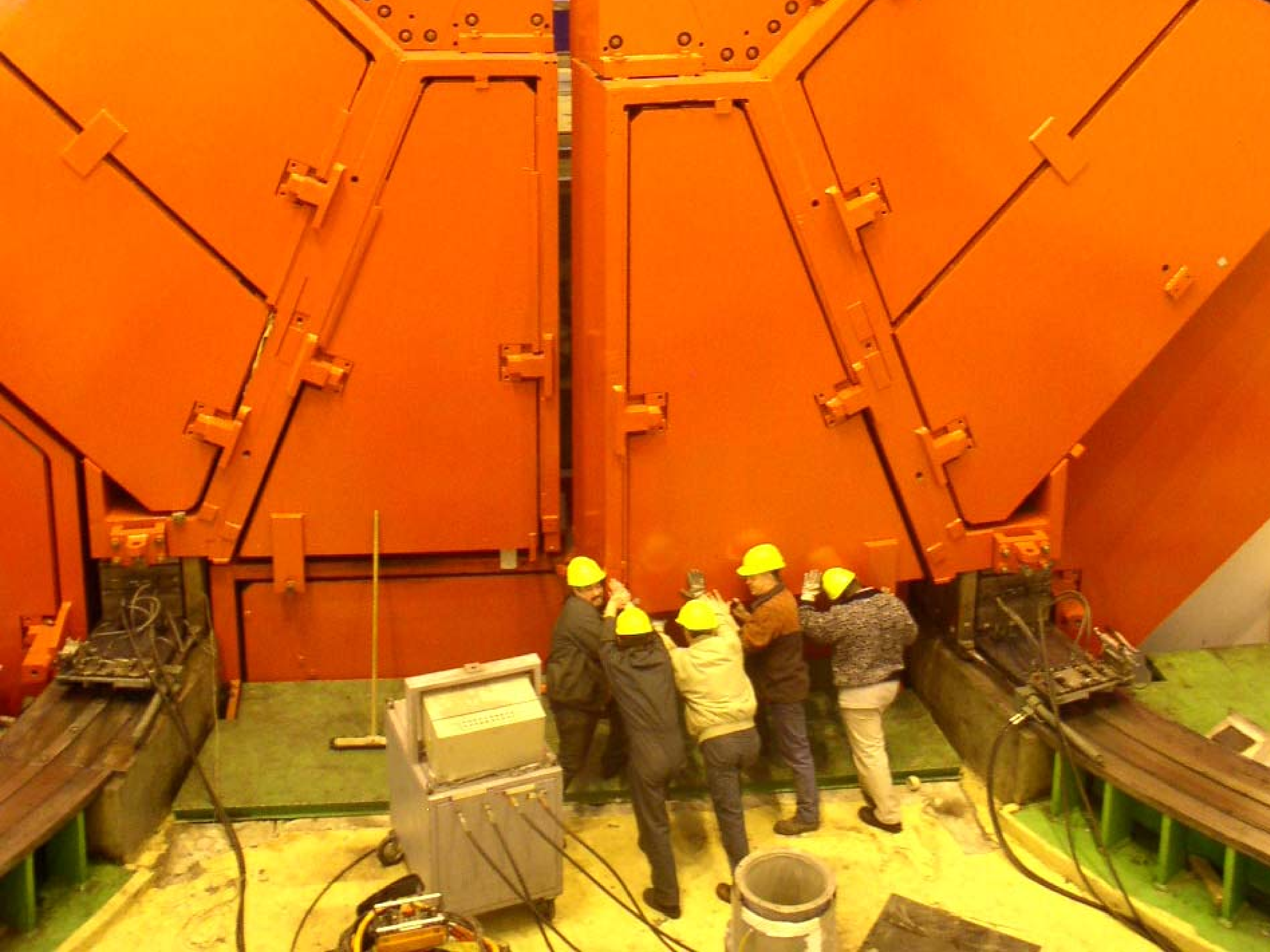
- **R&D made effective use of long (frustrating) wait for LHC**
- **was vital for all LHC experiments to meet LHC challenge !**


Installing rails (2003)

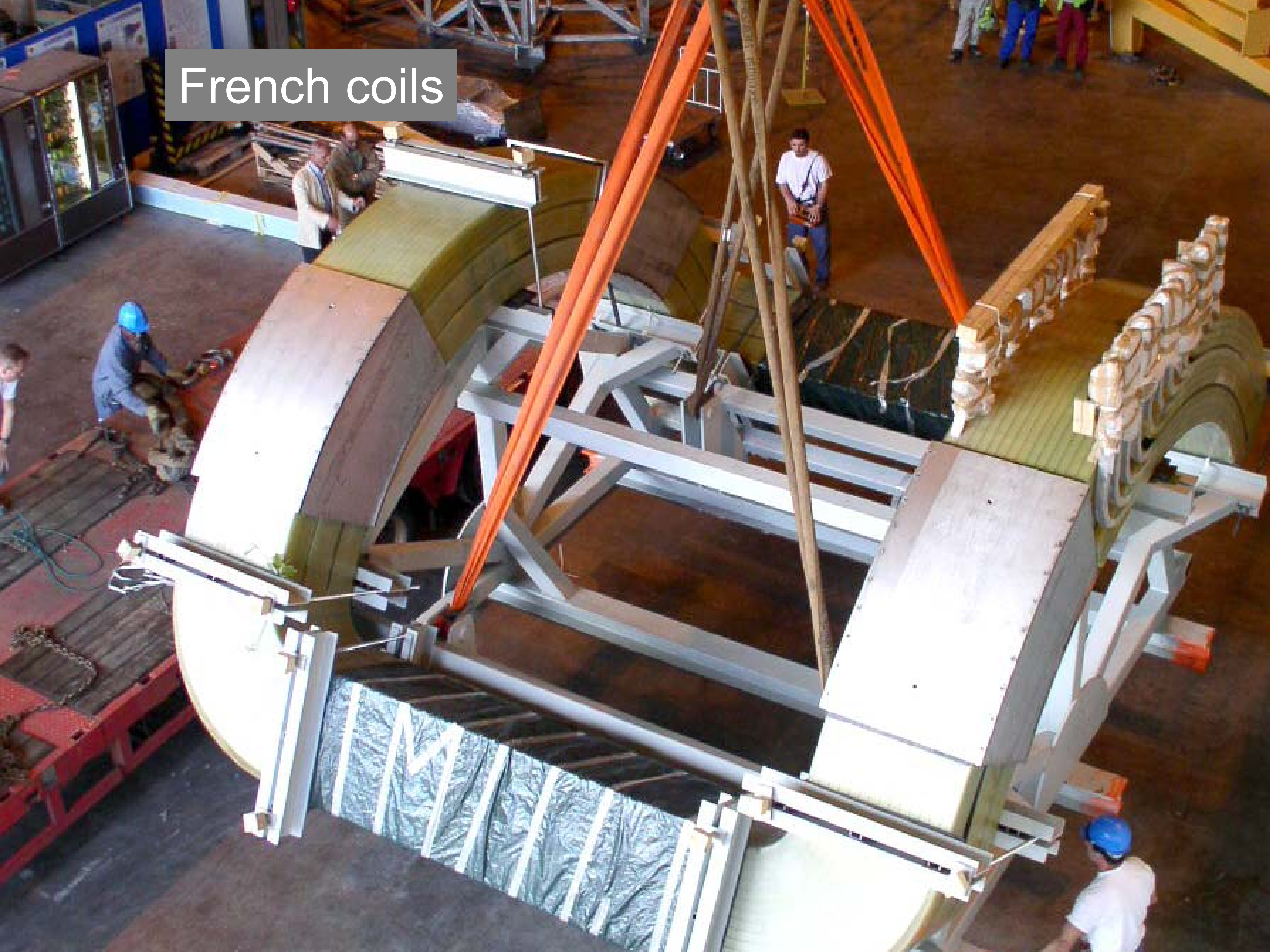


Dimuon Magnet Yoke (2002)

Winter in Russia

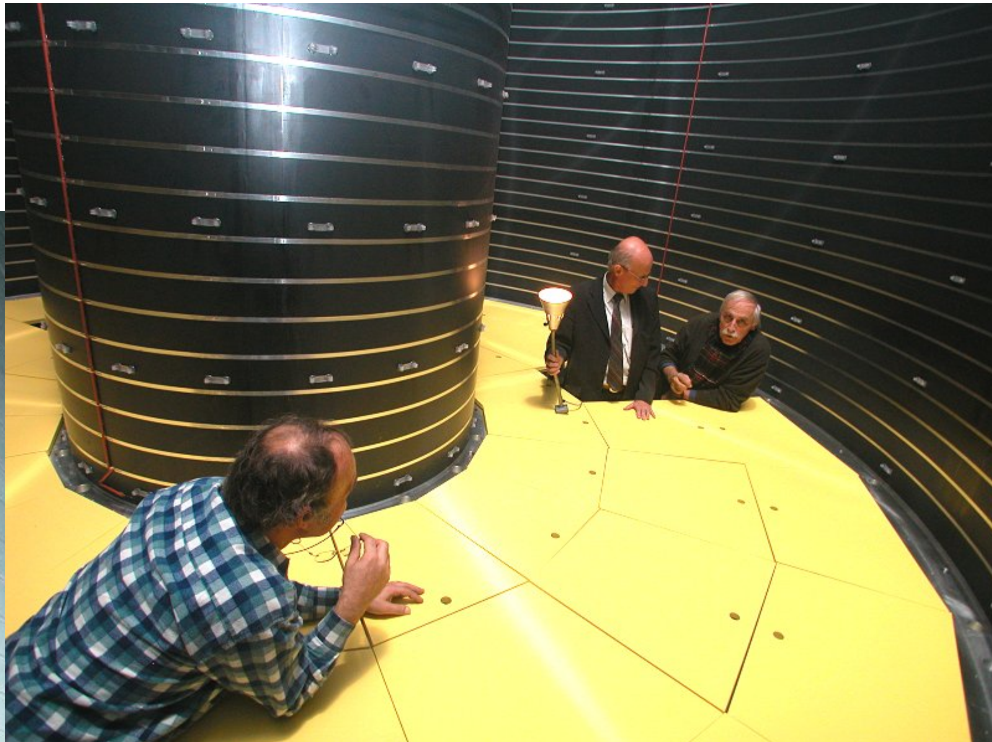
Rolling in

French coils

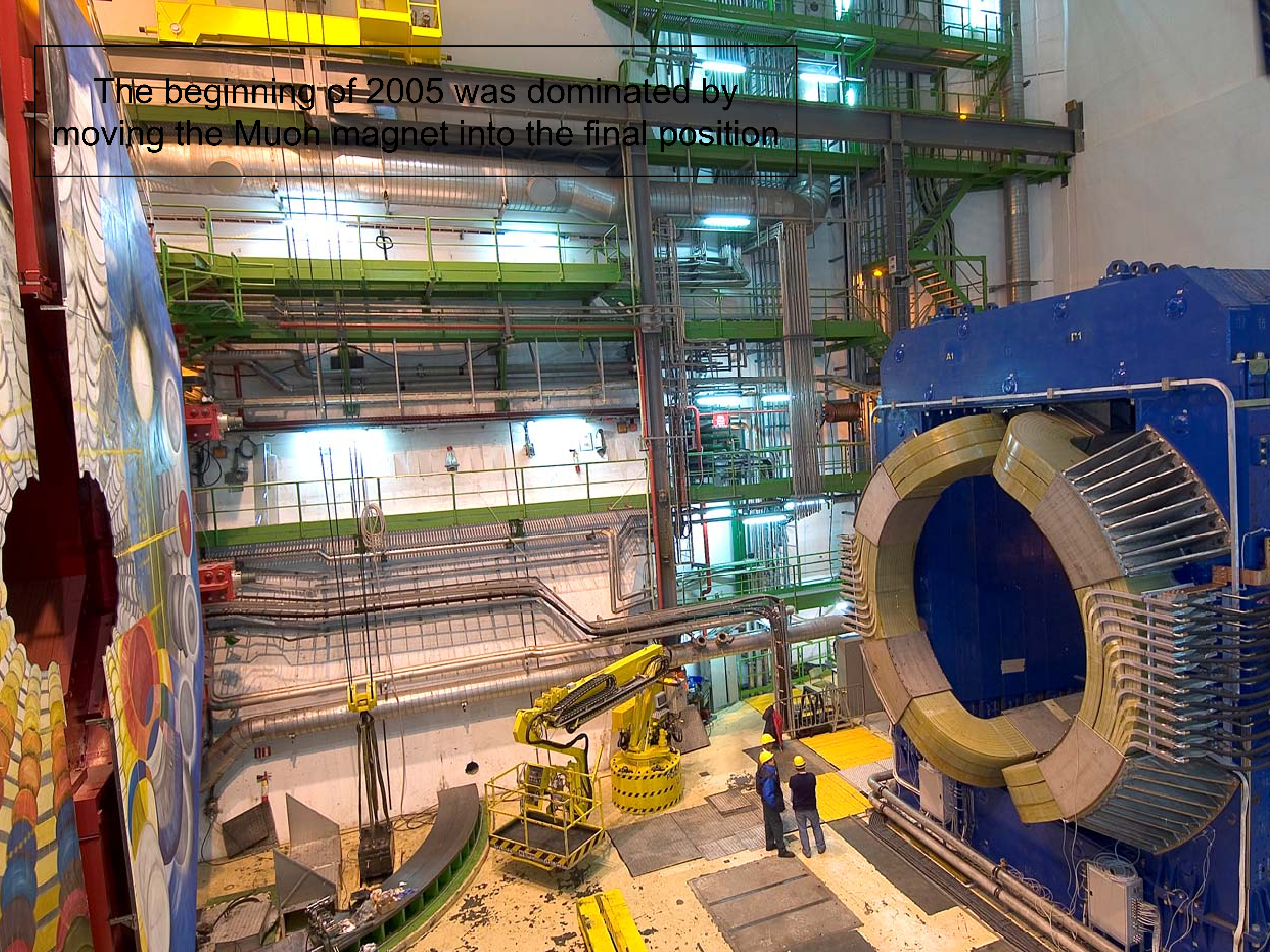


Yoke Assembly completed 19 Feb 2004

A last look at the TPC field cage …



The beginning of 2005 was dominated by moving the Muon magnet into the final position

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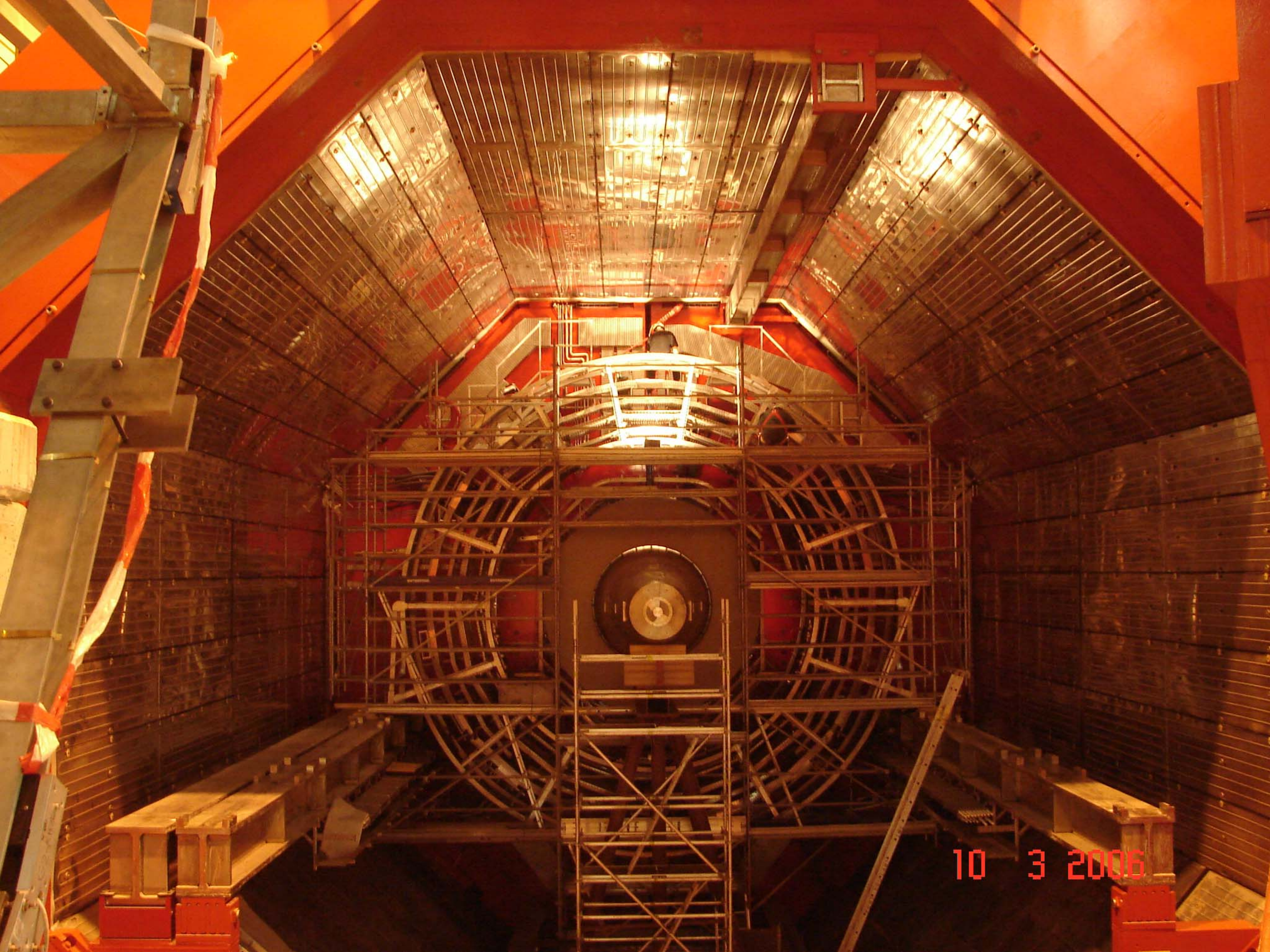
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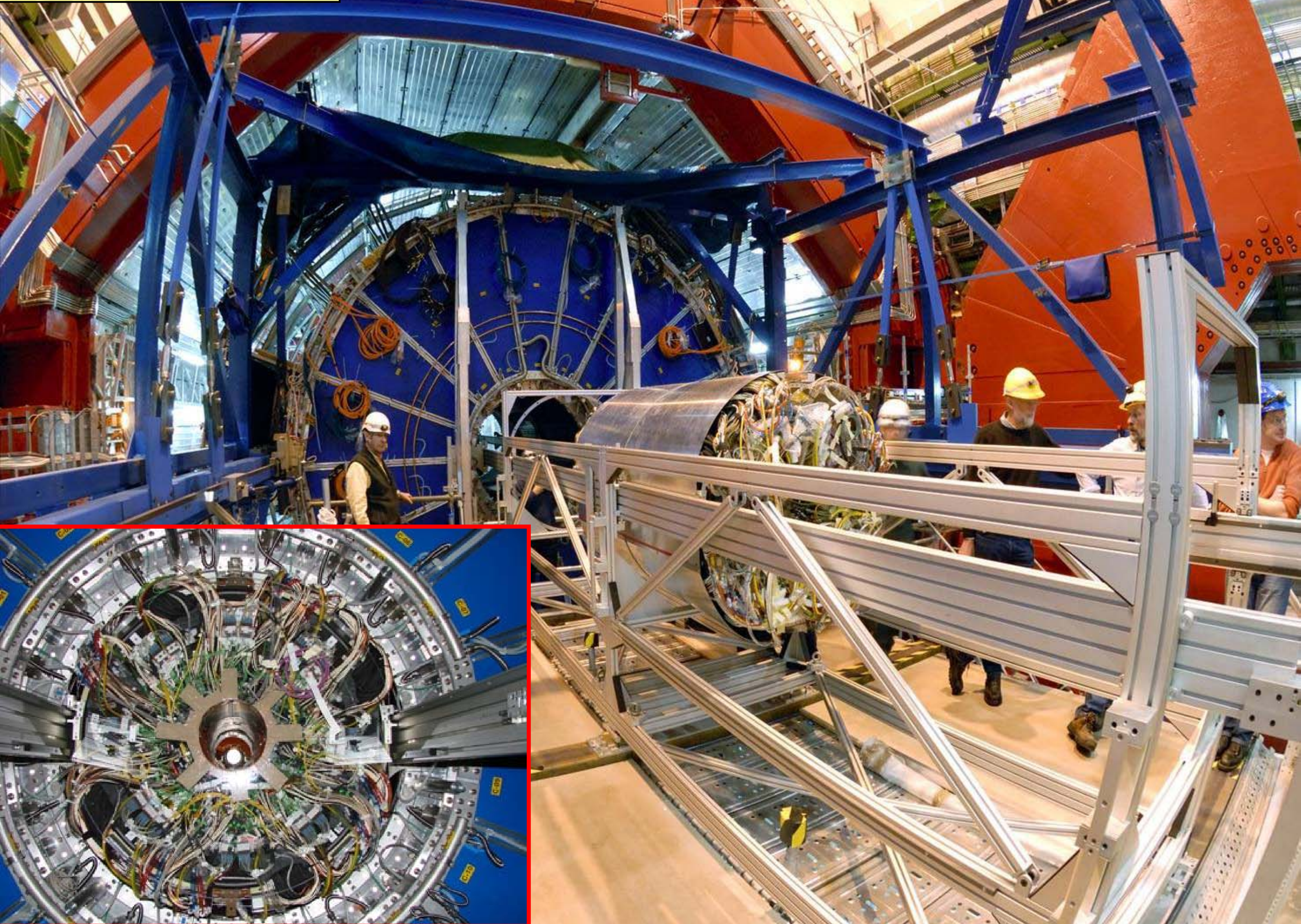
TPC Installation (January 2007)

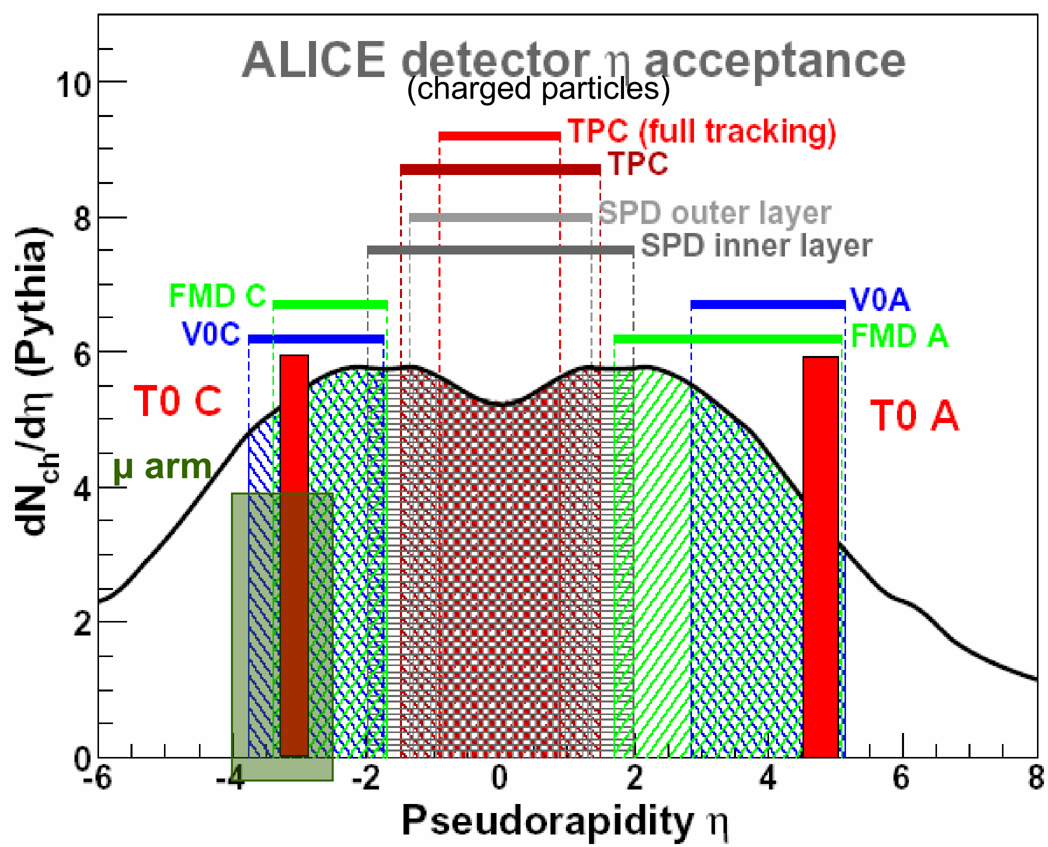
ITS Installation 15.3.07



Formal end of ALICE installation: July 2008

ALICE Acceptance

- central barrel -0.9 < η < 0.9
  - 2 π tracking, PID
  - single arm **RICH** (HMPID)
  - single arm **em. calo** (PHOS)
  - jet calorimeter (proposed)
- forward muon arm 2.4 < η < 4
  - absorber, 3 Tm dipole magnet
    10 tracking + 4 trigger chambers
- multiplicity -5.4 < η < 3
  - including photon counting in **PMD**
- trigger & timing dets
  - **T0:** ring of quartz window PMT's
  - **V0:** ring of scint. Paddles



Particle Identification in ALICE

- ‘stable’ hadrons (π, K, p): 100 MeV/c < p < 5 GeV/c; (π and p with ~ 80 % purity to ~ 60 GeV/c)
  - dE/dx in silicon (ITS) and gas (TPC) + time-of-flight (TOF) + Cherenkov (RICH)
- decay topologies (K^0, K^+, K^-, Λ, D)
  - K and L decays beyond 10 GeV/c
- leptons (e,μ), photons, π^0
  - electrons TRD: p > 1 GeV/c, muons: p > 5 GeV/c, π^0 in PHOS: 1 < p < 80 GeV/c

- excellent particle ID up to ~ 50 to 60 GeV/c

Inner Tracking System ITS

- Three different Silicon detector technologies; two layers each
  - Pixels (SPD), Drift (SDD), Strips (SSD)

Detector	Acceptance (η, ϕ)	Position (m)	Dimension (m^2)	N. of channels
ITS				
SPD	$\pm 2, \pm 1.4$	0.039, 0.076	0.21	9.8 M
SDD	± 0.9	0.150, 0.239	0.42, 0.89	133 000
SSD	$\pm 0.97, \pm 0.97$	0.38, 0.43	5.0	2.6 M

Status: installed; being commissioned

- $\Delta(r\varphi)$ resolution: 12 (SPD), 38 (SDD), 20 (SSD) µm
- Total material traversed at perpendicular incidence: 7 % X_0

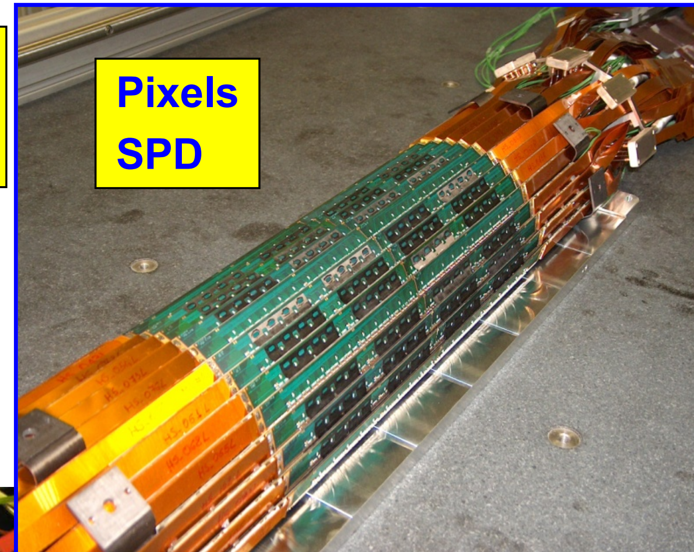
34

Inner Silicon Tracker

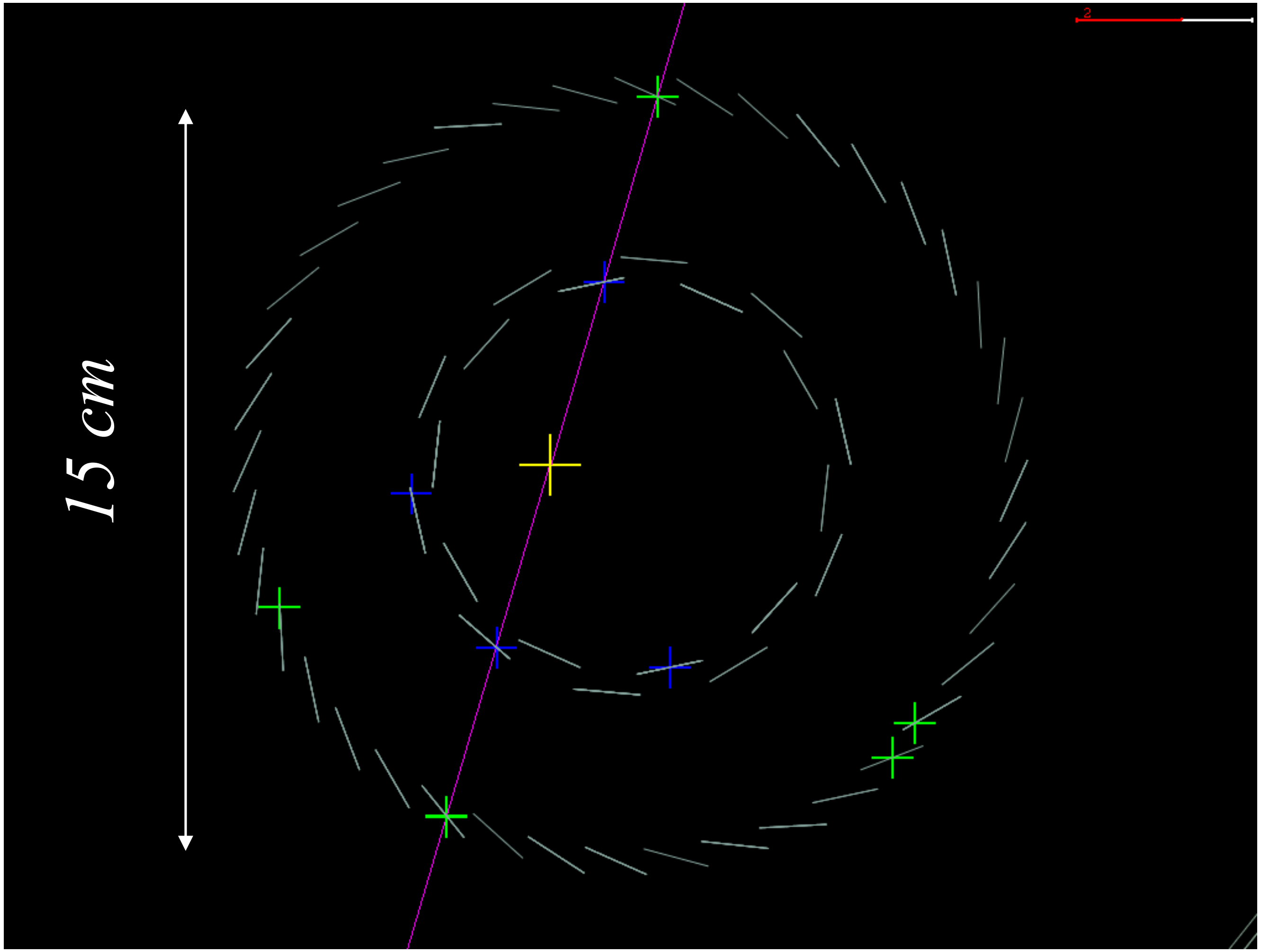
Inner Tracking System

~ 10 m^2 Si detectors, 6 layers

Pixels, Drift, double sided Strips

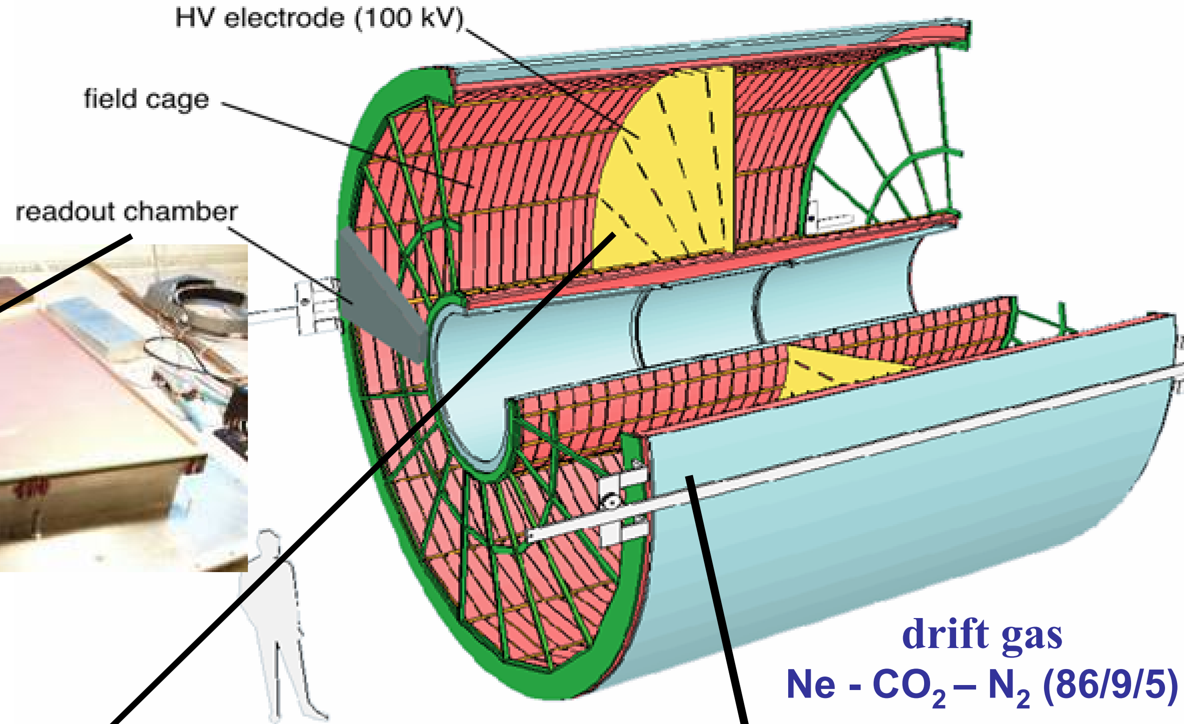


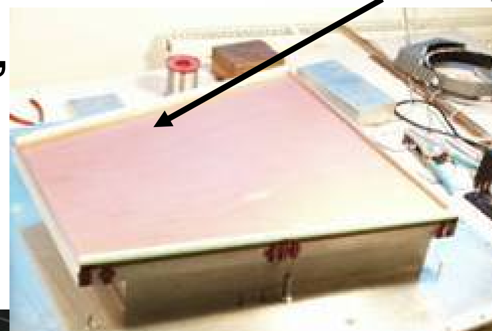
1st muon in SPD: Feb 17, 2008



TPC

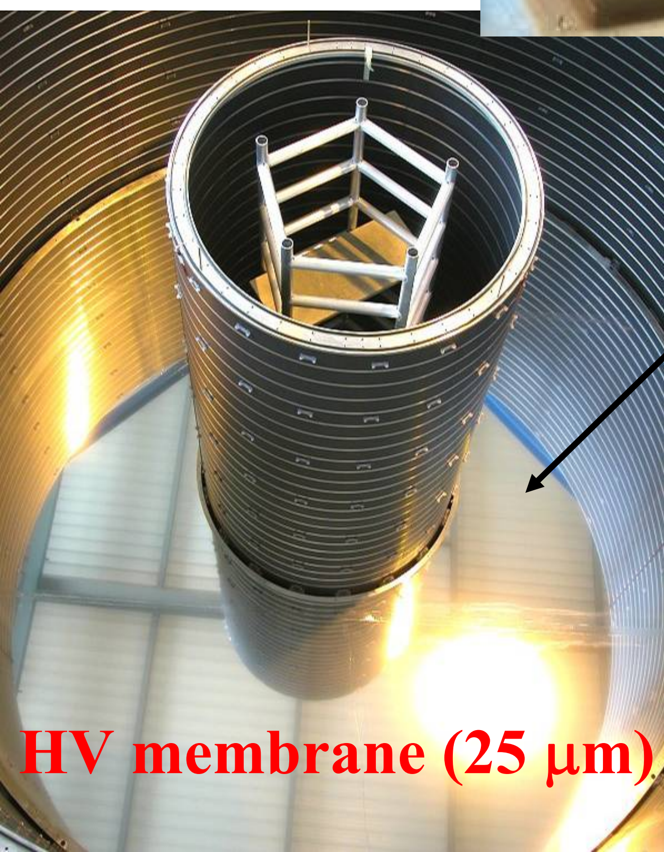
- largest ever: 88m^3, l=5m, d=5.6m 570 k channels

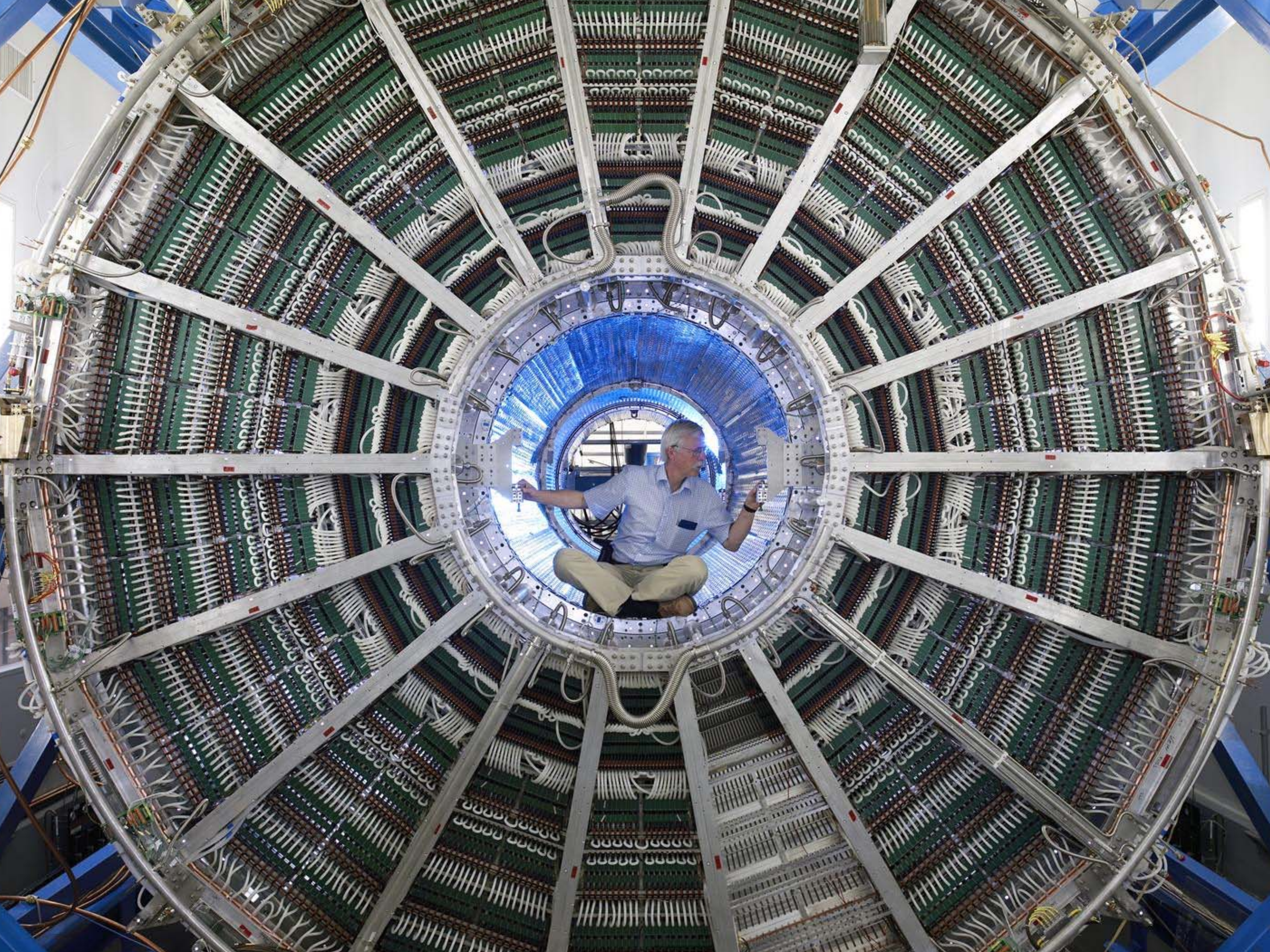




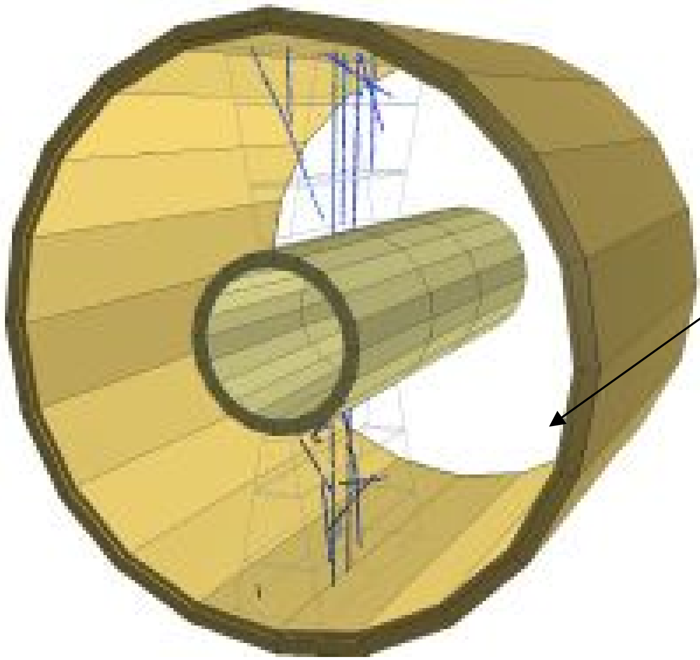
drift gas

Ne - CO_2 – N_2 (86/9/5)



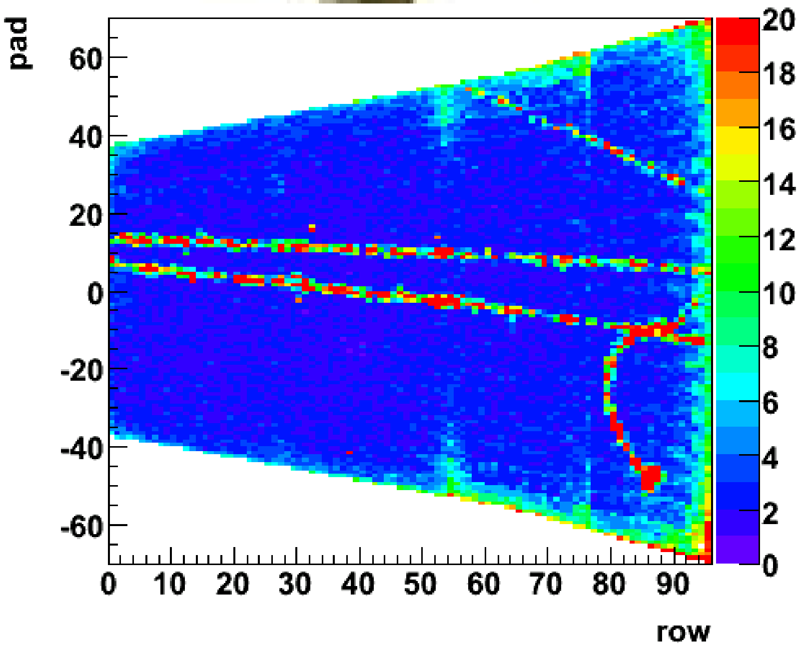


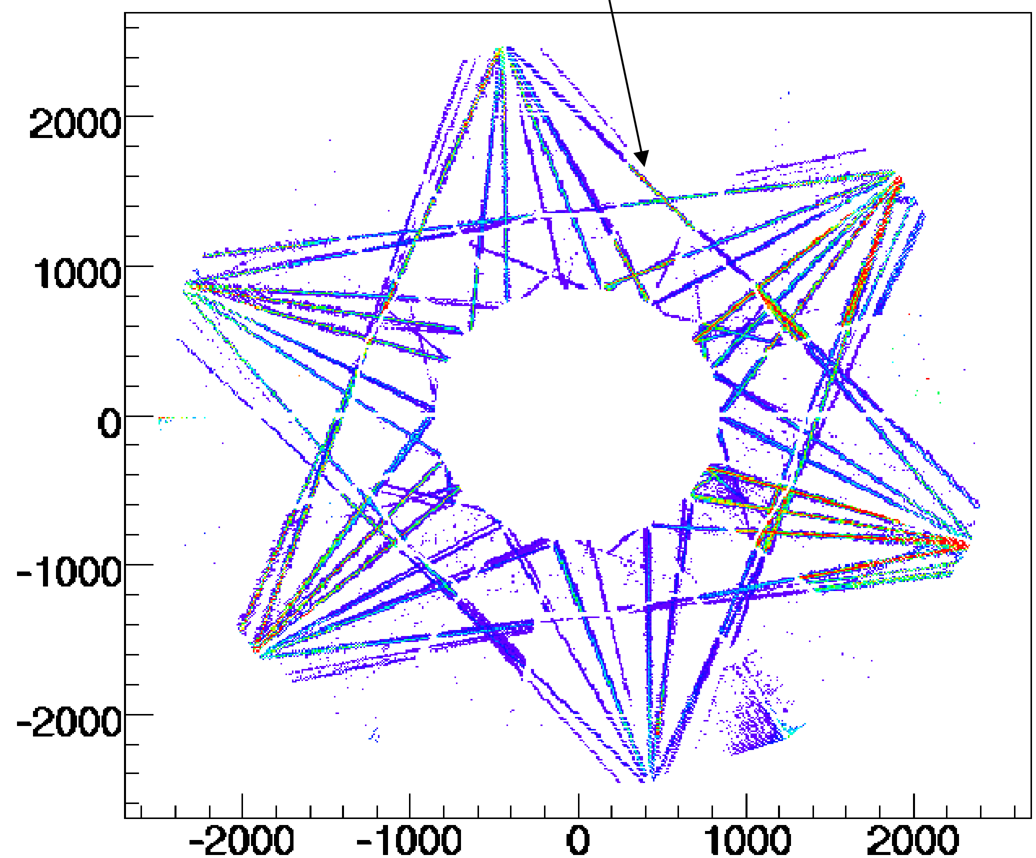
First TPC Tracks



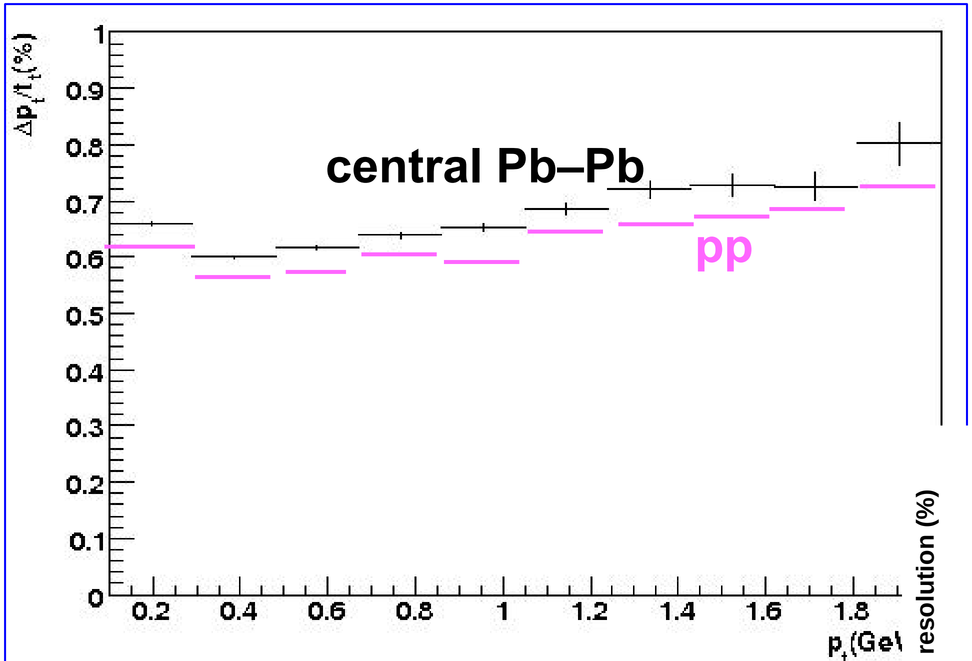
16 May 2006

First cosmic and laser tracks !



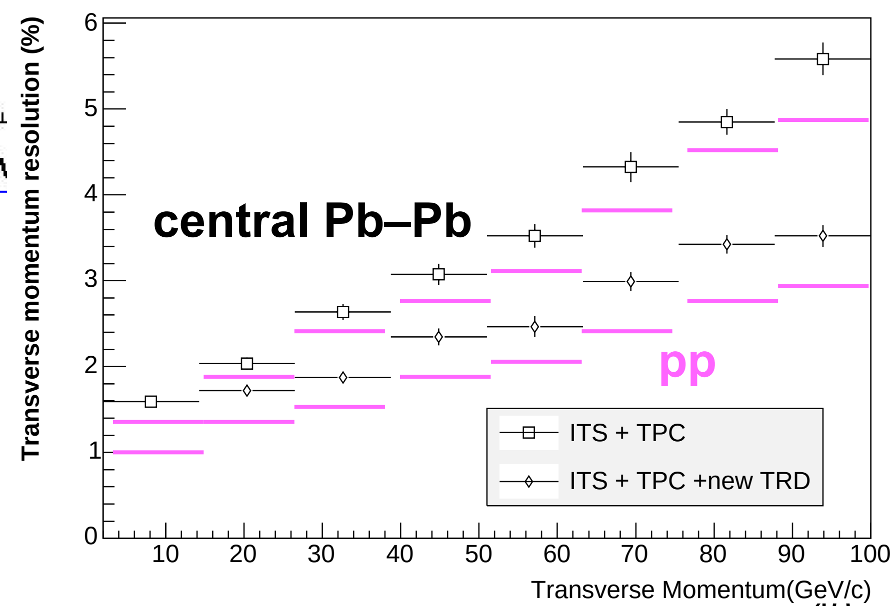


Momentum resolution



at low momentum dominated by

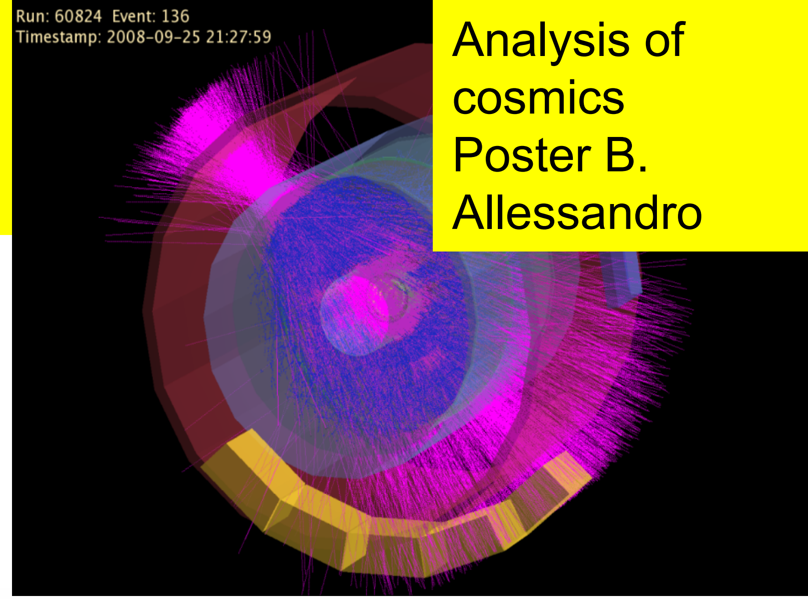
- ionization-loss fluctuations
- multiple scattering



at high momentum determined by

- point measurement precision
- and the alignment & calibration
(*which is here assumed ideal*)

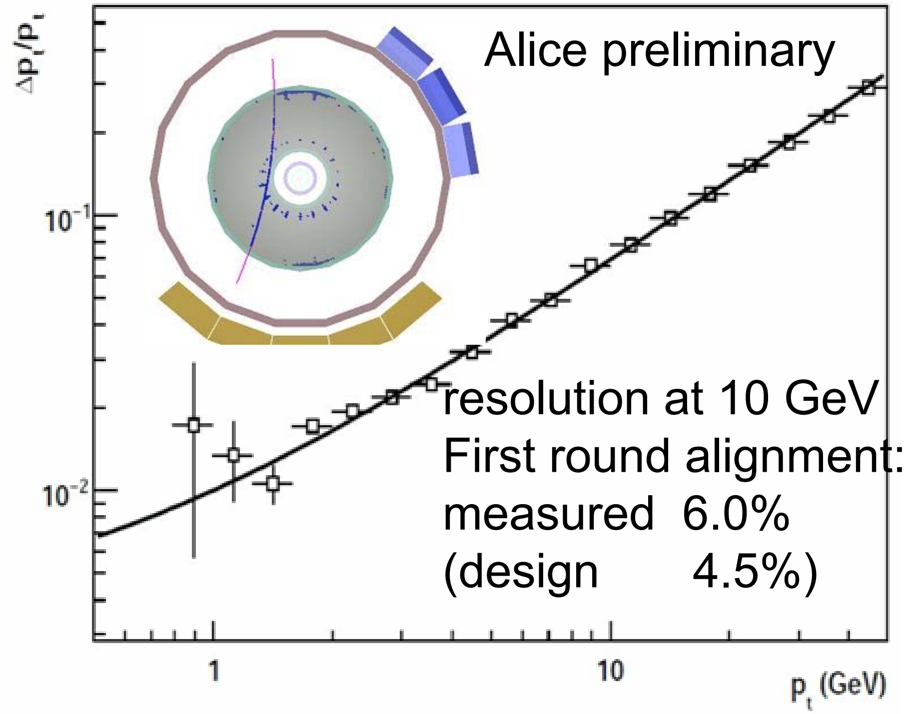
TPC Calibration QM09: (J.Wiechula)



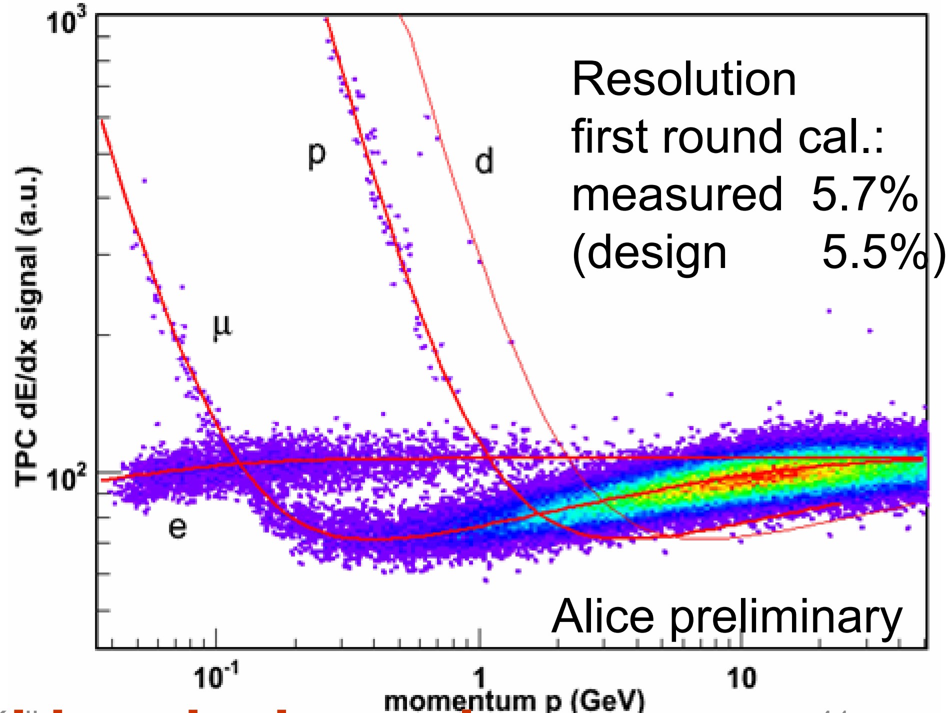
Analysis of cosmics Poster B. Allessandro

- TPC running continuously May-October 2008.
- 60 M events (Cosmic, krypton, laser) recorded.
- Initial calibration, ExB and alignment

transverse momentum resolution, B=0.5 T



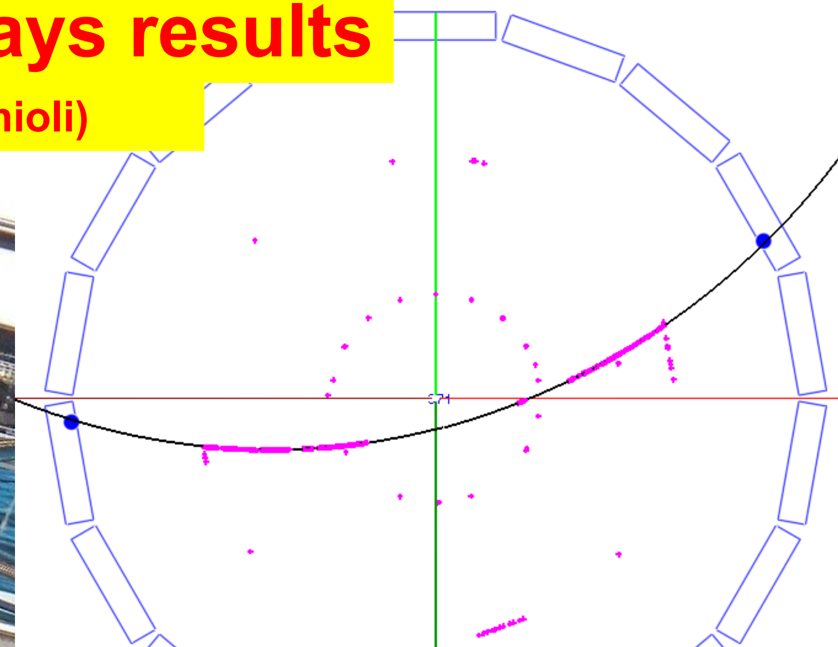
particle identification via dE/dx



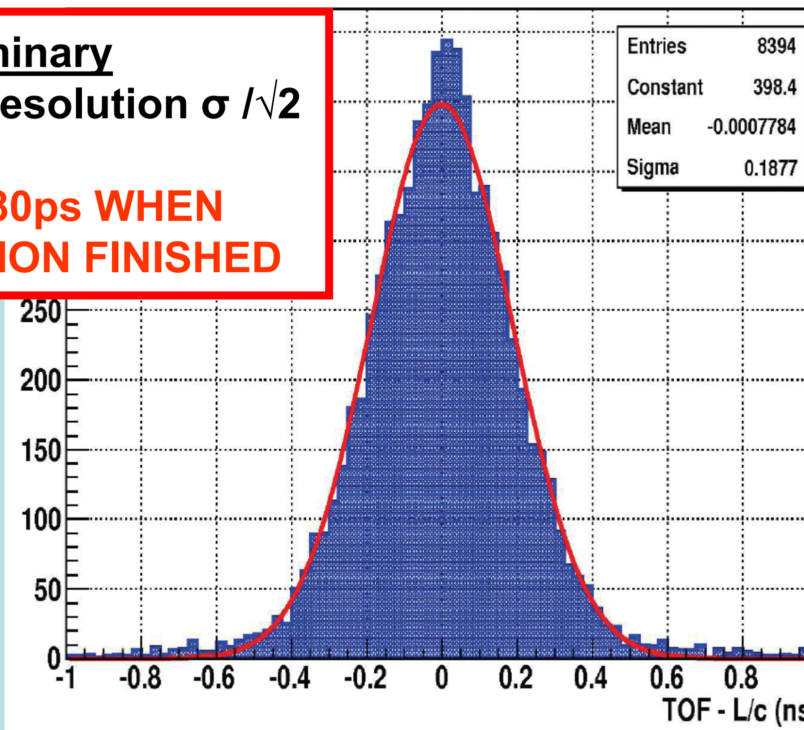
performance already approaching design value

TOF cosmic rays results

(QM09 P. Antonioli)



Very preliminary
Single hit resolution σ /√2 = 130 ps
EXPECT <80ps WHEN CALIBRATION FINISHED



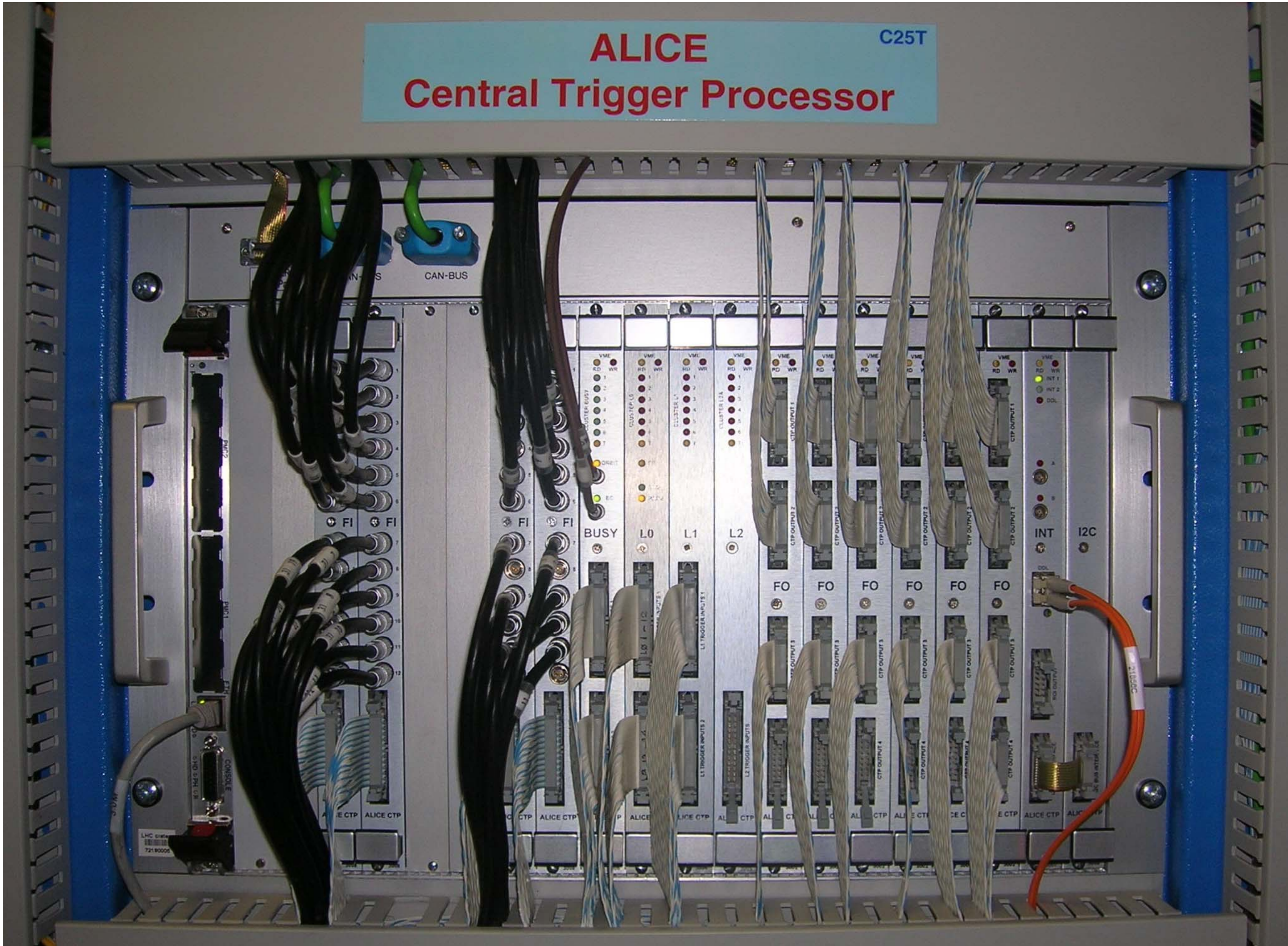
- **Detector fully installed**
- **Noise rate : 1.6 Hz/ch (< expectations)**
- **Trigger capability fully operational**
- **Commissioning underway**
- **Calibrations with cosmics very promising despite low statistics**

ALICE Central Trigger Processor

ALICE CTP features:

- 3 Levels (L0,L1,L2 ~ 1μs, 6μ, 88μs)
- Partitioning of detectors into independent groups – e.g. muon arm and central barrel
- Pile up (past-future) protection – tens of interactions in TPC drift time

- **Birmingham responsibility:**
  - hardware
  - software
  - operation
  - 1st physics analysis: trigger correction, high multiplicity,…


ALICE
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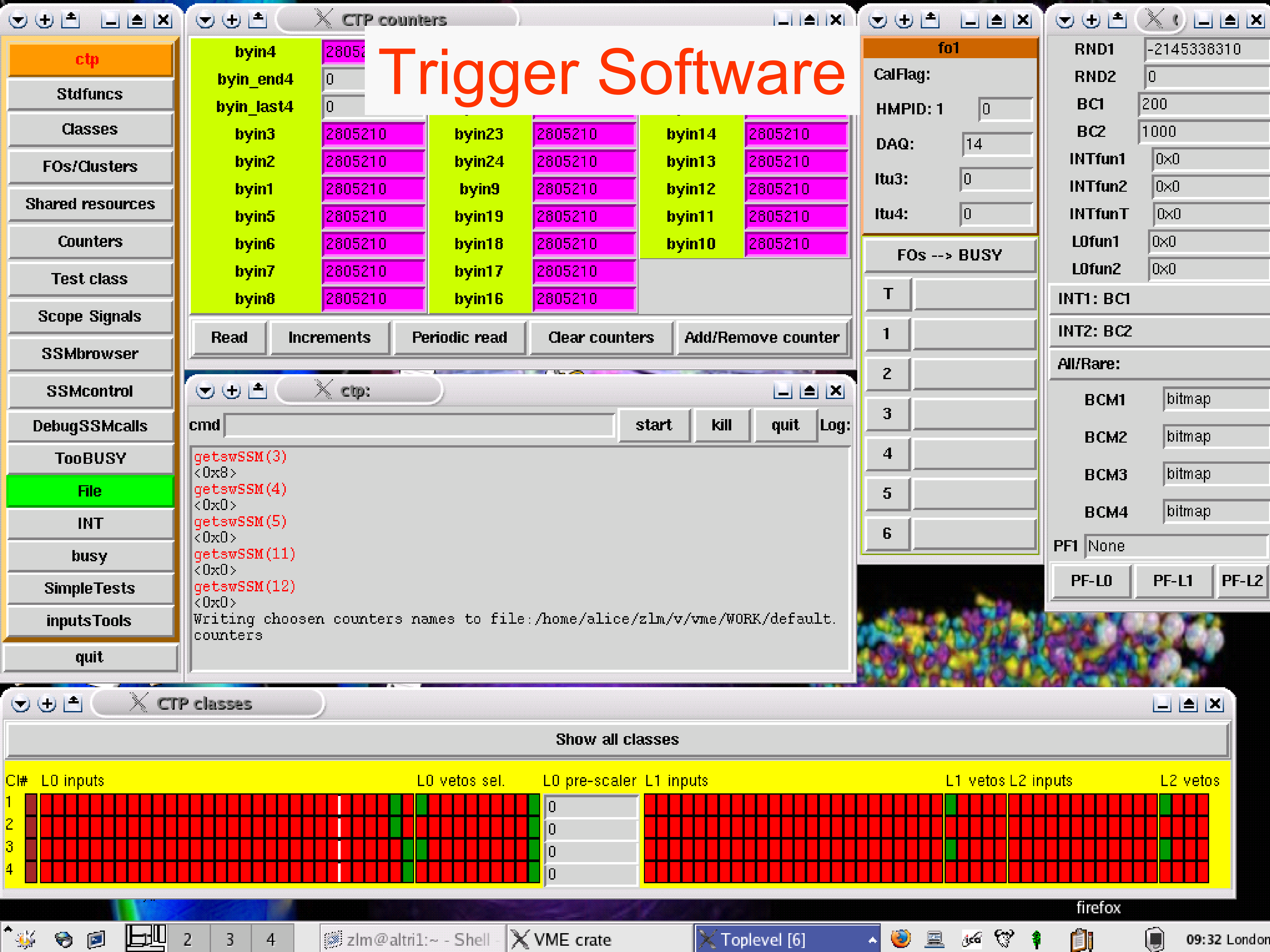
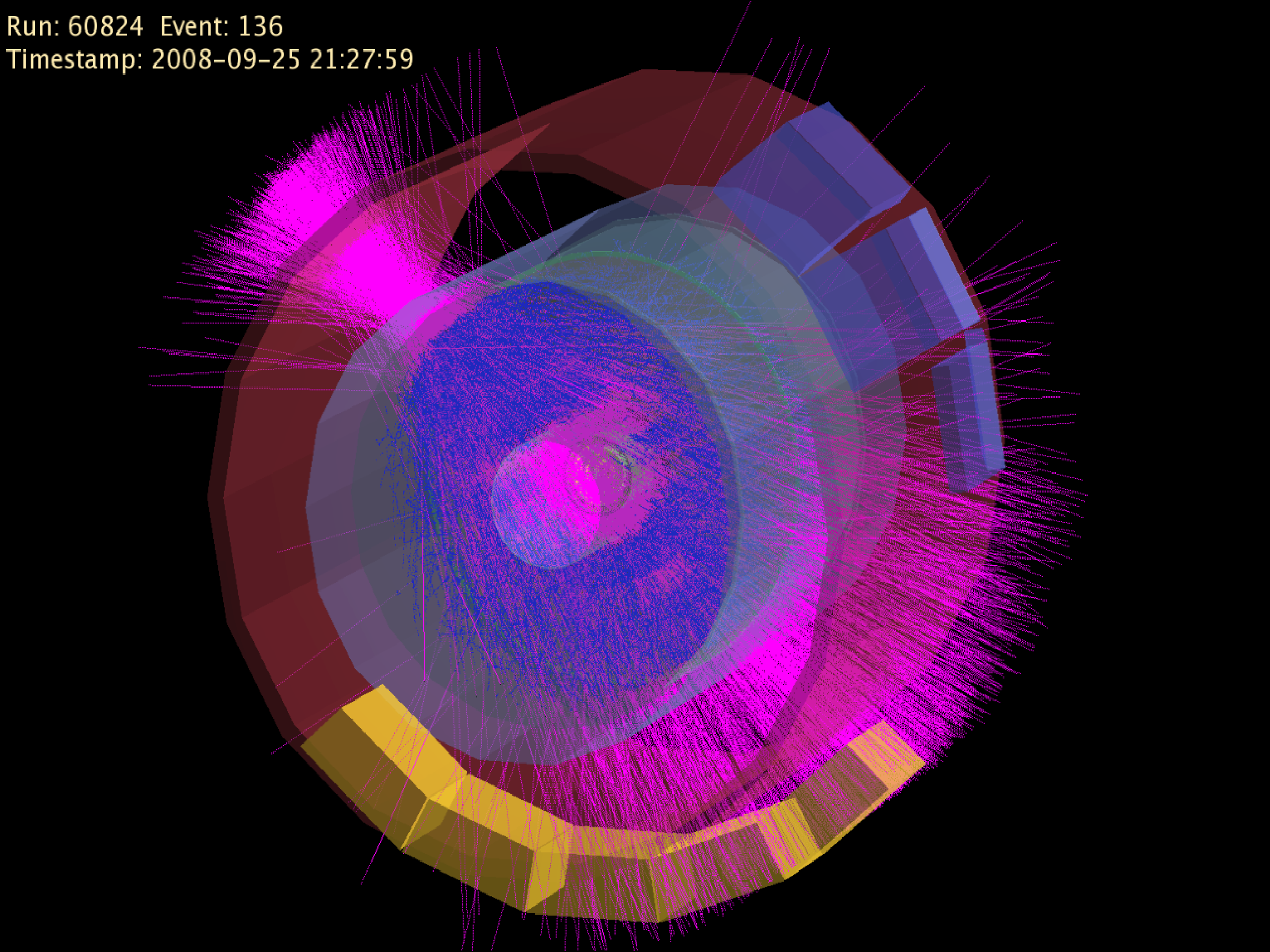
ALICE CTP
ALICE CTP

Trigger Software

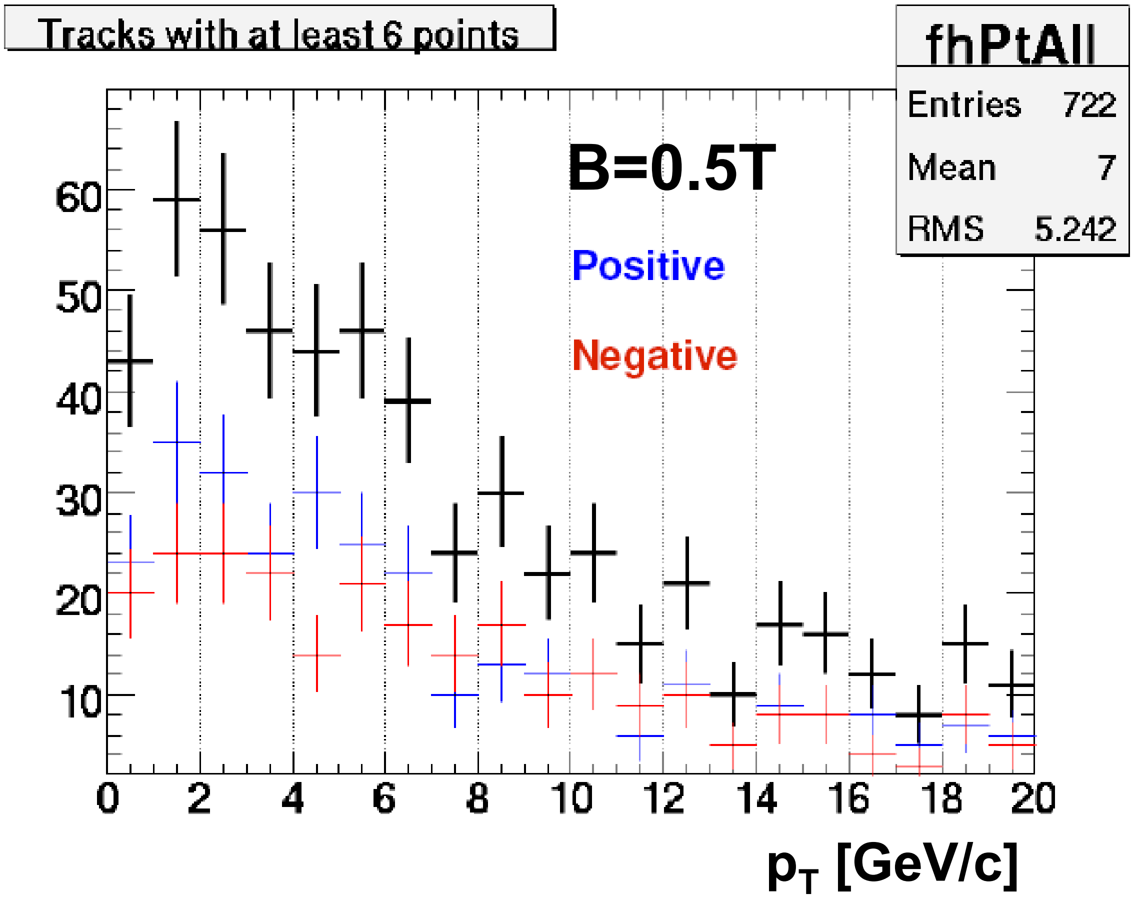


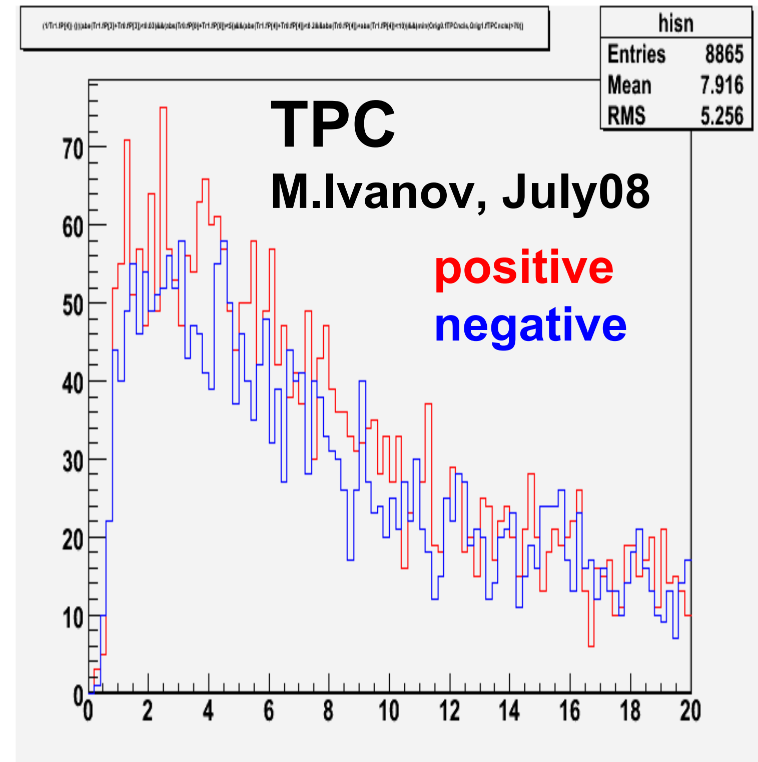
Data Taking & Commissioning 2008

- **Comissioning runs (24/7)**
  - Cosmics I (2 weeks, Dec 2007)
    - local (individual detectors) and start of global (several detectors) commissioning
  - Cosmics II (3 weeks, Febr/Mar 2008)
    - local/global commissioning, first few days of alignment 'test' run, magnet commissioning
  - Cosmics III (since May 2008 continuous operation 24/7)
    - global commissioning, calibration & alignment production runs
- **Injection tests**
  - TI2 dump in June , injection tests August, first circulating beam September
  - observed very high particle fluxes during dumps and even during injection through ALICE
    - 10's to 1000's of particles/cm^2 with beam screens in LHC and/or TI2
    - decided to switch off all sensitive detectors during injection
      - SPD, V0 always on (trigger),
      - SSD, SDD, FMD, T0 occasionally
      - (beam was useful only for a small subset of detectors !)


Run: 60824 Event: 136
Timestamp: 2008-09-25 21:27:59

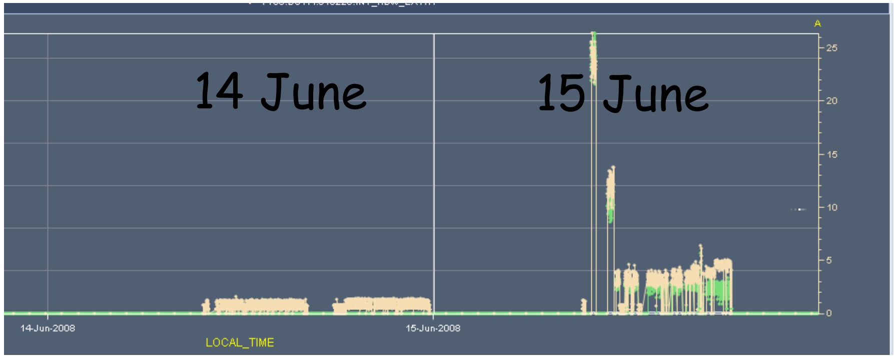
Cosmic p_T-spectra and charge





C.Bombonati

Extraction tests: 14-15 June



Federico Antinori, SQM2008

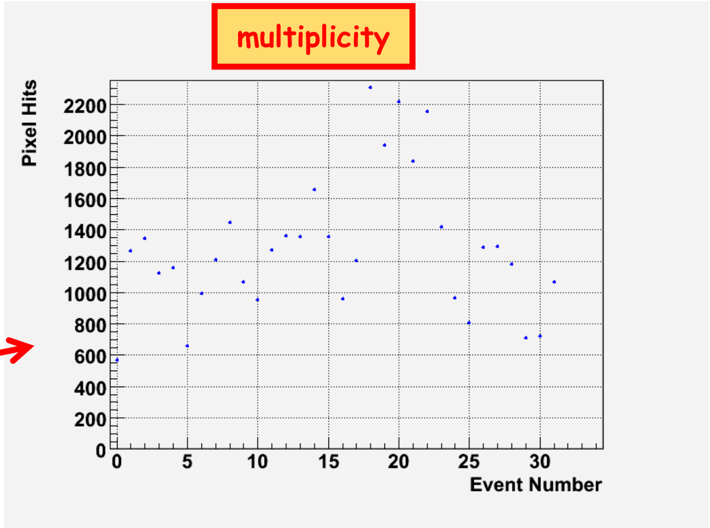
- beam extracted from the SPS and dumped in the transfer line →
- muons make it all the way to ALICE

ALICE Pixels

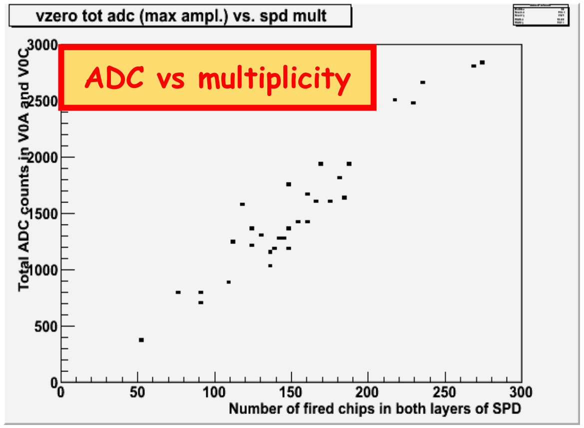
First injection in the LHC!

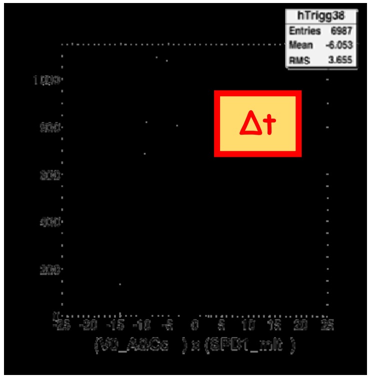
- 8 August 2008
- ALICE SPD (pixel) and V0 (scintillator) switched on during first phase (upstream dump)
  - pilot bunches: ~ 5 10^9 protons
- Trigger: ≥ 10 hits on layer 2
- 32 events triggered
  - Run 51403 (16:53 to 18:05)

- SPD



- V0 vs SPD





naturenews

Published online 25 August 2008 | Nature | doi:10.1038/news.2008.1061

News

Double first for Large Hadron Collider

Counter-clockwise beam test produces historic particle collisions.

Matthew Chalmers

Champagne corks popped at the Large Hadron Collider (LHC) this weekend after one of the facility's four giant particle detectors tasted its first authentic data. Crammed into a stuffy control room on the afternoon of Friday 22 August, physicists tracked the debris produced by protons that had struck a block of concrete during a test of the €3 billion (£2.1 billion) collider's beam-injection system.

Some 15 years in construction, the LHC is based at the European particle facility CERN near Geneva, Switzerland, and is due to fully switch on its proton beams on 10 September. But the LHC's particle detectors have been recording hits from cosmic rays for several months — and Friday's test now marks the first time particle tracks have been reconstructed from a man-made event generated by the collider. "It's amazing to have seen the first LHC tracks," Themis Bowcock of University of Liverpool, UK, who led the team, told *Nature*. "It's quite overwhelming actually."

Joy in the LHCb control room as the proton smashing commences.

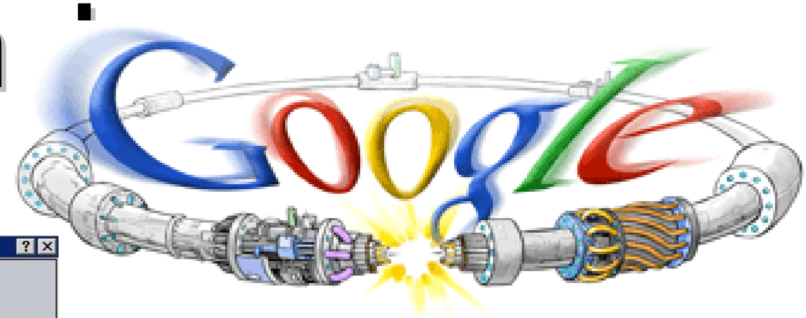
Matthew Chalmers

The first useful physics data is expected to come in October, when the two counter-rotating beams of protons racing through the LHC's 27-kilometre-long tunnels are made to collide, packing sufficient energy into a small enough space to produce fundamental particles from thin air. Full high-energy collisions at a combined energy of 14 trillion electron volts will begin next spring, exceeding the energies accessible to the current world record holder — the Tevatron at Fermilab in Batavia, Illinois — by a factor of seven. The LHC's high-energy collisions will allow physicists to search for new particles such as the fabled Higgs boson, which is thought to be responsible for conferring the property of mass on other particles.

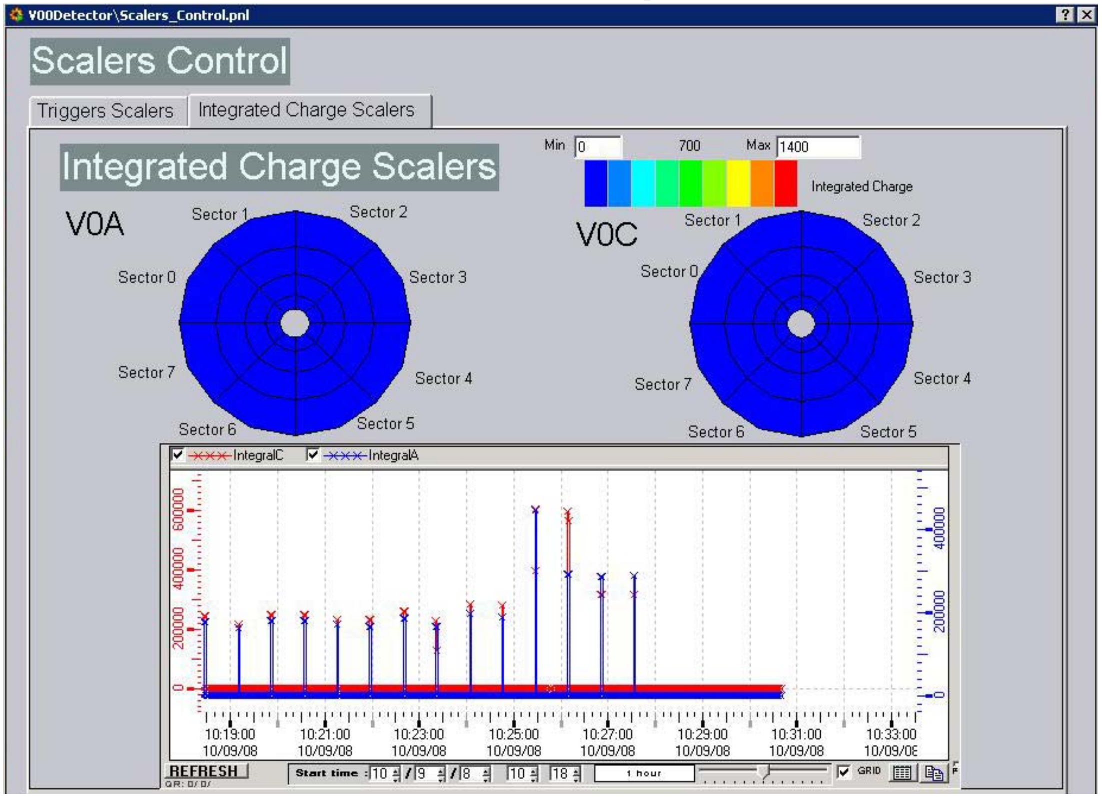
Opportunity collides

The purpose of this weekend's injection test was to make sure protons are magnetically kicked out of the smaller Super Proton Synchrotron (SPS) — the last link in a chain of other CERN accelerators that whip protons up to faster speeds — at the precise moment the LHC is ready to accept them. For this transfer process to happen smoothly, magnetic pulses in the accelerator chain must be synchronized to within a fraction of a microsecond.

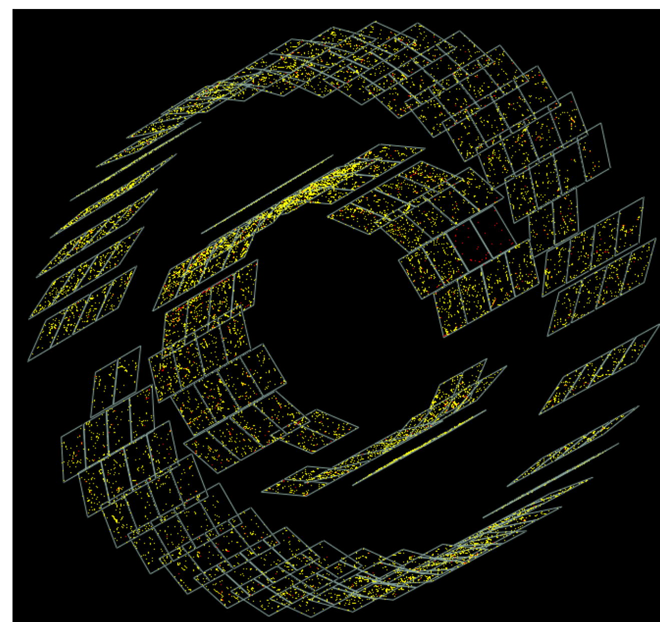
10 September: circulating beam



- beam 1: 1st complete orbit ~

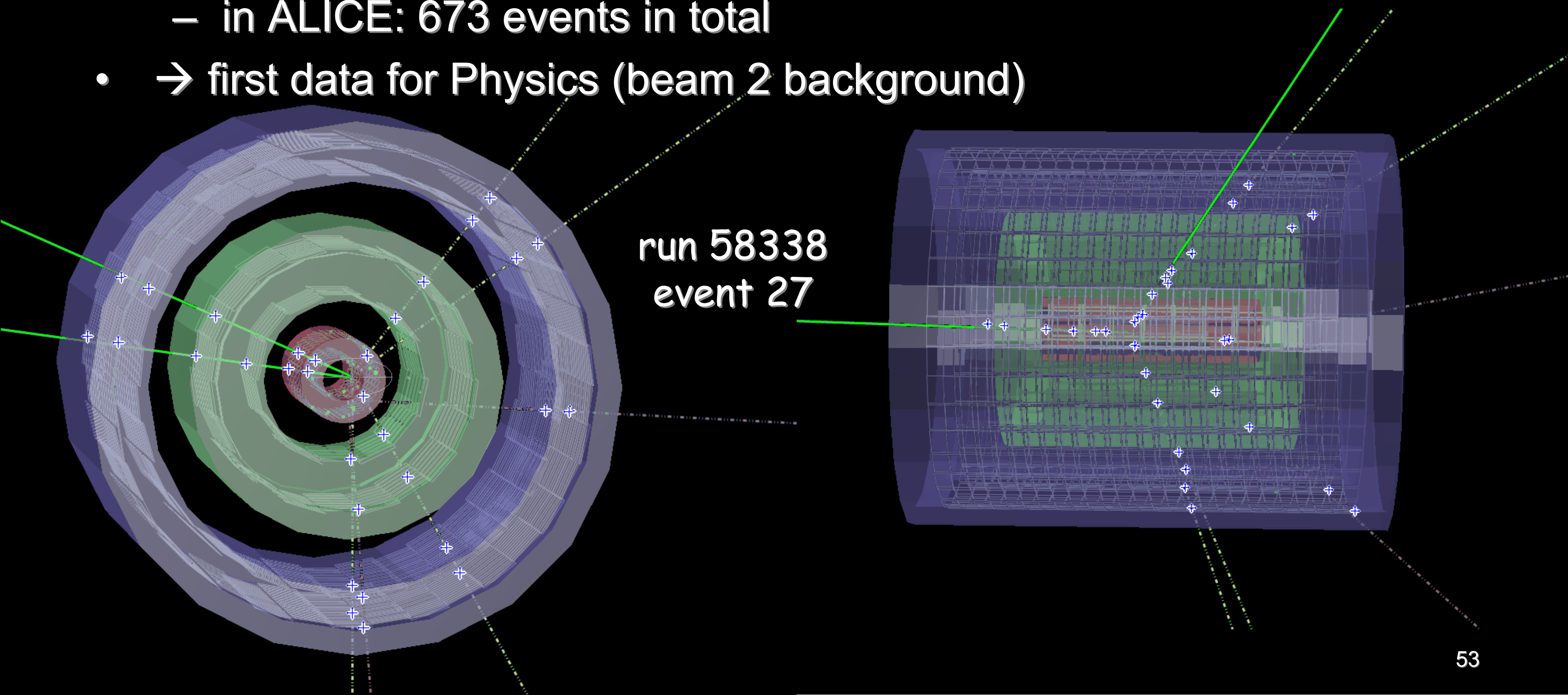


- *first signals from ALICE*

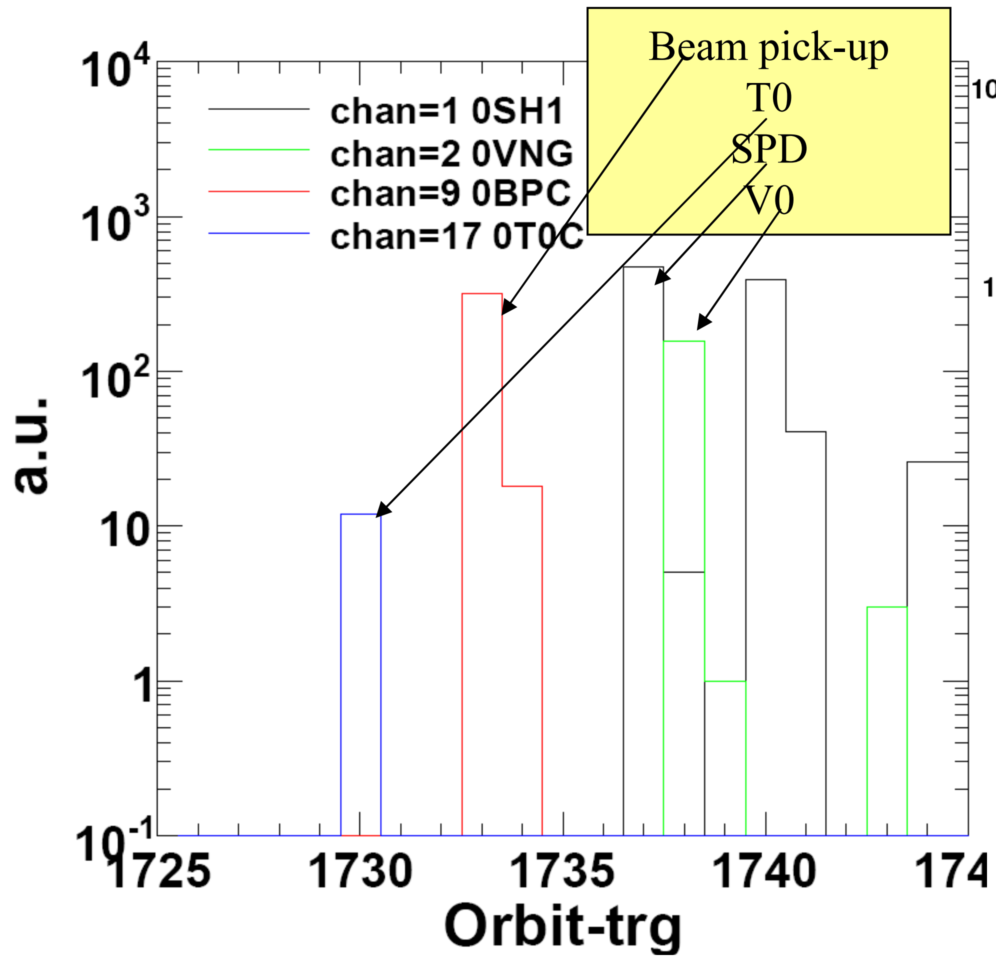


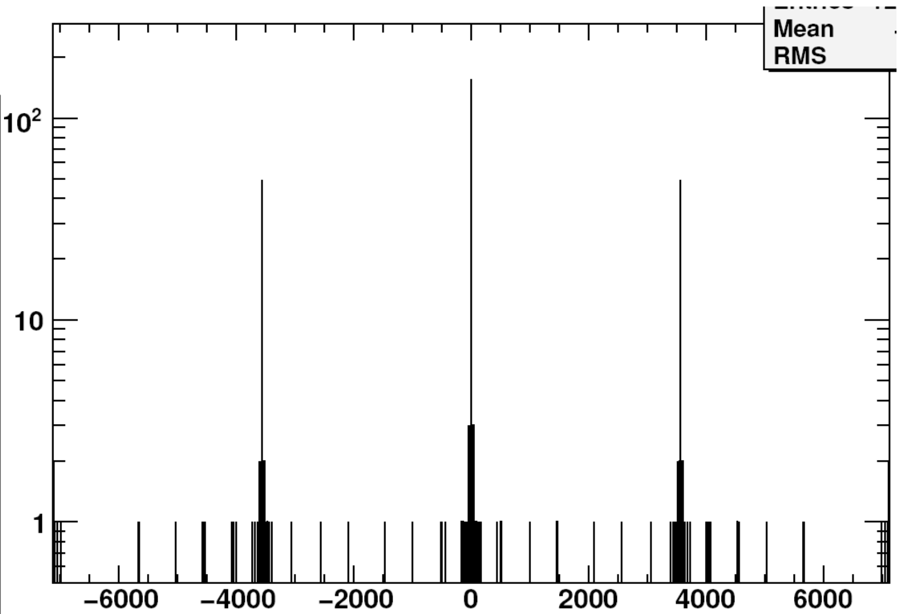
11 September: RF capture (Physics data!)

- 11 September, ~ 22:35 first capture
  - beam 2 kept in orbit for over 10 minutes!
- series of injections with tens of mins RF capture during night
  - in ALICE: 673 events in total
- → first data for Physics (beam 2 background)



CTP - September 2008



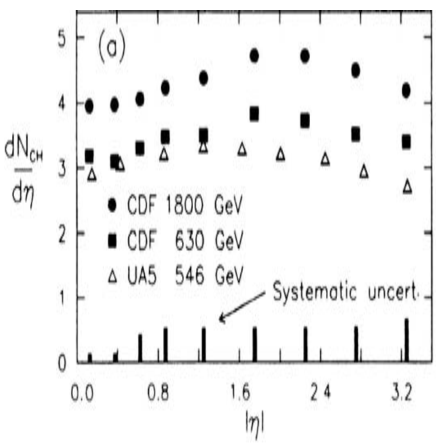


Auto-correlation for SPD trigger,
with multi-turn correlations
(3564 bunch crossings)

Trigger timing (before alignment) versus bunch number
single shot
for SPD, V0, beam-pickup BPTX, T0 triggers

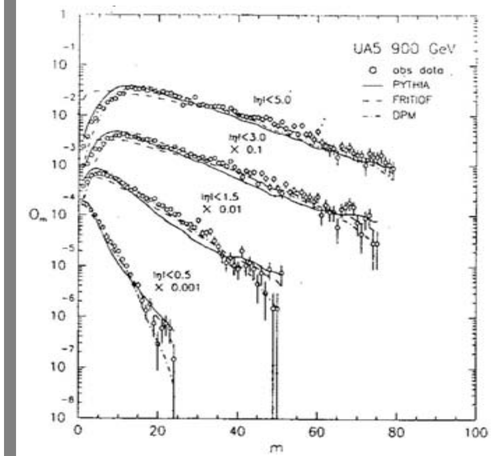
"First 3 minutes"

Pseudorapidity density dN/dη



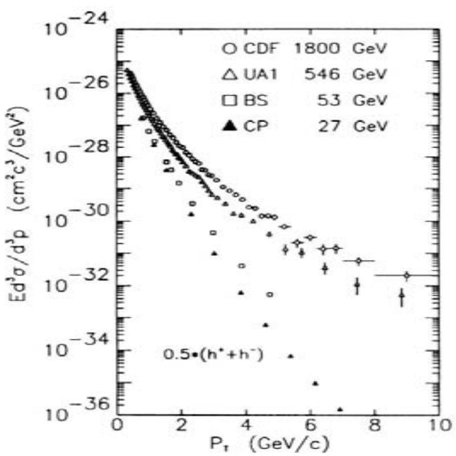
CDF:
Phys. Rev.
D41, 2330 (1990)

Multiplicity distribution



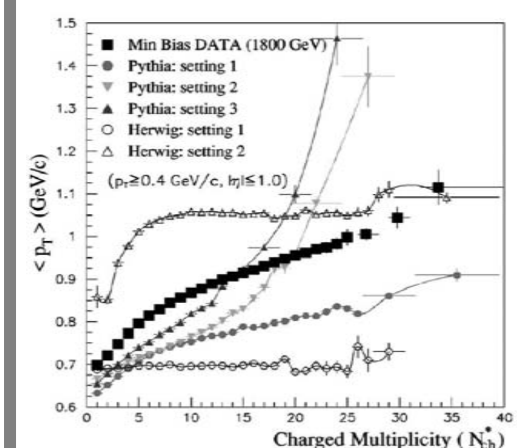
UA5:
Z. Phys
43, 357 (1989)

p_T spectrum unidentified hadrons



CDF:
Phys. Rev. Lett.
51, 1819 (1988)

Mean p_T vs multiplicity



CDF:
Phys. Rev.
D65,72005(2002)

"First Papers" from previous energies; all required only small event samples (~20K events)

$dN/d\eta$ at $\eta=0$

- Feynman (1969):

  $N_{tot} = a + b*\ln(s)$

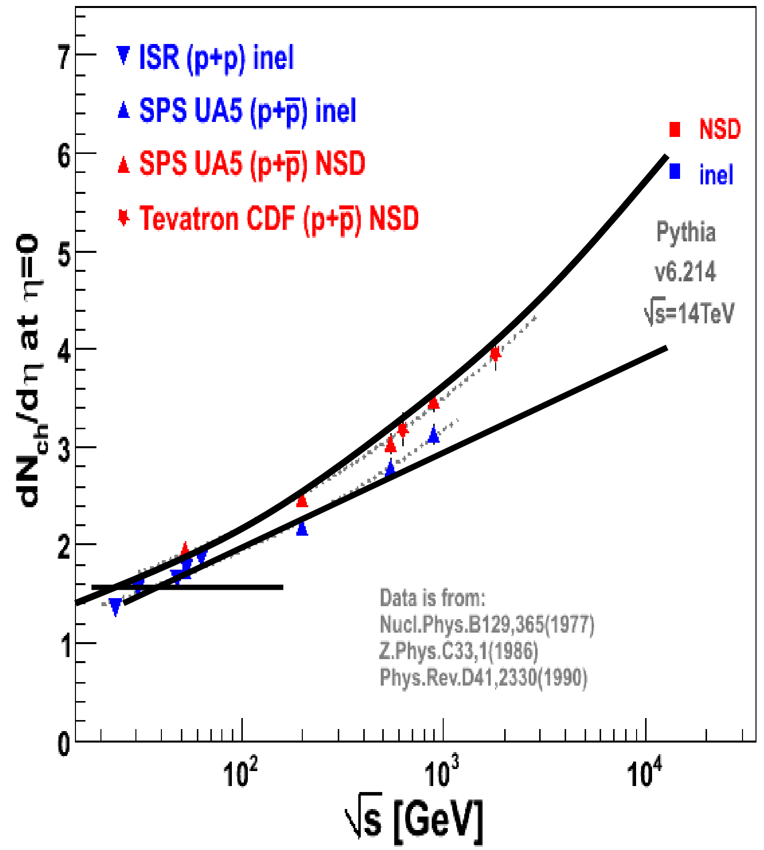
  $dN/d\eta = const$

- ISR(1977):

  $dN/d\eta = a + b*\ln(s)$

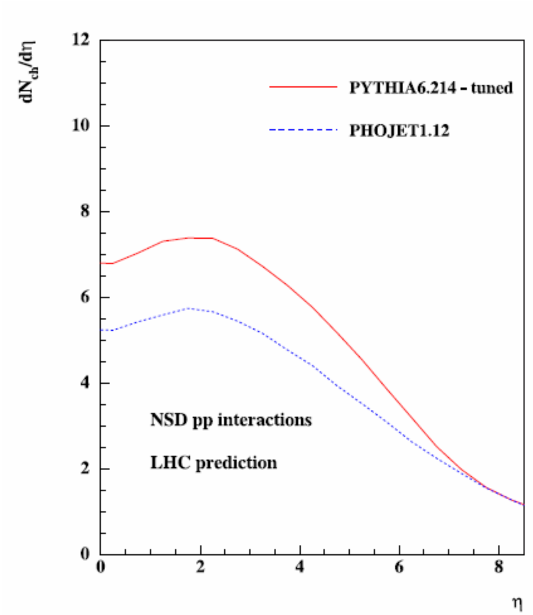
- SppS (1981):

  $dN/d\eta = a + b*\ln(s) + c*\ln(s)^2$

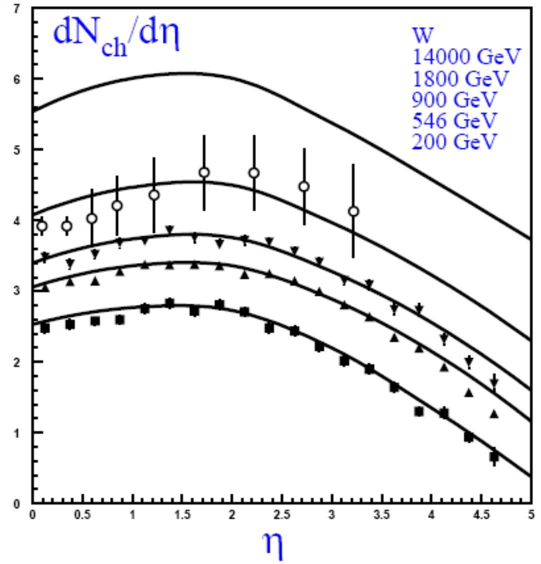


Model discrimination/tuning

• Pythia and Phojet predictions different
 => First measurements will be able to distinguish
Eur. Phys. J. C 50, 435–466 (2007)



• Colour glass condensate
Nucl.Phys.A747:609-629(2005)

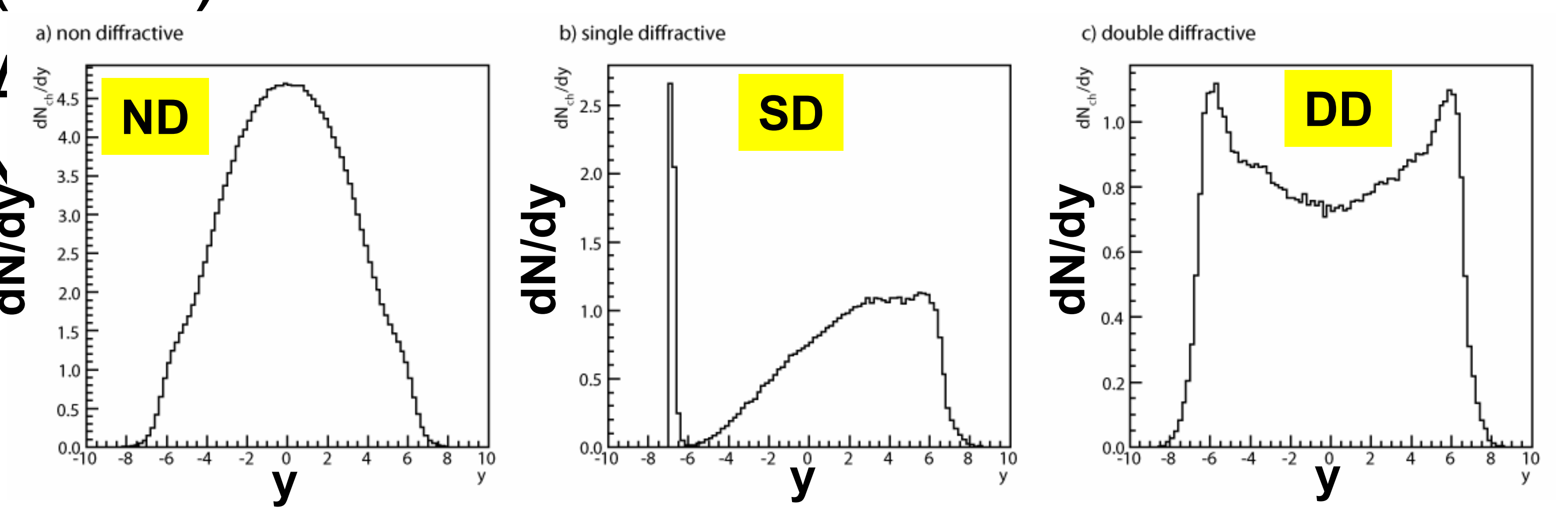


Proton-Proton collisions

$$\sigma_{\text{total}} = \sigma_{\text{elastic}} + \underbrace{\sigma_{\text{non-diffractive}} + \sigma_{\text{single-diffractive}} + \sigma_{\text{double-diffractive}}}_{\text{ALICE trigger}}$$

↑ insensitive (elastic)

- Many experiments triggered on and published non-single-diffractive events (NSD)
- A



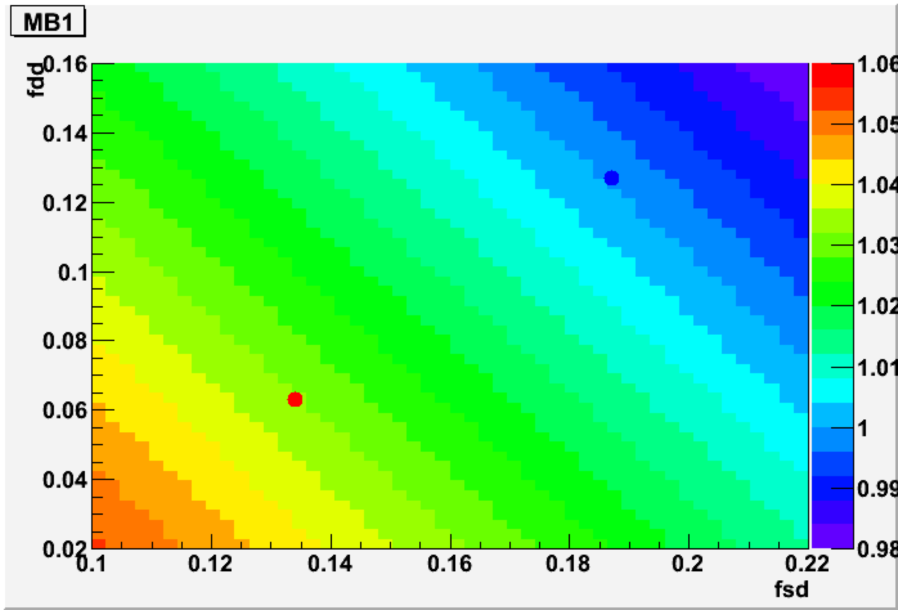
Trigger Corrections

- Minimum Bias triggers react differently to the diffractive and non-diffractive contributions.
- Effect of varying the relative fractions for these processes has been studied – systematic error in measurement (S. Navin, C. Lazzeroni, R. Lietava)
- Differences in the default event generators (PYTHIA, PHOJET) for diffractive processes have been noted and are being investigated (M. Bombara, S. Navin, R. Lietava)
- Relative fractions for different processes can be estimated from trigger ratios (Z.L. Matthews, O. Villalobos Baillie)

Multiplicity correction

• Multiplicity is a measure of the number of charged tracks per event
• Kinematic differences between Pythia and Phojet affect our efficiency of multiplicity measurements

MB1 trigger with Pythia as default



fsd

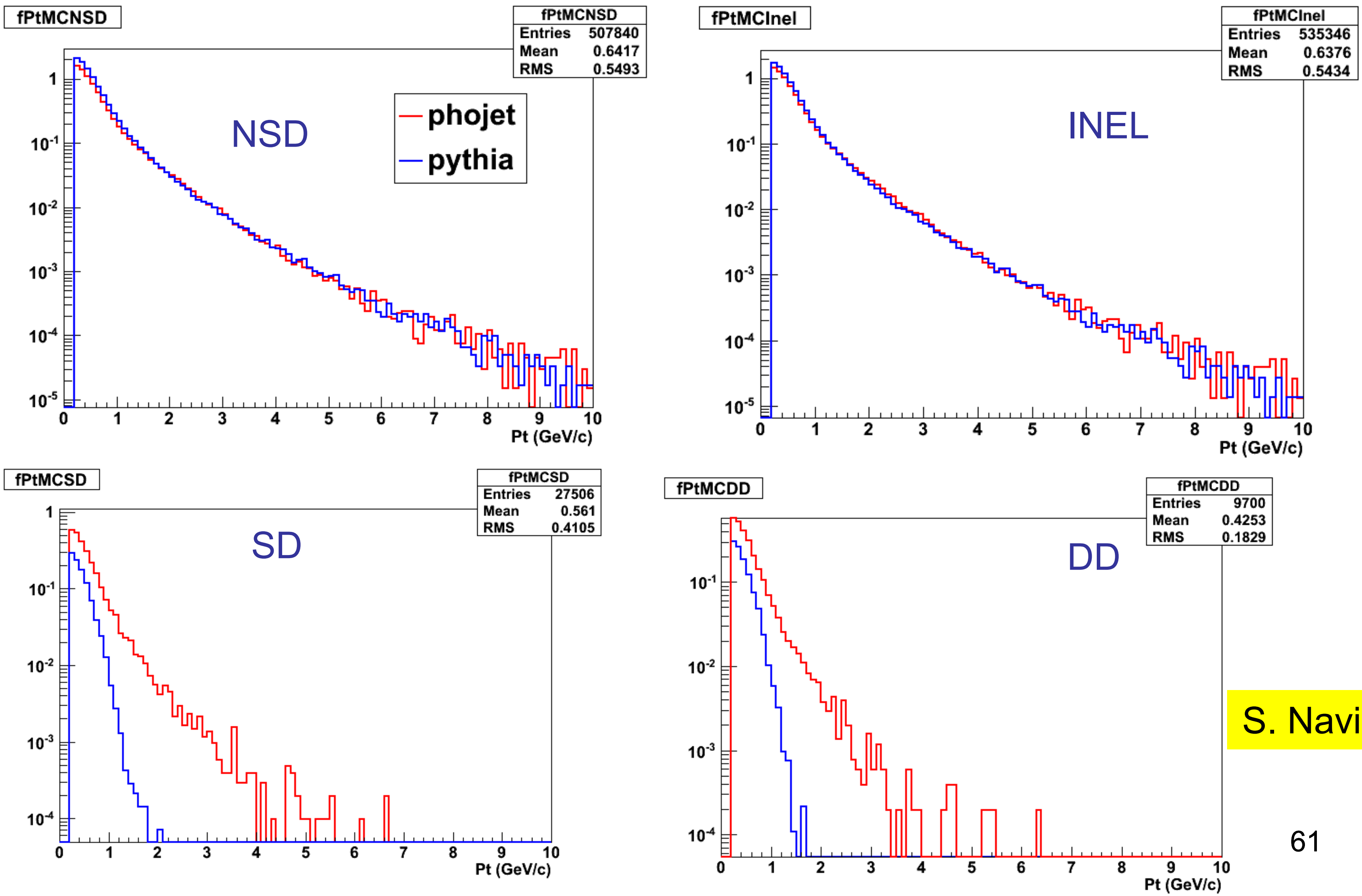
Varying fractions to view effect of multiplicity change with respect to Pythia's default multiplicities

Phojet and Pythia default fractions

S.Navin

Systematics error = 4%

Kinematic comparison of generators

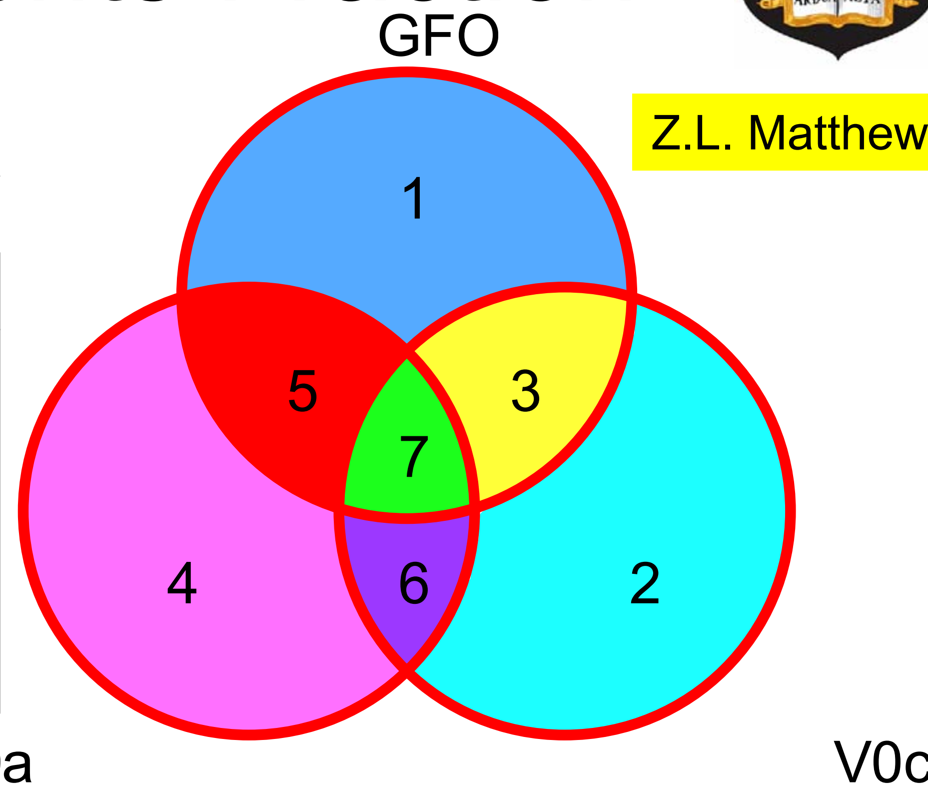


S. Navin

Diffractive Events Fraction

Z.L. Matthews

Tr	V0A	GFO	V0C
1	0	1	0
2	0	0	1
3	0	1	1
4	1	0	0
5	1	1	0
6	1	0	1
7	1	1	1



$$N_{trig} = N_{trig}^{DD} + N_{trig}^{SD} + N_{trig}^{ND} + N_{trig}^{NI}$$

$$N_{trig} = N_{rec}\left(f_{DD}\varepsilon_{trg}^{DD} + f_{SD}\varepsilon_{trg}^{SD} + f_{ND}\varepsilon_{trg}^{ND} + f_{NI}\varepsilon_{trg}^{NI}\right)$$

$$= N_{rec}\left(f_{DD}\varepsilon_{trg}^{DD} + f_{SD}\varepsilon_{trg}^{SD} + f_{ND}\varepsilon_{trg}^{ND} + \left(1-\left(f_{DD}+f_{SD}+f_{ND}\right)\right)\varepsilon_{trg}^{NI}\right)$$

$$Ntrig_{calc(i)} = \sum_{j=1,3} a_{ij} Type(j)$$

$$\chi^2 = \sum_{trig}\left(\frac{\left(Ntrig_{calc}(i) - Ntrig_{measured}(i)\right)}{Error\left(Ntrig(i)\right)}\right)^2$$

$$Dof = 8 - 4 + 1 = 5$$

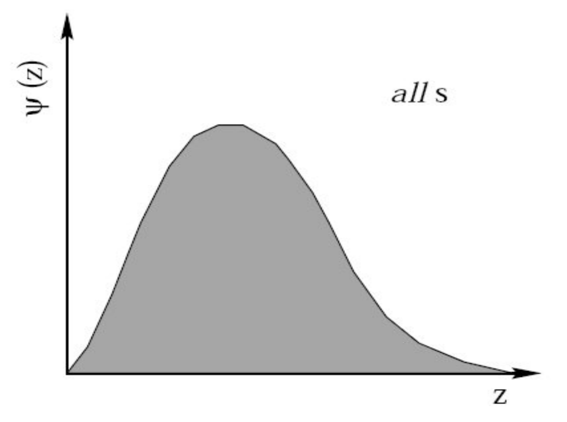
Extract f_{sd}, f_{dd} from data !

Multiplicity distribution

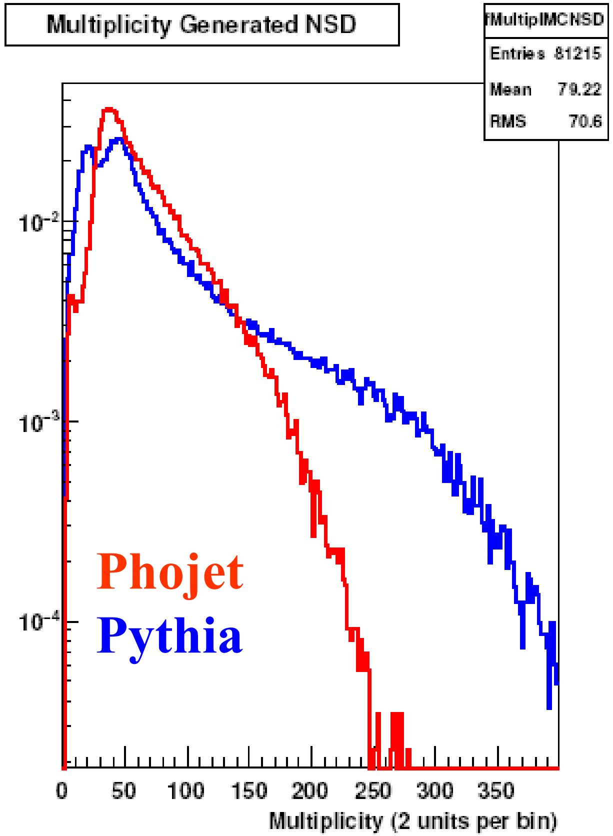
1972:
KNO (statistical) scaling law

$$P_n(s) = \frac{1}{\langle n \rangle} \Psi\left(\frac{n}{\langle n \rangle}\right)$$

$\Rightarrow$ shape of distribution is independent of s

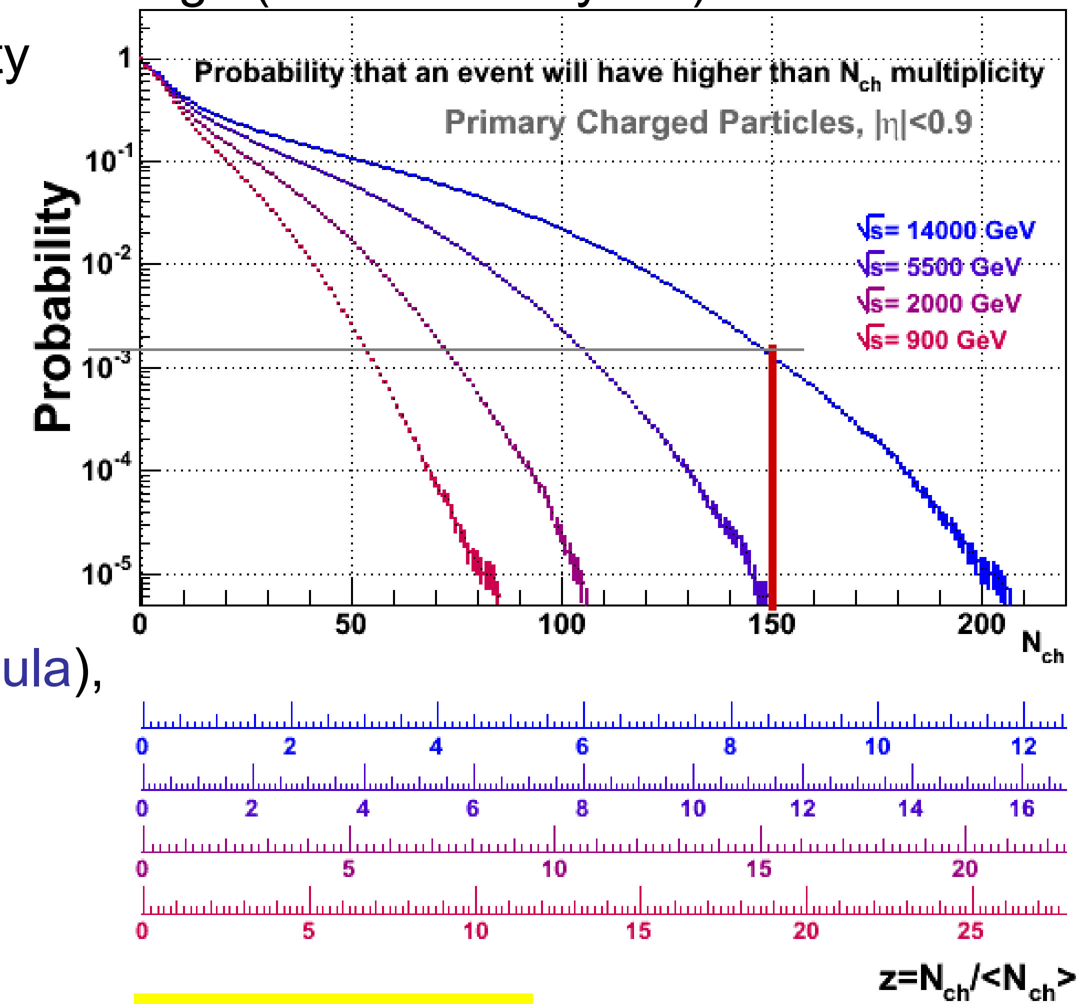


NPB 40, 317 (1972)



Initial multiplicity reach

- With $2x10^4$ minimum bias pp events we will have statistics up to multiplicity ~150 – 10 times the average (30 events beyond)
- We plan to use also multiplicity trigger (with silicon pixel detector) – to enrich the high-multiplicity
- Energy density in high-multiplicity pp events can reach that of a heavy-ion collision (according to the Bjorken formula), however, in much smaller volume

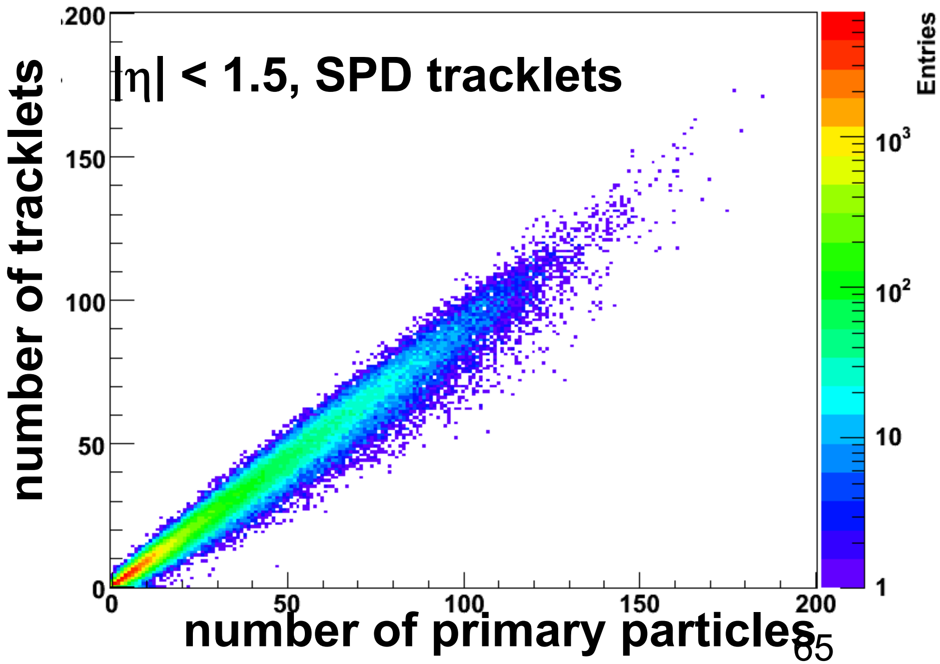


Claus Jorgensen

Detector Response

- Described by matrix R_{tm}
  - Probability that a collision with the true multiplicity ***t*** is measured as an event with the multiplicity ***m***
  - Created from full detector simulation (if needed: as function of vertex-z)
  - $M_m = R_{tm}\, T_t$
    ➔ $T_t = R_{tm}^{-1}\, M_m$
  - R_{tm} can (usually) not be inverted (singular, statistic fluctuation)

Two approaches considered:
-χ^2 minimization
-Application of Bayes' Method



High-multiplicity trigger

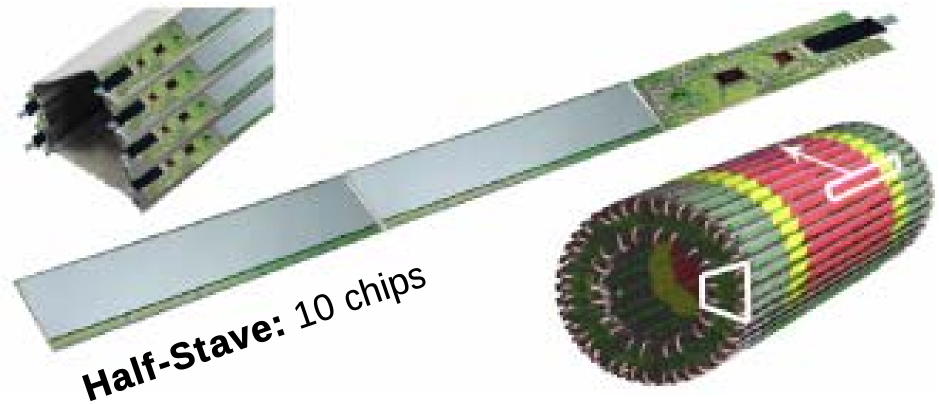
Silicon pixel detector

- fast-OR trigger at Level-0

  OR signal from each pixel chip
- two layers of pixel detectors

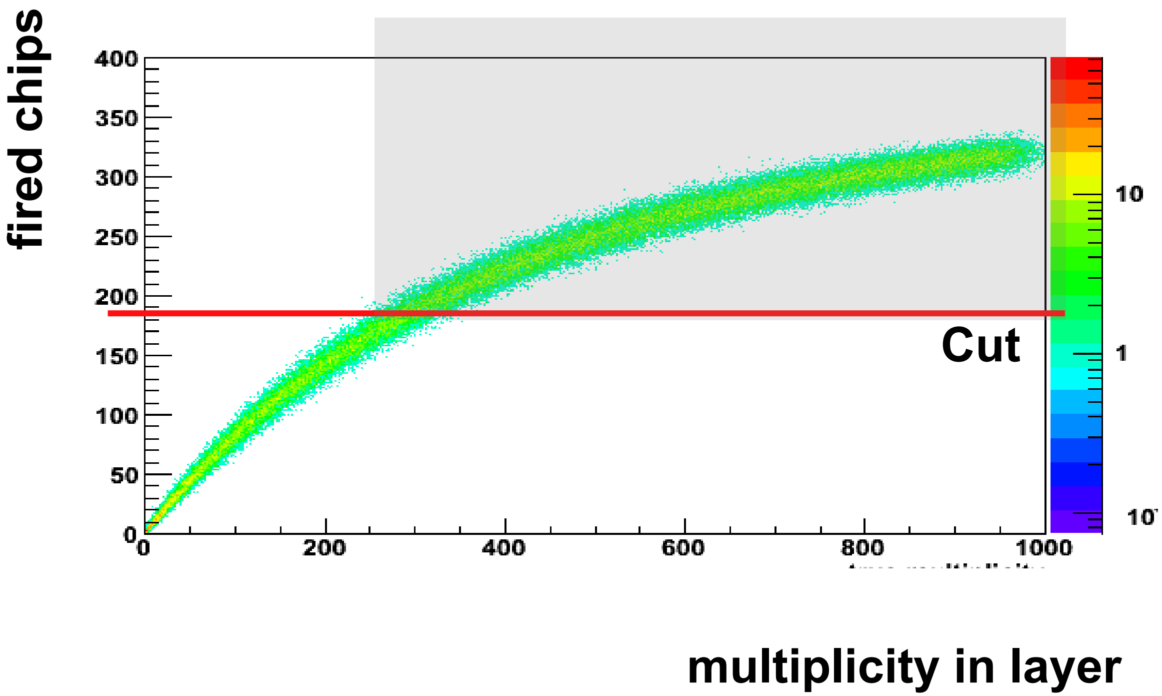
  400 chips layer 1; 800 layer 2
- trigger on chip-multiplicity per layer

Sector: 4 (outer) + 2 (inner) staves



SPD: 10 sectors (1200 chips)

Fired chips vs. true multiplicity (in η of layer)



Few trigger thresholds

- tuned with different downscaling factors
- maximum threshold determined by

  event rate

  background

  double interactions

High-multiplicity trigger – example

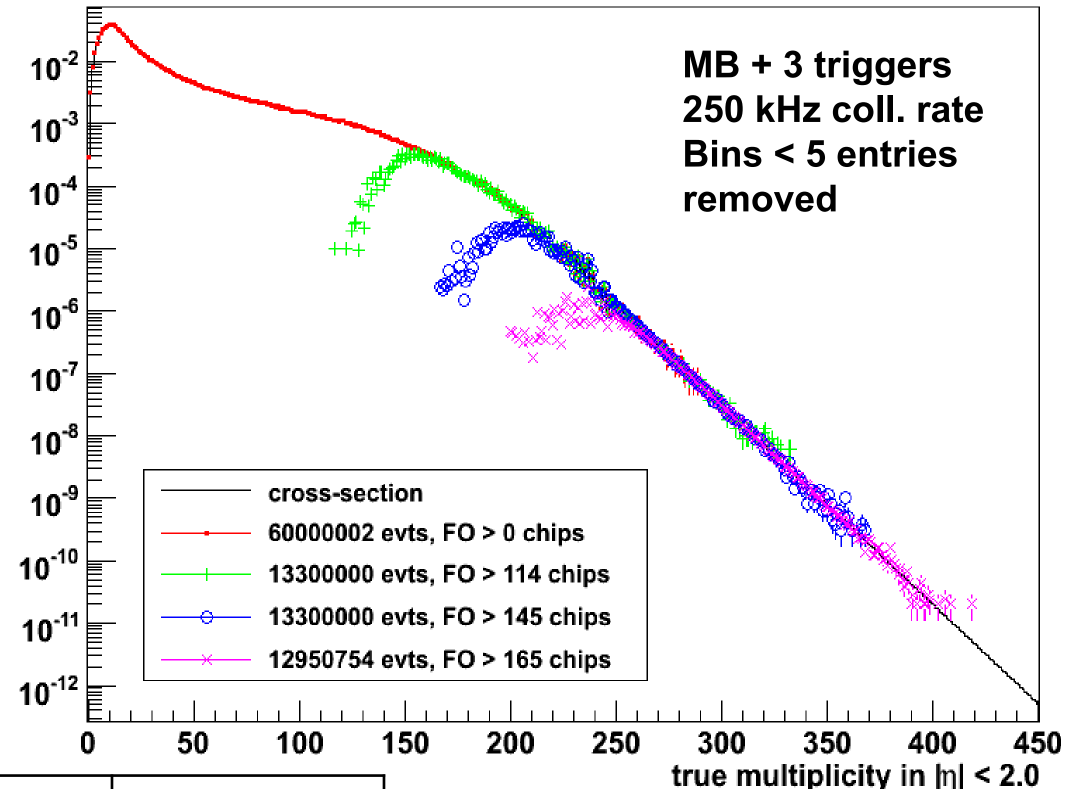
Example of threshold tuning:

MB and 3 high-mult. triggers

250 kHz collision rate
recording rate 100 Hz

MB 60%

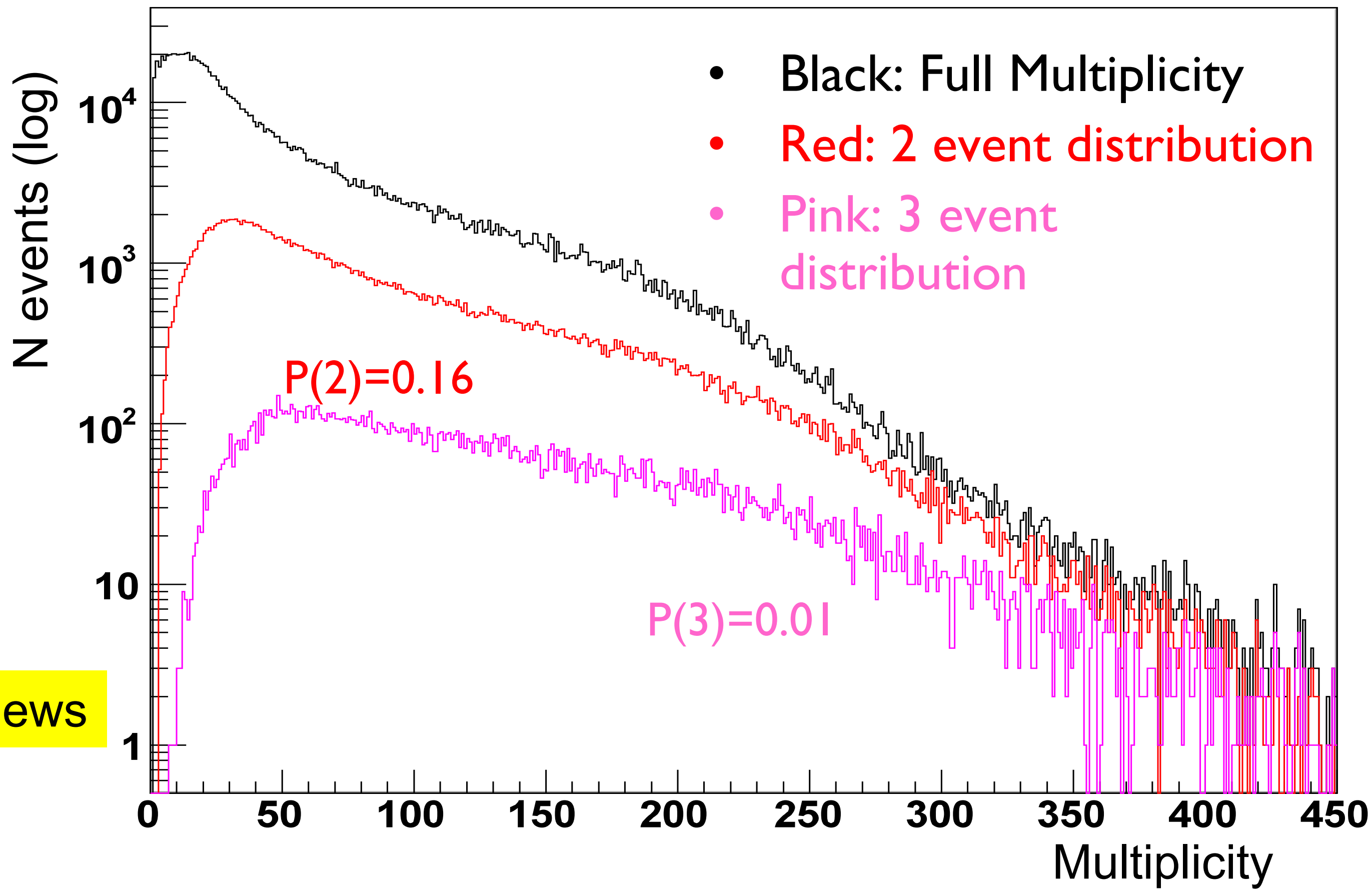
3 HM triggers: 40%



trigger rate Hz	scaling	raw rate	threshold layer 1
60.0	4167	250000	min. bias
13.3	259	3453.3	114
13.3	16	213.3	145
13.3	1	13.3	165

J F Grosse-Oetringhaus

“Full” distribution from single MC



Z.L.Matthews

- Created using the probabilities assuming nominal int. rate of μ =0.2 interactions / bunch crossing

High Multiplicity pp

- For QGP in collisions, need to exceed the energy density limit
- J. D. Bjorken: multiplicity (number of charged tracks) of an event can be related to the energy density in the collision

$$\epsilon_{Bj} = \frac{dE_\perp}{dy} \frac{1}{S_\perp \tau} \qquad \frac{d\langle E_\perp \rangle}{dy} \approx \frac{3}{2} \left(\langle m_\perp \rangle \frac{dN}{dy} \right)$$

Systematic Measurements of Identified Particle Spectra in pp, d+Au and Au+Au collisions from STAR arXiv:0808.2041v1 [nucl-ex] 14 Aug 2008

τ is formation time, S is overlapping area

- Higher multiplicity reach at LHC pp, some events should exceed threshold energy density

- Provided it can be considered a statistical system, could even see QGP in pp at ALICE

Heavy-ion physics with ALICE

- fully commissioned detector & trigger
  - **alignment, calibration available from pp**
- first 10^5 events: **global event properties**
  - **multiplicity, rapidity density**
  - **elliptic flow**
- first 10^6 events: **source characteristics**
  - **particle spectra, resonances**
  - **differential flow analysis**
  - **interferometry**
- first 10^7 events: **high-p_t, heavy flavours**
  - **jet quenching, heavy-flavour energy loss**
  - **charmonium production**
- **yield bulk properties of created medium**
  - **energy density, temperature, pressure**
  - **heat capacity/entropy, viscosity, sound velocity, opacity**
  - **susceptibilities, order of phase transition**

- early ion scheme
  - **1/20 of nominal luminosity**
  - **$\int Ldt = 5 \cdot 10^{25}$ cm^{-2} s^{-1} x 10^6 s**
    0.05 nb^{-1} for PbPb at 5.5 TeV
    $N_{pp\ collisions} = 2 \cdot 10^8$ collisions
    400 Hz minimum-bias rate
    20 Hz central (5%)
  - **muon triggers:**
    ~ 100% efficiency, < 1kHz
  - **centrality triggers:**
    bandwidth limited
    $N_{PbPbminb} = 10^7$ events (10Hz)
    $N_{PbPbcentral} = 10^7$ events (10Hz)

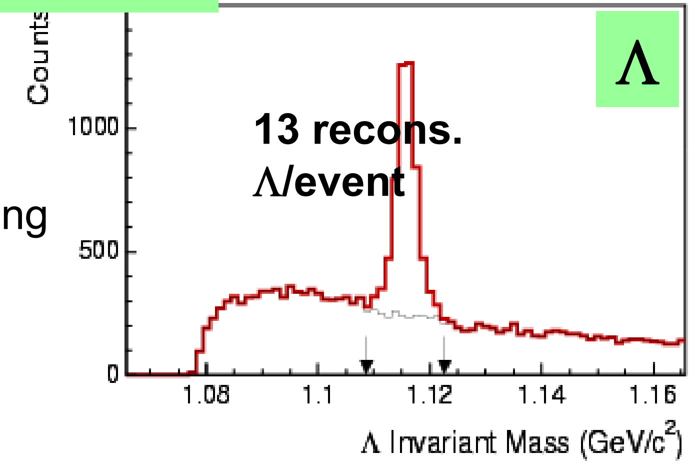
Topological identification of strange particles 7

Statistical limit : p_T ~8 - 10 GeV for K^+, K^-, K^0_s, Λ, 3 - 6 GeV for Ξ, Ω

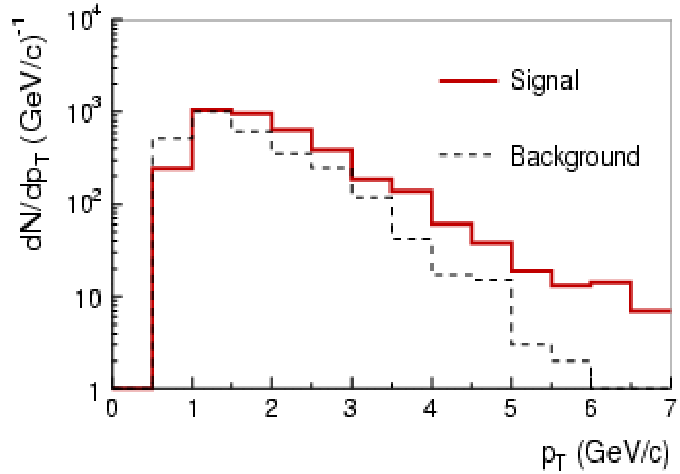
Secondary vertex and cascade finding

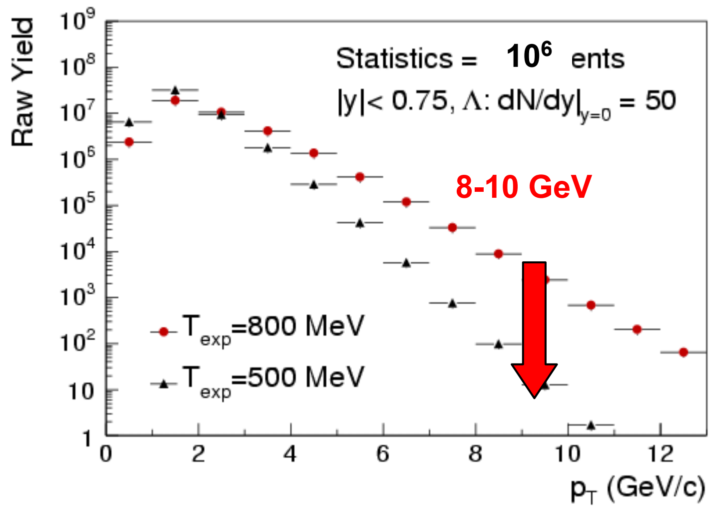
Pb-Pb central

300 Hijing events



p_T dependent cuts -> optimize efficiency over the whole p_T range





Reconst. rates:

Ξ: 0.1/event

Ω: 0.01/event

p_T: 1 to 3-6 GeV

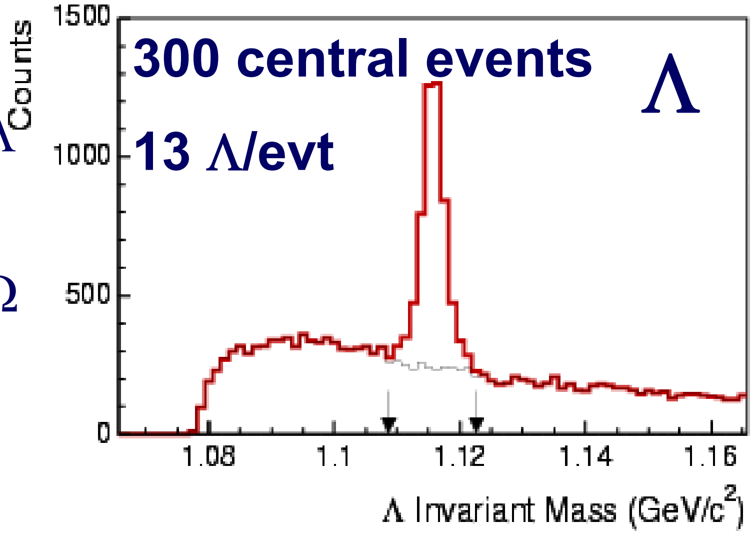
→

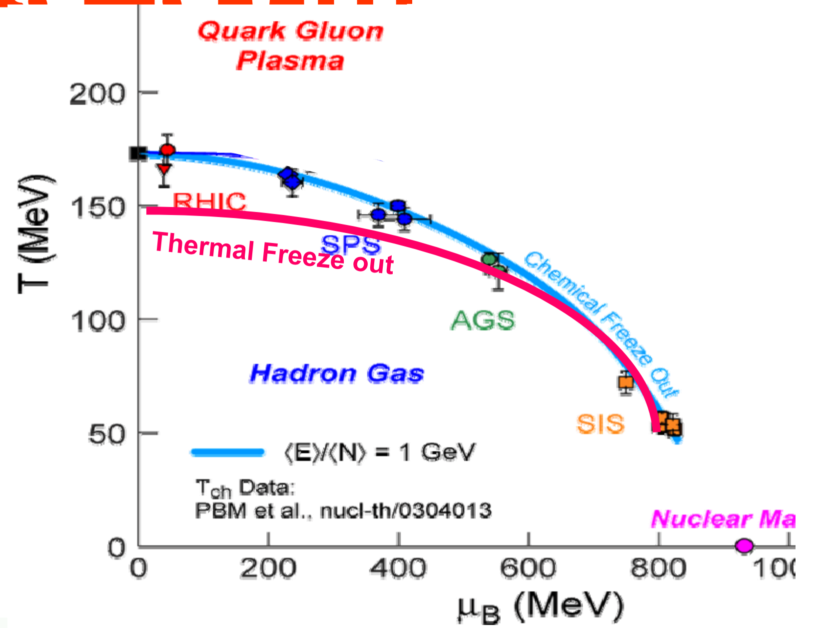
ρ, φ, K* , K^0_s, Λ. Ξ. Ω…

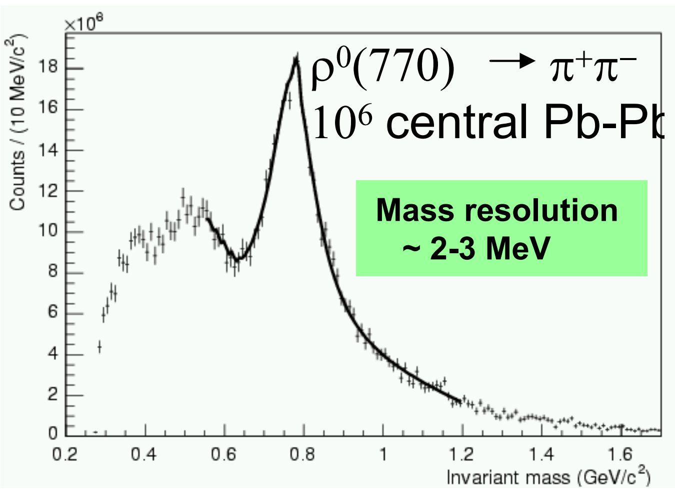
10^7 events:

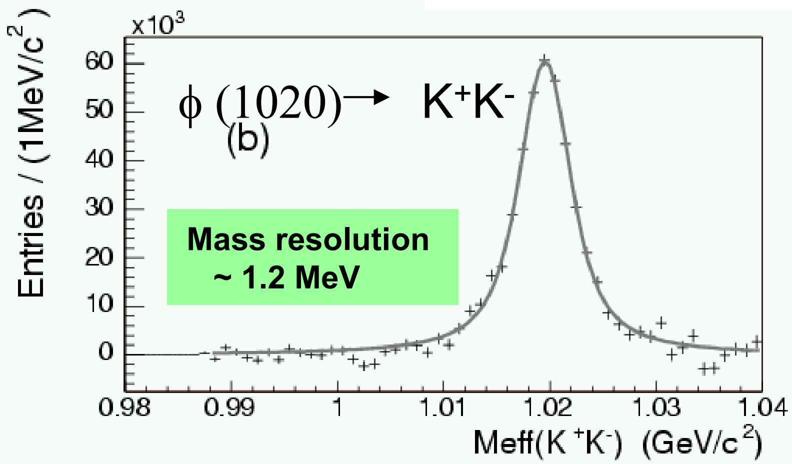
p_t reach φ,K,Λ
~ 13-15 GeV

p_t reach ρ,Ξ,Ω
~ 9-12 GeV





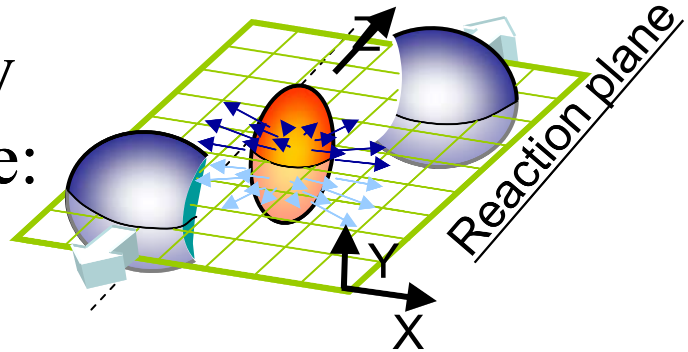


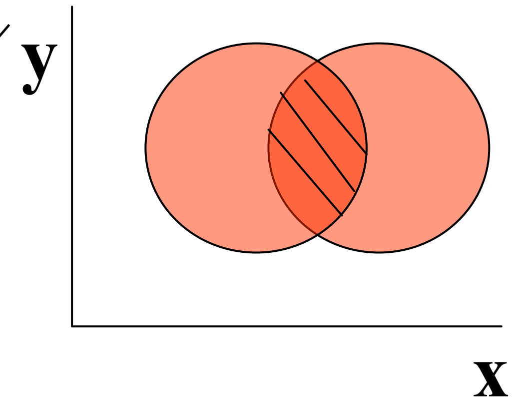


- hadrochemical analysis
- chemical/kinetic freeze-out
- medium modifications of mass, widths

Flow

Azimuthal asymmetry in the transverse plane:





Eccentricity:

$$\varepsilon \equiv \frac{\langle y^2 - x^2 \rangle}{\langle y^2 + x^2 \rangle}$$

Flow:

$$E\frac{d^3N}{d^3p} = \frac{1}{2\pi}\frac{d^2N}{p_t dp_t dy}\left[1 + \sum_{n=1}^{\infty} 2v_n \cos(n\phi)\right]$$

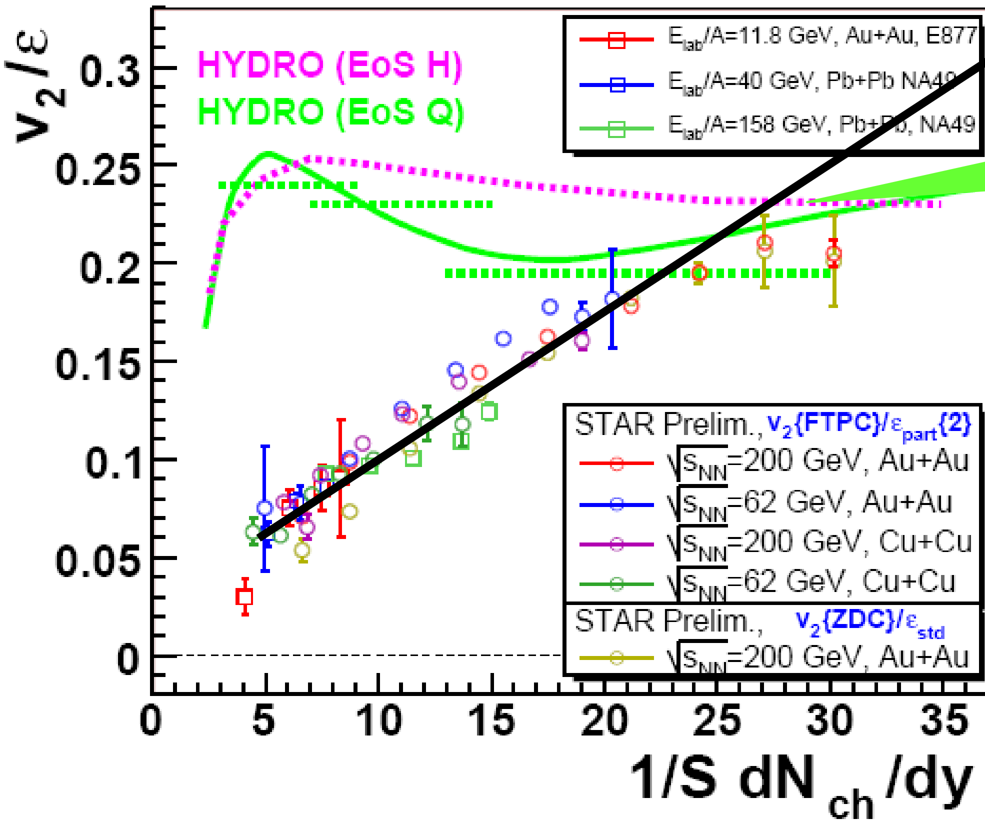
v_1 = directed flow v_2 = elliptic flow

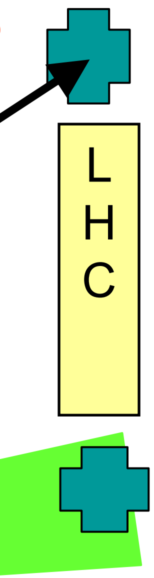
Φ – angle with respect to reaction plane

Relativistic hydrodynamics prediction: $v_2/\varepsilon \sim$ constant

Is the QGP an ideal fluid ?

- one of the first ‘expected’ answers from LHC
  - Hydrodynamics: modest rise (Depending on EoS, viscosity, speed of sound)
  - experimental trend & scaling predicts large increase of flow





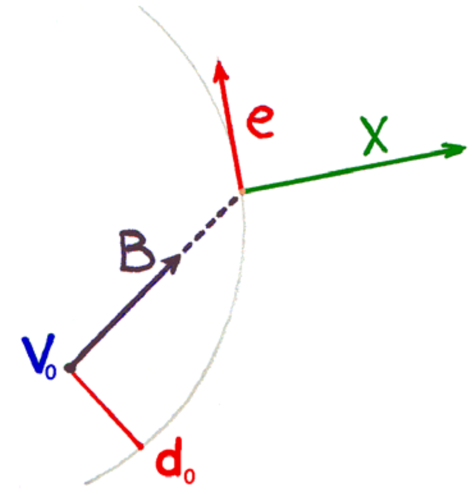
BNL Press release, April 18, 2005:

RHIC Scientists Serve Up "Perfect" Liquid

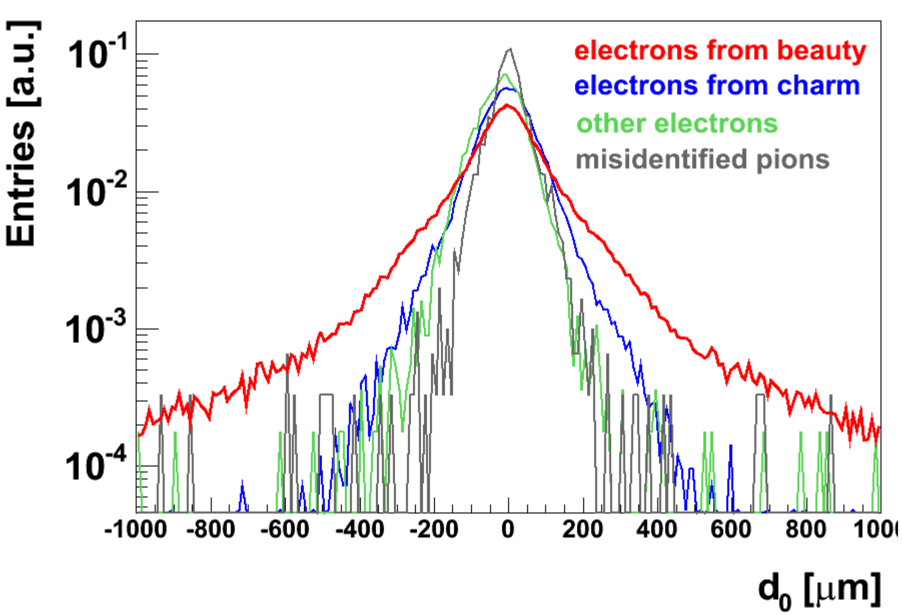
New state of matter more remarkable than predicted – raising many new questions

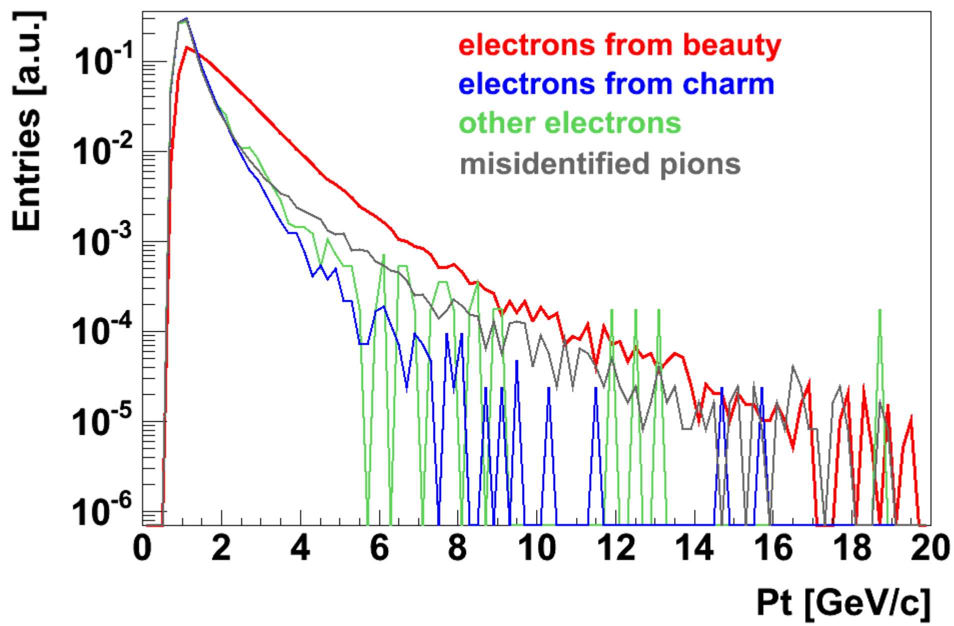
J. Phys. G: Nucl. Part. Phys. 34 (2007) S883–S886

Beauty: semi-leptonic decays
detection strategy



d_0 and p_T distributions for "electrons" from different sources:

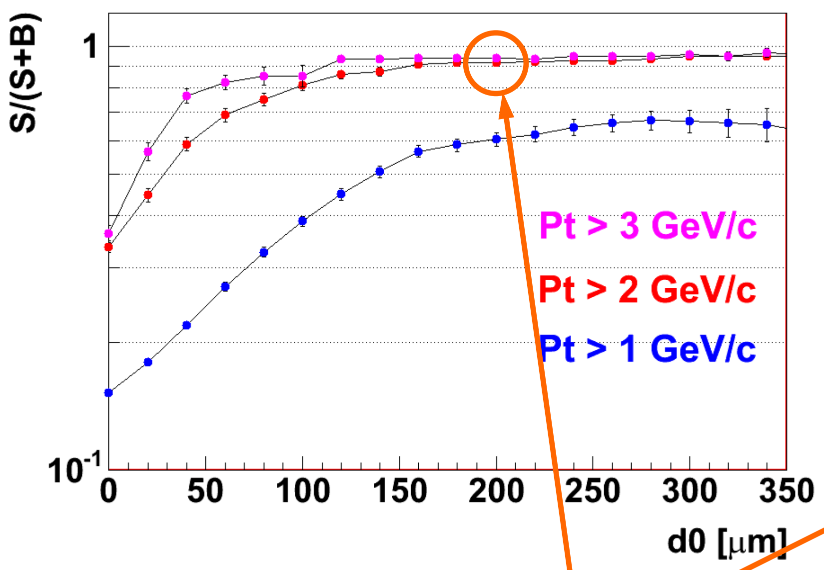




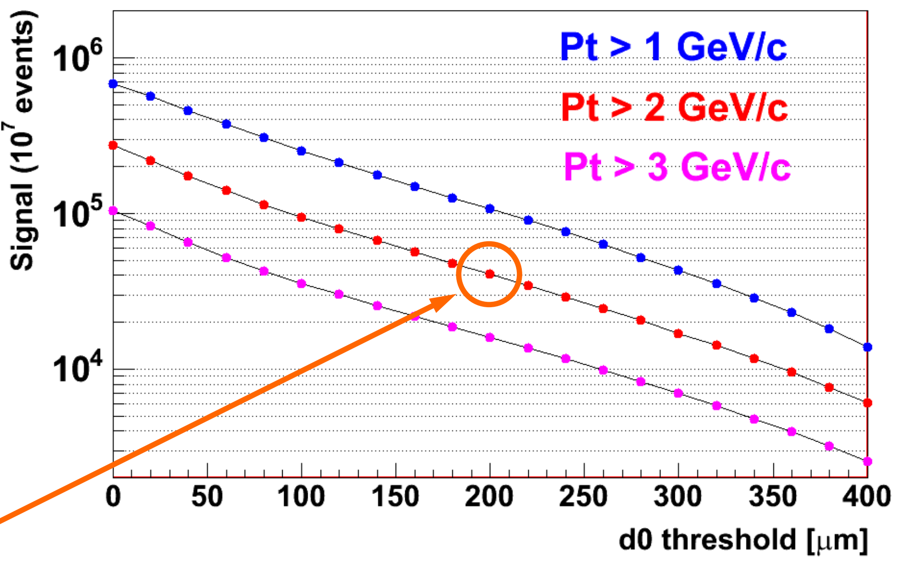
Distributions normalized to the same integral in order to compare their shapes

Semi-electronic Beauty detection
simulation results

Signal-to-total ratio and expected statistics in 10^7 Pb-Pb events



Expected statistics (10^7 Pb-Pb events)

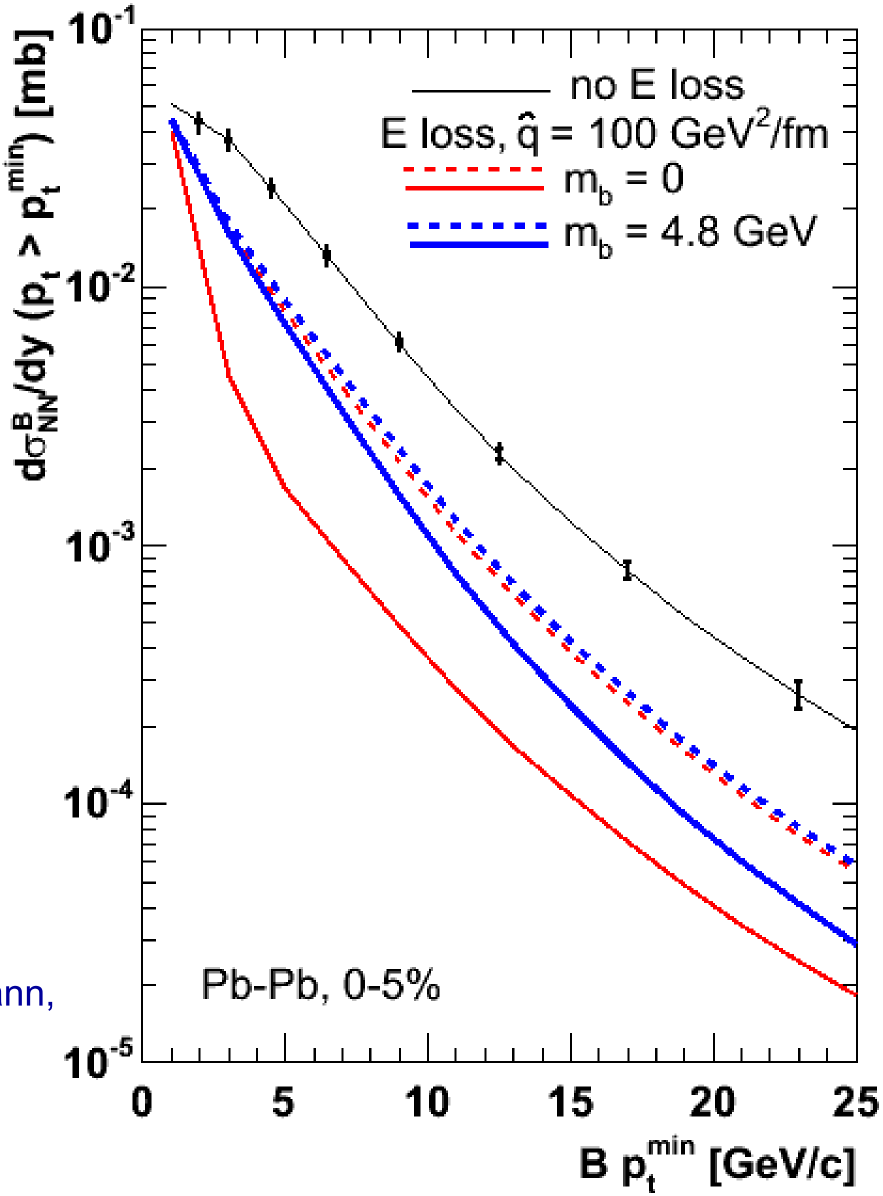


p_T > 2 GeV/c , 200 < $|d_0|$ < 600 μm ⇨ **90% purity**
40,000 e from B

Extraction of a minimum-p_T-differential cross section for B mesons

Using electrons in $2 < p_T < 16$ GeV/c

obtain B-meson $2 < p_T^{min} < 23$ GeV/c



stat
p_t-dep. syst
11% norm. err. (not shown)

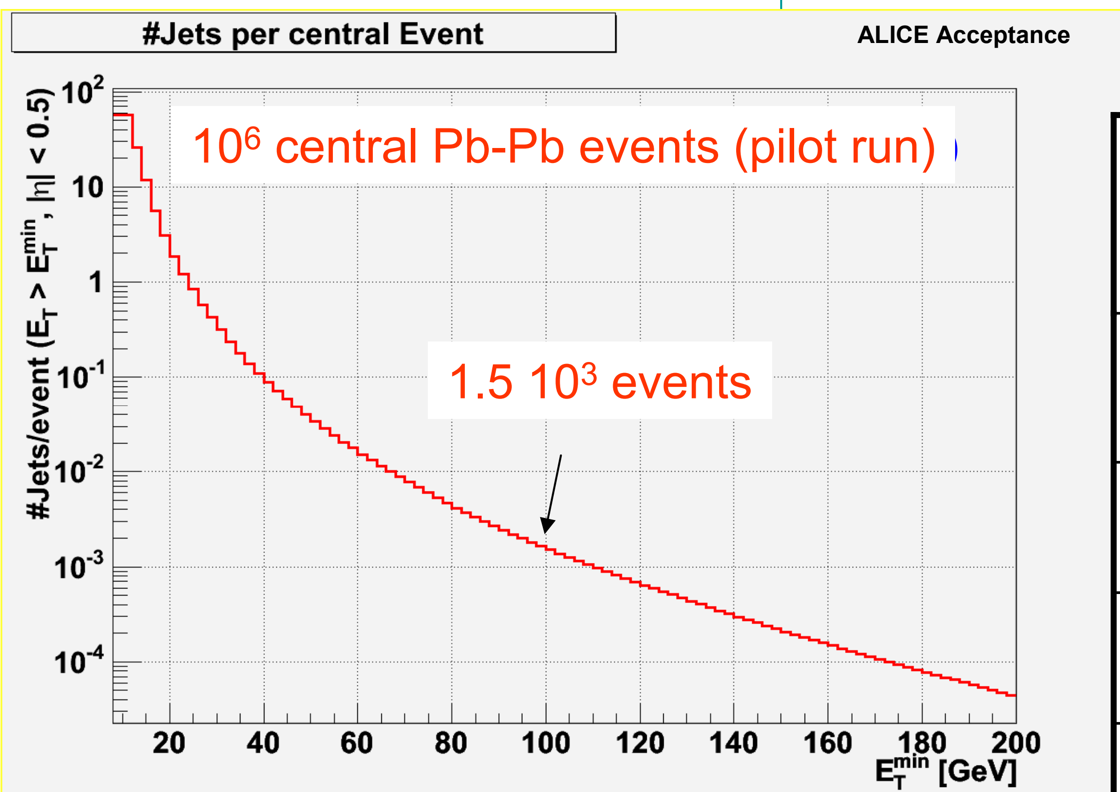
E loss calculations:
N. Amesto, A. Dainese, C.A. Salgado, U.A. Wiedemann, hep-ph/0501225

Jet statistics in pilot Pb run

Jets are produced copiously

2 | 20 | 100 | 200 | p_t (GeV)

100/event | 1/event | 10^3 in first 10^6 Pb-Pb events



10^6 central PbPb collisions

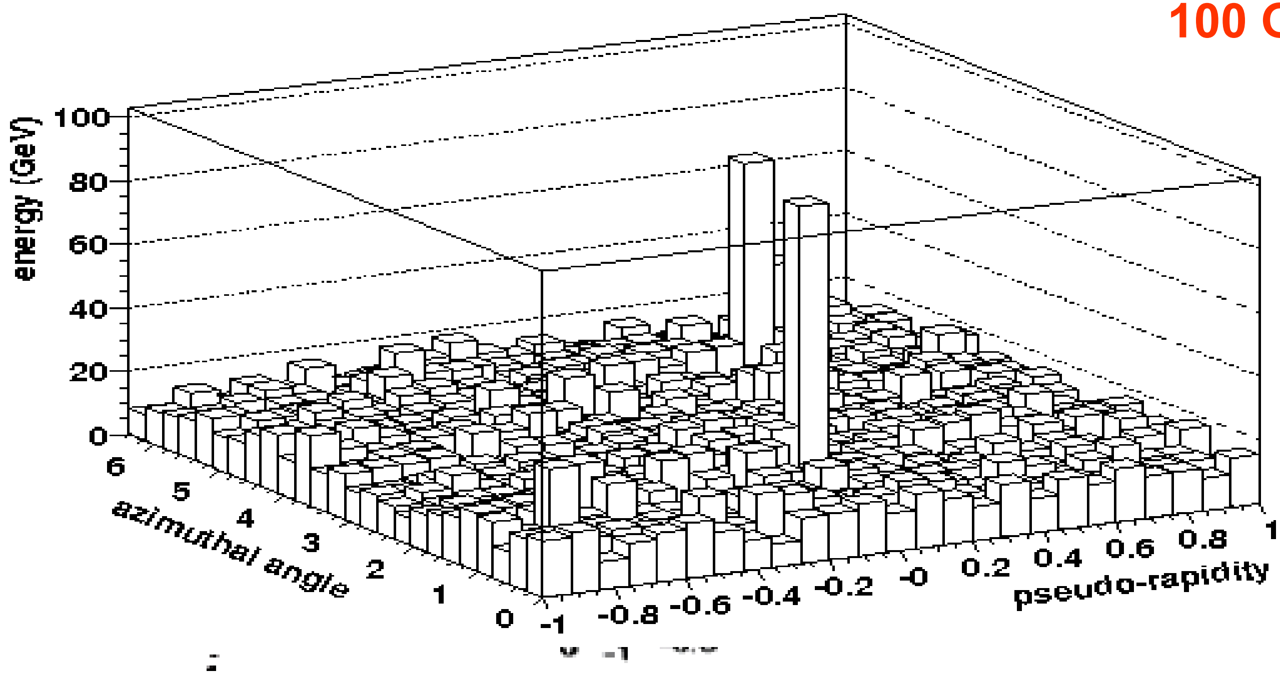
E_T threshold	N_{jets}
50 GeV	5×10^4
100 GeV	1.5×10^3
150 GeV	300
200 GeV	50

50 – 100 GeV jets in Pb–Pb

At large enough jet energy – jet clearly visible
But still large fluctuation in underlying energy

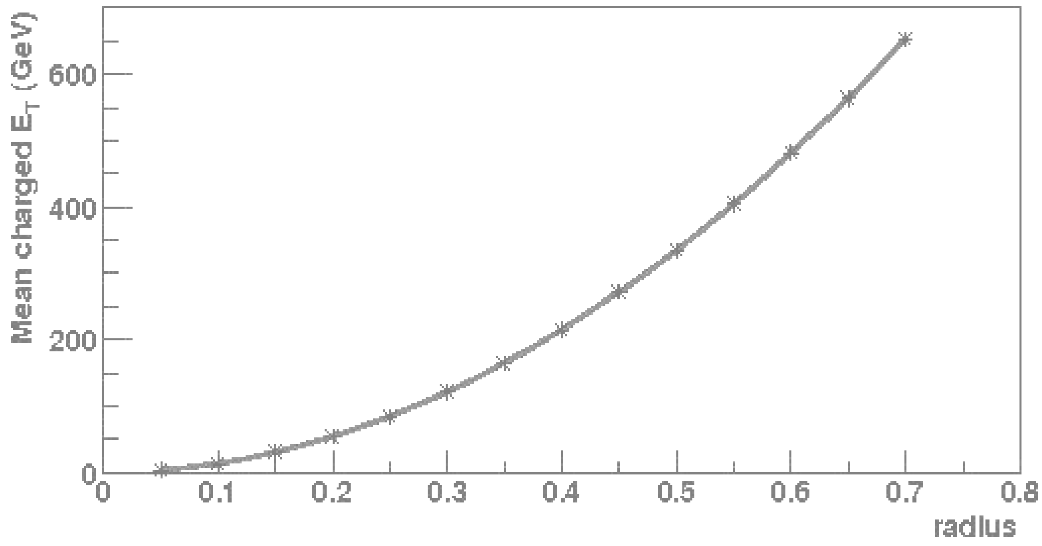
η–φ lego plot with Δη 0.08 × Δφ 0.25 ***C. Loizides***

100 GeV jet

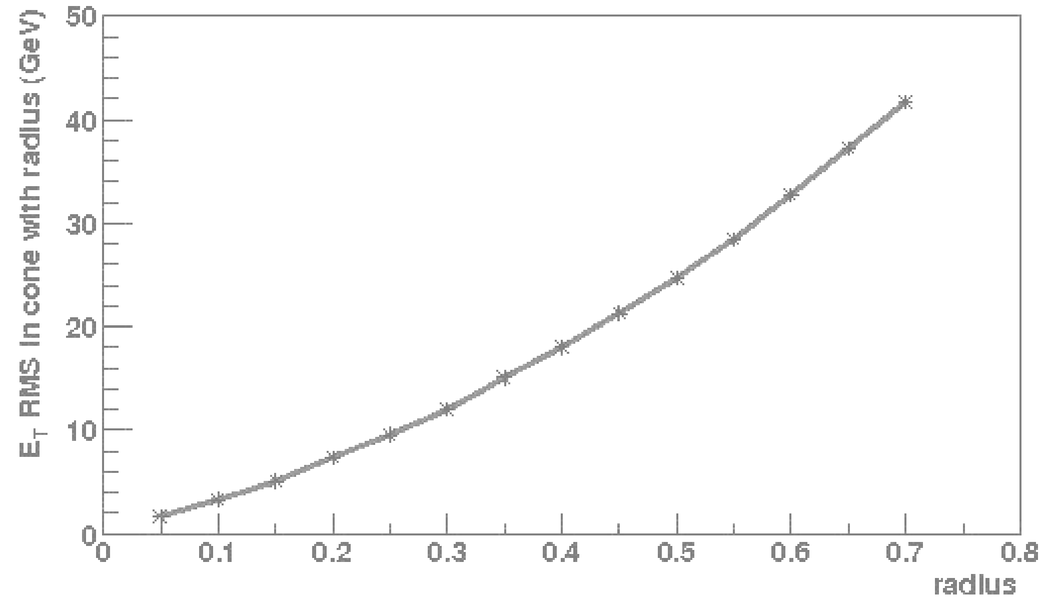


Central Pb–Pb event (HIJING simulation) with 100 GeV di-jet (PYTHIA simulation)

Energy fluctuation in UE



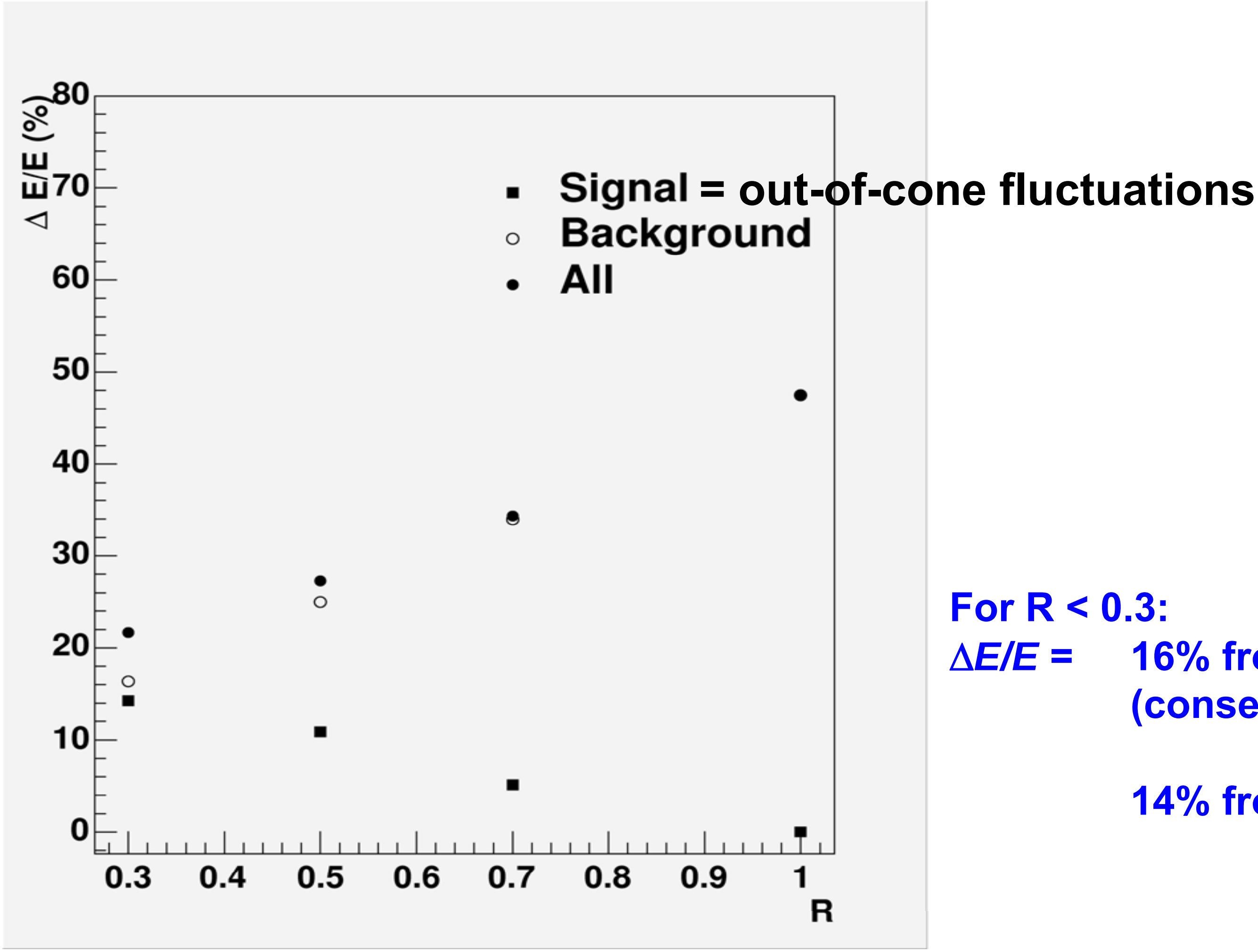
Mean energy in a cone of radius R coming from underlying event



Fluctuation of energy from an underlying event in a cone of radius R

More quantitatively ...

Intrinsic resolution limit for E_T = 100 GeV



For R < 0.3:

$\Delta E/E$ = 16% from Background (conservative dN/dy = 5000)

14% from out-of-cone fluctuations

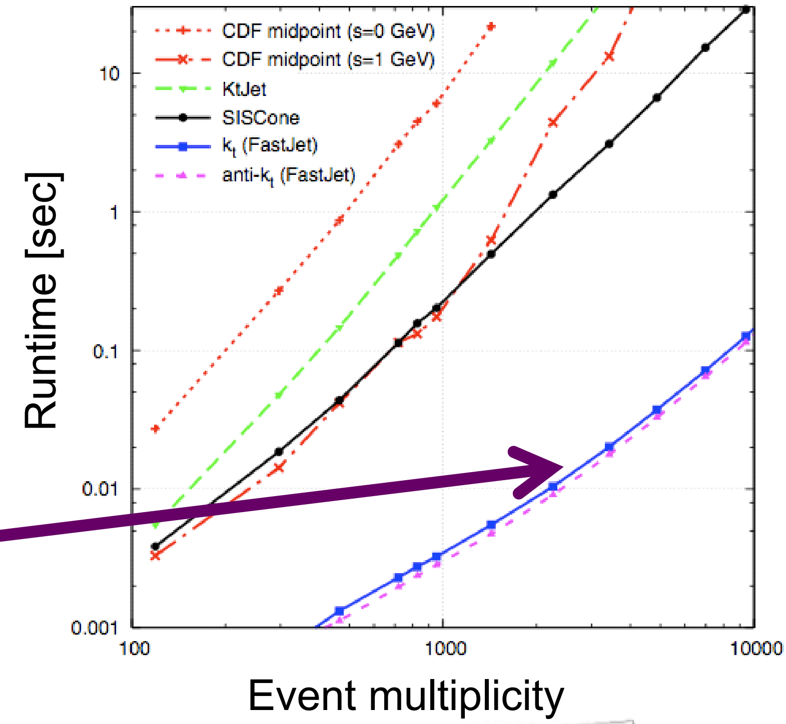
Summary

- The ALICE detector offers excellent tracking and charged particle identification over a wide momentum range
- Detectors are ready for data. Much useful experience gained from 2008 operation.
- "First Physics" programme in pp provides a focus for the first measurements. Interesting first survey of the new energy regime can be underway even before calibration of apparatus is complete.
- Long and detailed programme of study available in Pb-Pb collisions.
- In particular, LHC offers the possibility to use hard probes extensively for the first time. Allows use of perturbative methods to calculate yield in absence of partonic medium effects.
- Principal design goal, to maintain high reconstruction efficiency even at the highest Pb-Pb multiplicities (up to dN/dy ~8000), coupled with low material budget and precision vertexing, allows detection of close secondary vertices from heavy flavour.
- High jet cross-sections allow measurement of abundant, fully reconstructed jets.

Jet Finding Algorithms

- Tremendous recent progress on jet finding algorithms

  - novel class of IR and collinear safe algorithms satisfying SNOWMASS accords
    kt(FastJet)
    anti-kt(FastJet)
    SISCone
  - new standard for p+p@LHC
  - fast algorithms, suitable for heavy ions!



M. Cacciari, G. Salam, G. Soyez, JHEP 0804:005,2008

- Catchment area of a jet

  - novel tools for separating soft fluctuations from jet remnants

  - interplay with MCs of jet quenching needed

Wiedemann QM09