First Physics with ALICE

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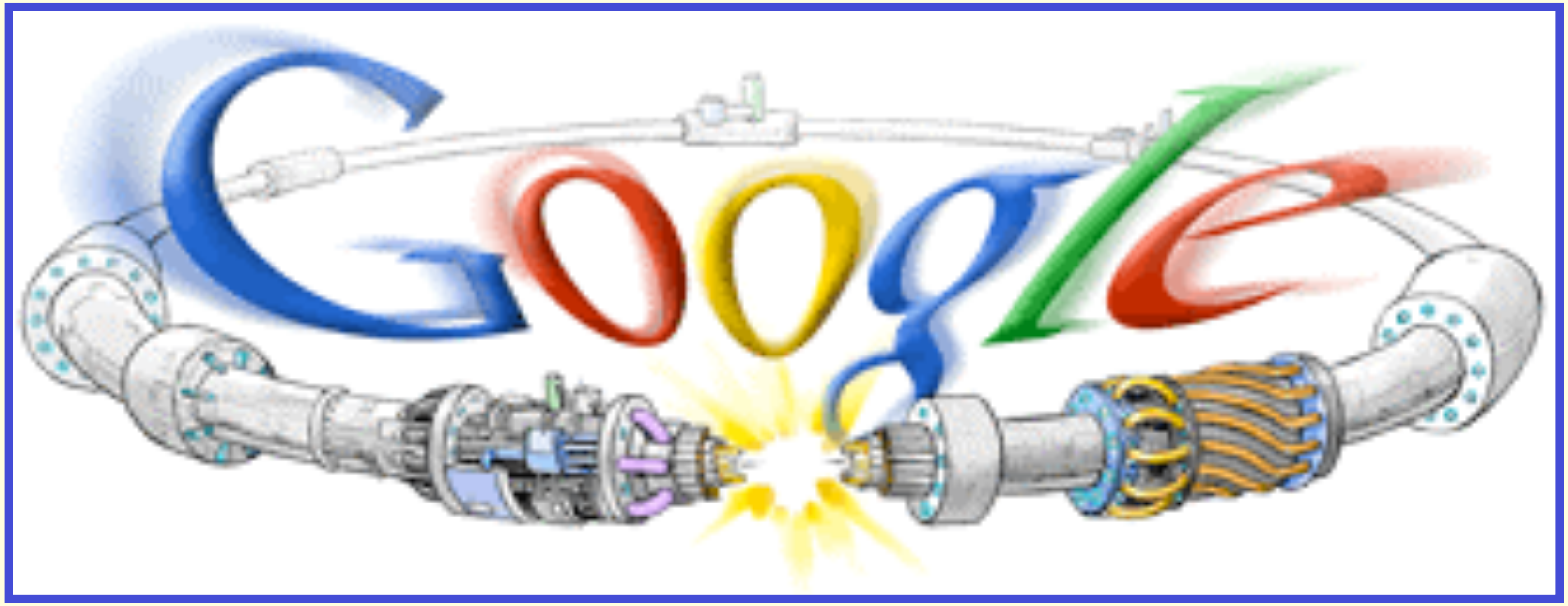
Institute for Nuclear Physics, WWU Münster
International School of Nuclear Physics, 30th Course,
Erice, 20 Sep 2008

Westfälische Wilhelms-Universität Münster

BMBF Forschungsschwerpunkt ALICE Experiment 201

ALICE

10 September 2008



19 September 2008

Spiegel Online, 20 Sep 2008

overheated supermagnet

the most expensive experiment of the world is broken

ÜBERHITZTER SUPERMAGNET

Das teuerste Experiment der Welt ist kaputt

Der Schaden ist noch größer als zunächst befürchtet - der nagelneue, Milliarden Euro teure Teilchenbeschleuniger bei Genf muss für mindestens zwei Monate abgeschaltet werden. Grund: Die Überhitzung von mächtigen Elektromagneten, die den Teilchenstrahl im Zaum halten müssen. *Von Christian Stöcker*

mehr... [Forum]

Prospects for First Physics with ALICE

- **commissioning without beam**
- **first pp running**
- **early heavy ion physics**

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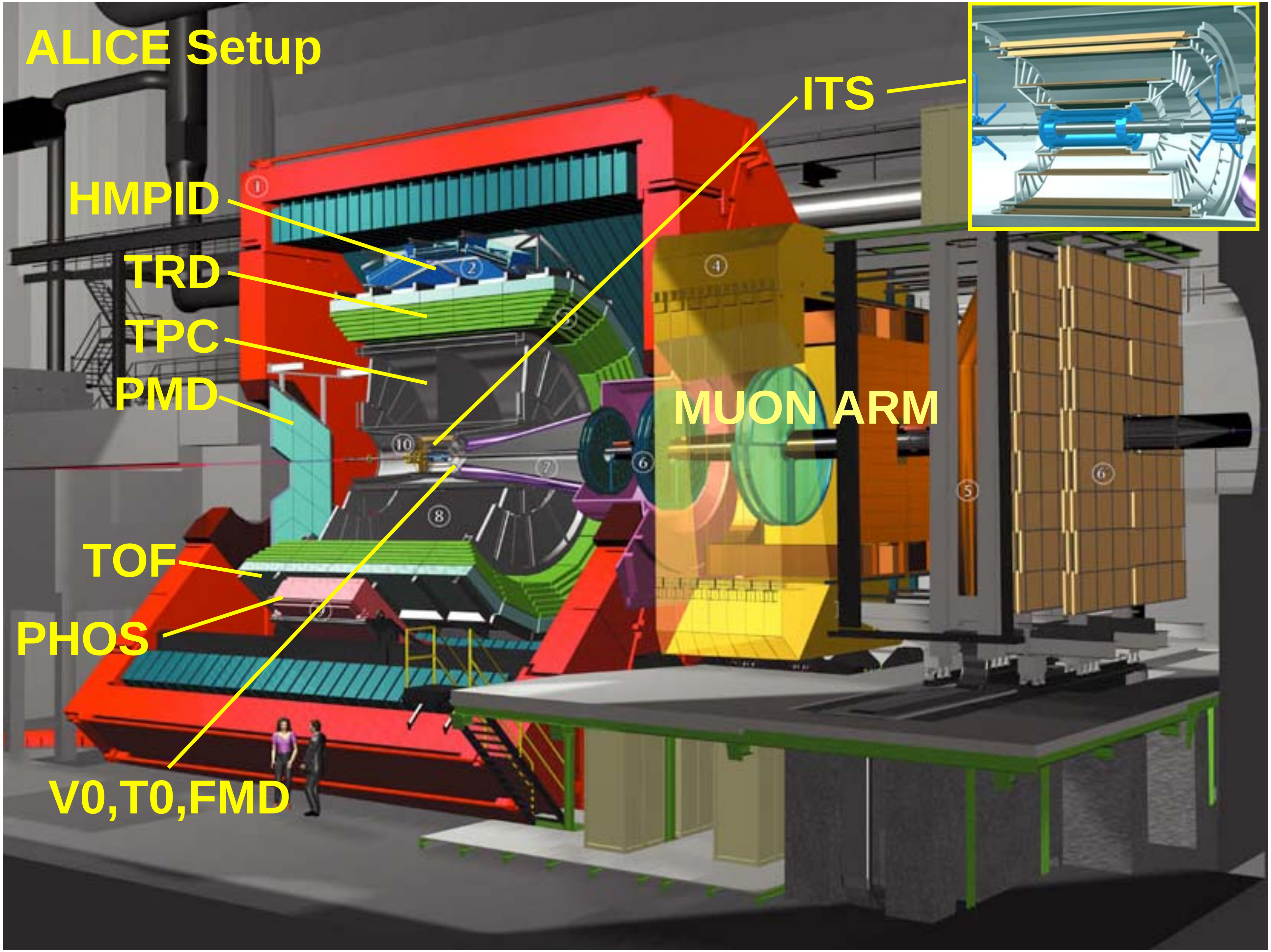

ALICE Setup
ITS
HMPID
TRD
TPC
PMD
MUON ARM
TOF
PHOS
V0,T0,FMD

Start-up Configuration 2008

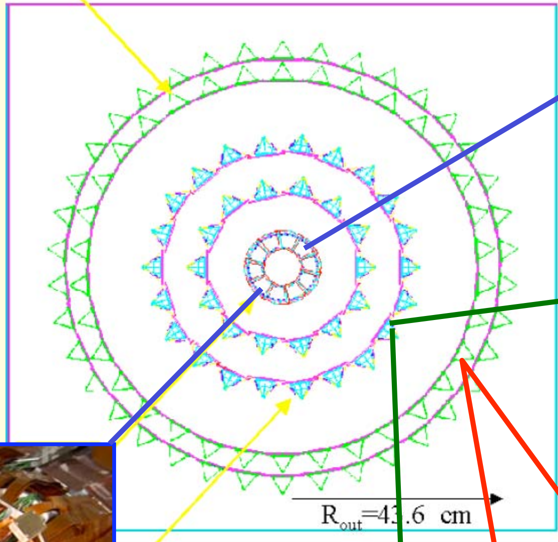
- complete - fully installed & commissioned
  - ITS, TPC, TOF, HMPID, MUONS, PMD, V0, T0, FMD, ZDC, ACORDE, DAQ
- partially completed
  - TRD (25%) to be completed by 2009
  - PHOS (60%) to be completed by 2010
  - HLT (30%) to be completed by 2009
  - EMCAL (0%) to be completed by 2010/11

- at start-up full hadron and muon capabilities
- partial electron and photon capabilities

Overall Plan

- **commissioning phase (ongoing since February)**
  - fully commission trigger, DAQ, ECS
  - align and calibrate the entire system
  - use of beam gas interactions (10 Sep 08)
- **first pp run (on the verge of being started)**
  - important pp reference data for heavy ions
  - minimum bias running
  - unique pp physics to ALICE
- **early heavy ion run (10^6 s @ 1/20 luminosity - 10d 2009)**
  - establish global event characteristics
  - bulk properties (thermodynamics, hydrodynamics…)
  - start of hard probe measurements

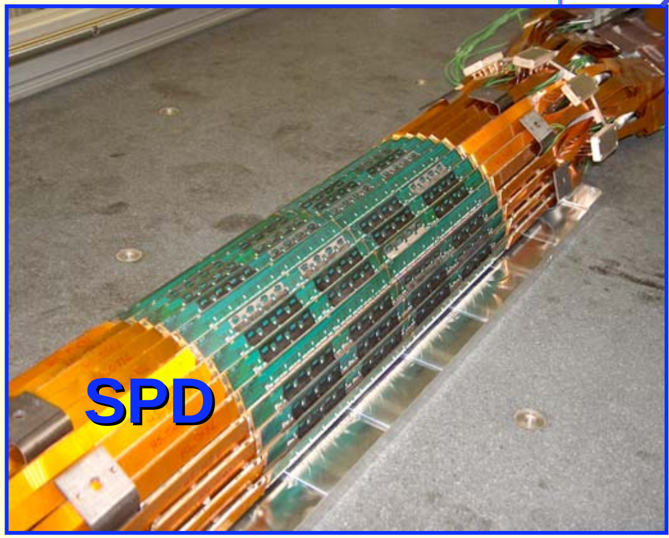
Alignment of Inner Tracking System (ITS)

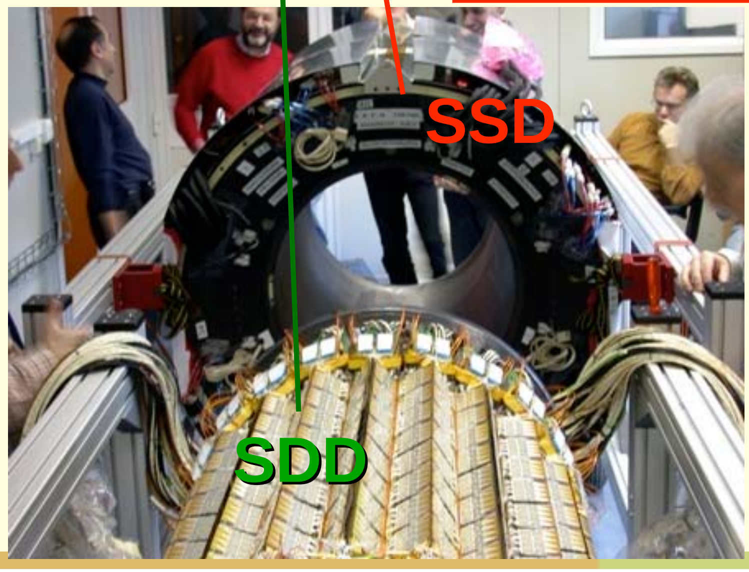


Silicon Pixel Detector (SPD):
- ~10M channels
- 240 sensitive vol. (60 ladders)

Silicon Drift Detector (SDD):
- ~133k channels
- 260 sensitive vol. (36 ladders)

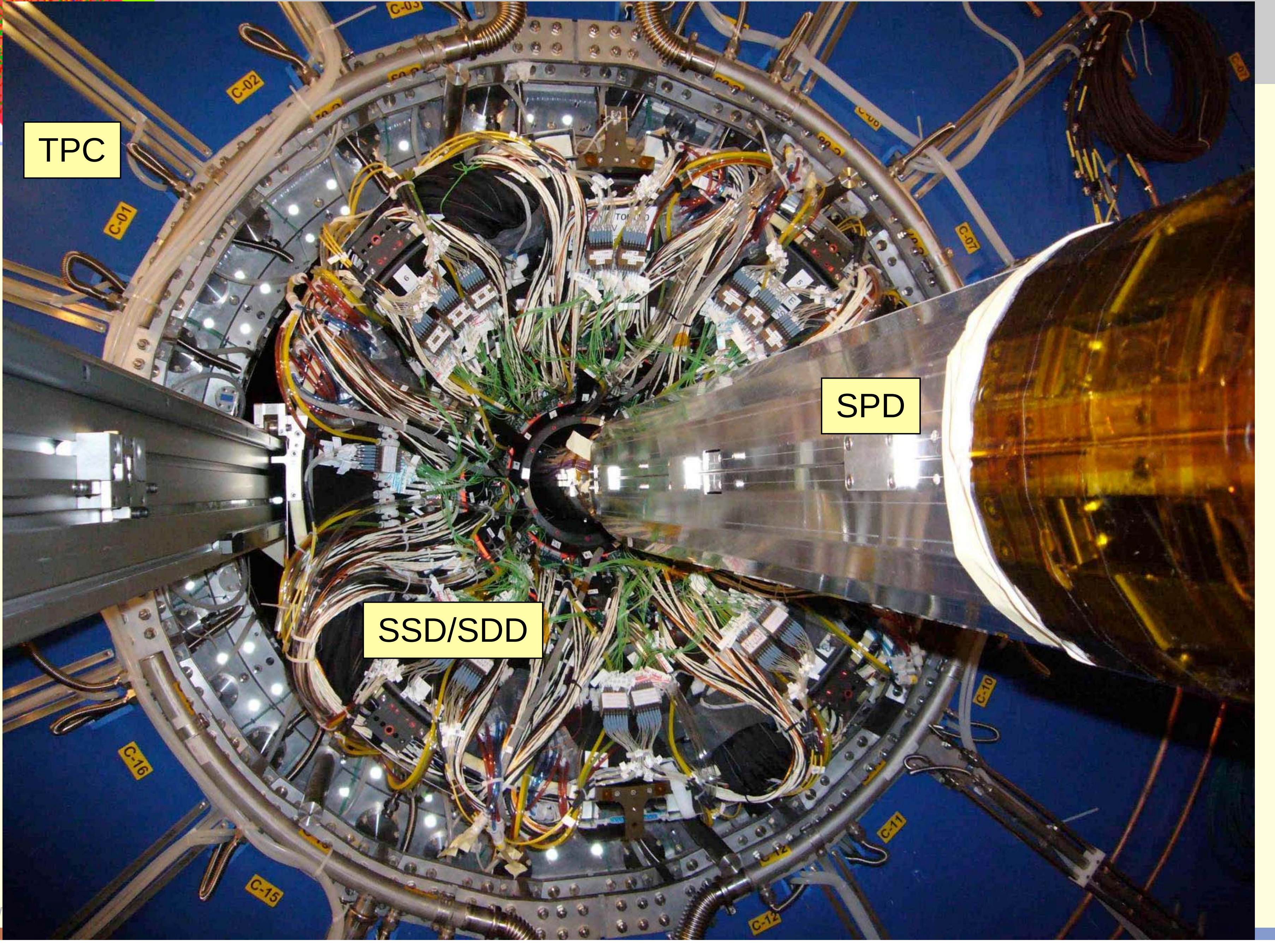
Silicon Strip Detector (SSD):
- ~2.6M channels
- 1698 sensitive vol. (72 ladders)



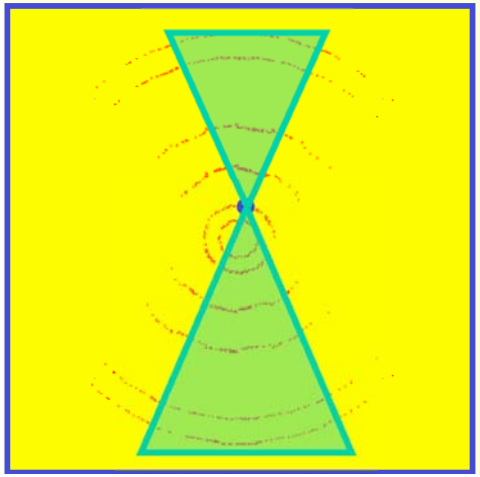


ITS total:
2198 alignable sensitive volumes
→ 13188 d.o.f.

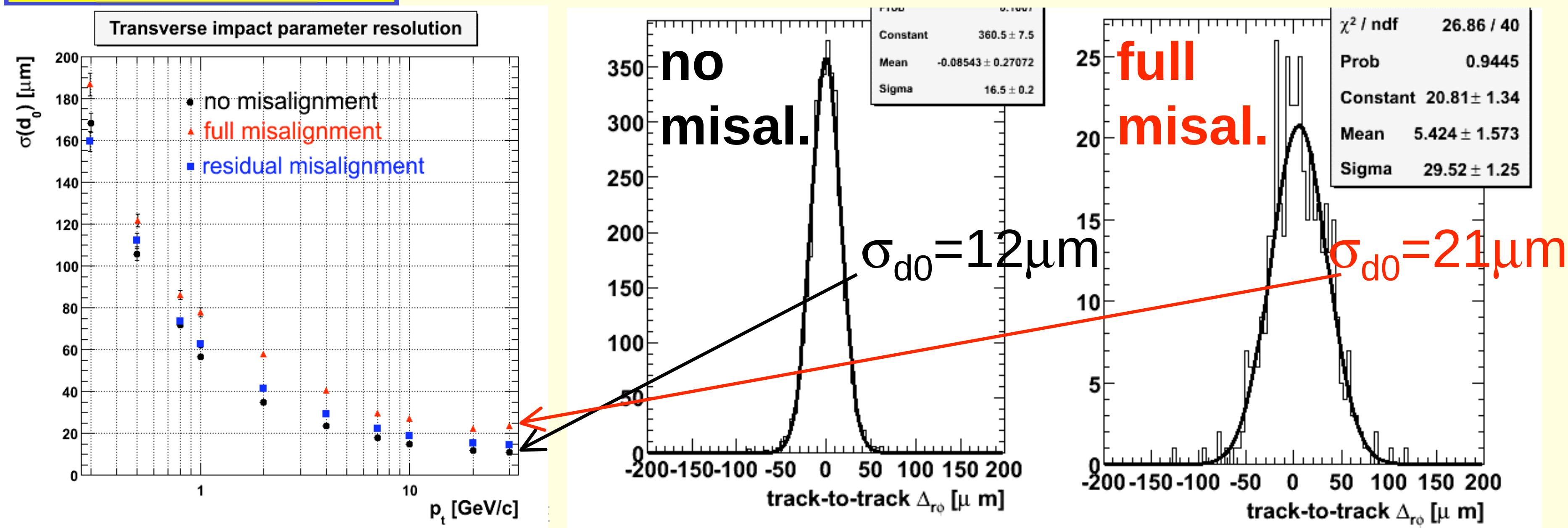
ITS Russian Dolls - Sliding the SSD/SDD over the SPD



ITS Alignment with Cosmics

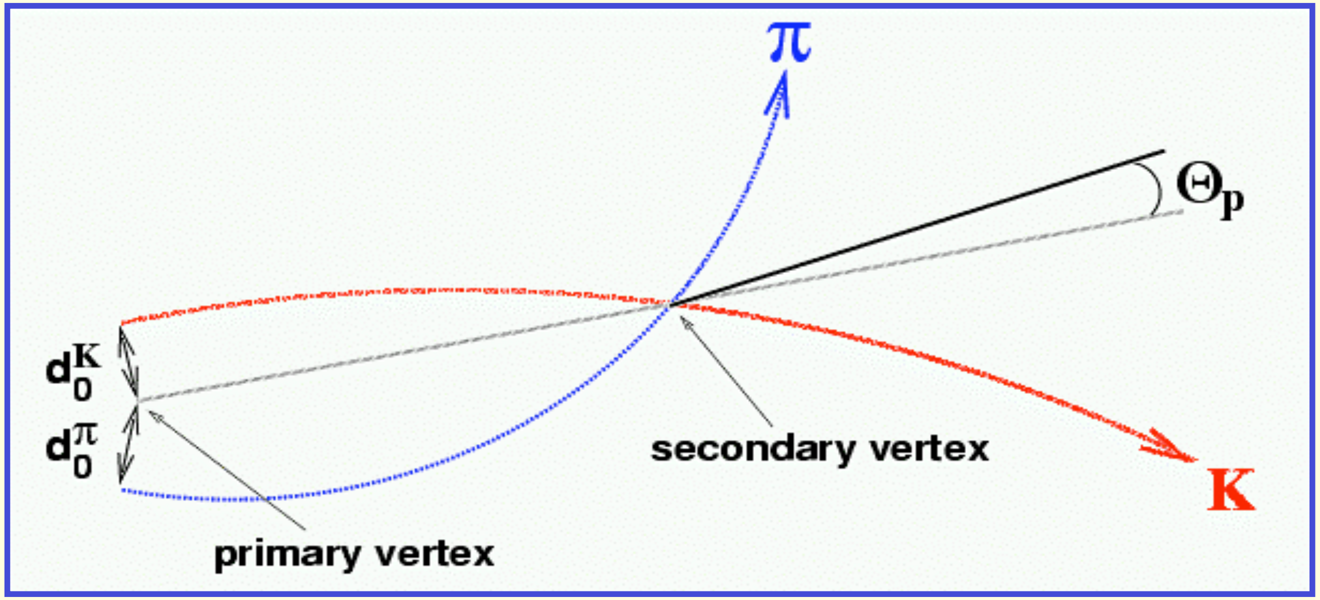


- ITS tracking of cosmics: at IP2: p > 10 GeV/c, <p>~20 GeV/c
  (Hebbeker, Timmermans, 2001)
  - expect 10^4 μ/wk in ITS
  - uses L0 SPD FastOR trigger (ε=81% w. 97% purity)
  - robustness tested with “extreme” misalignment scenarios
- provides partial alignment (5 weeks -> SPD - order 10 μm)
- d_0 resolution measurement via two-track matching of cosmics



Importance for Weak Decays (D,B)

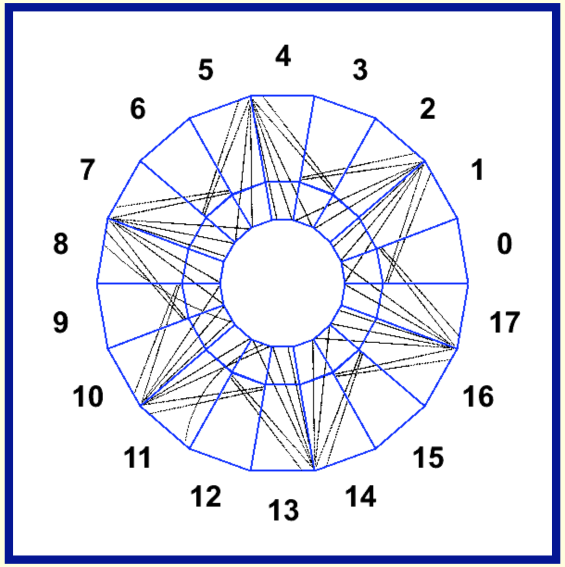
- **resolution of d_0 is the key parameter for the reconstruction of weak decays of D- and B-mesons**



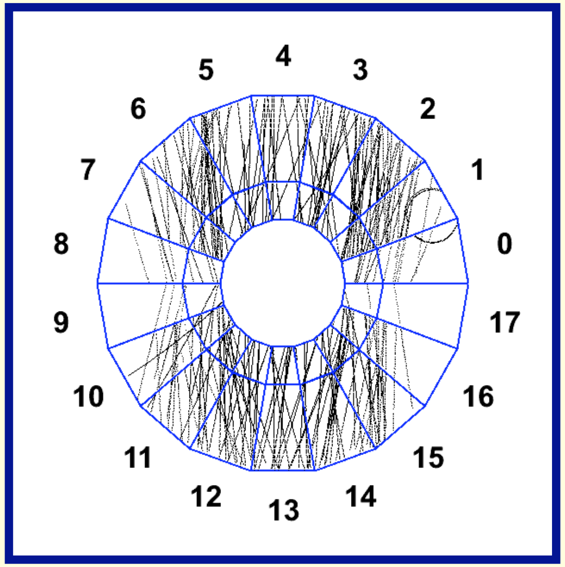
decay length: $c\tau$= 300-500 μm ($D^{\pm}$), $c\tau$ =124 μm (D^0)

TPC Alignment Calibration

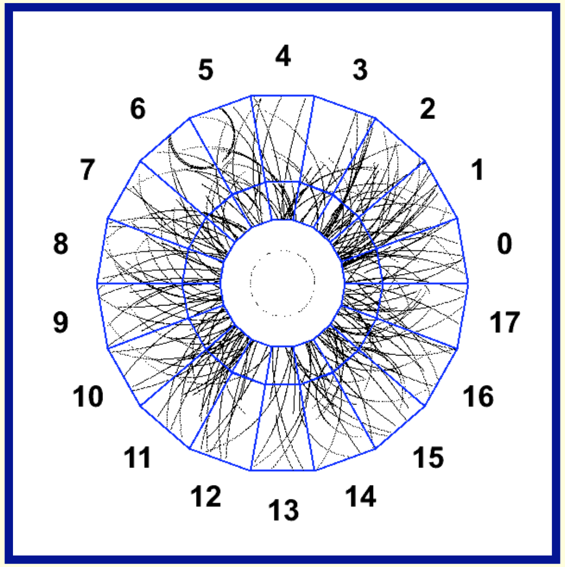
Laser



Cosmics

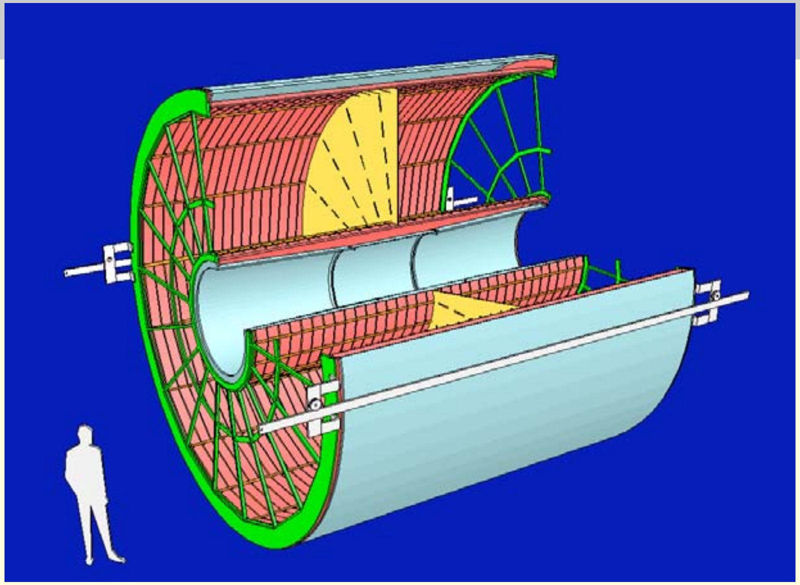


pp Events



- **laser system for drift velocity determination and ExB-measurement**
- **100 samples, each with ~2300 tracks (fitted and extrapolated)**
- **60-70 μm precision in x and y, 30 μm – in z**
initial requirement: better than 100 μm
- **< 0.05 mrad precision on rotation angles**
initial requirement: better than 0.1 mrad

TPC - The Largest Ever

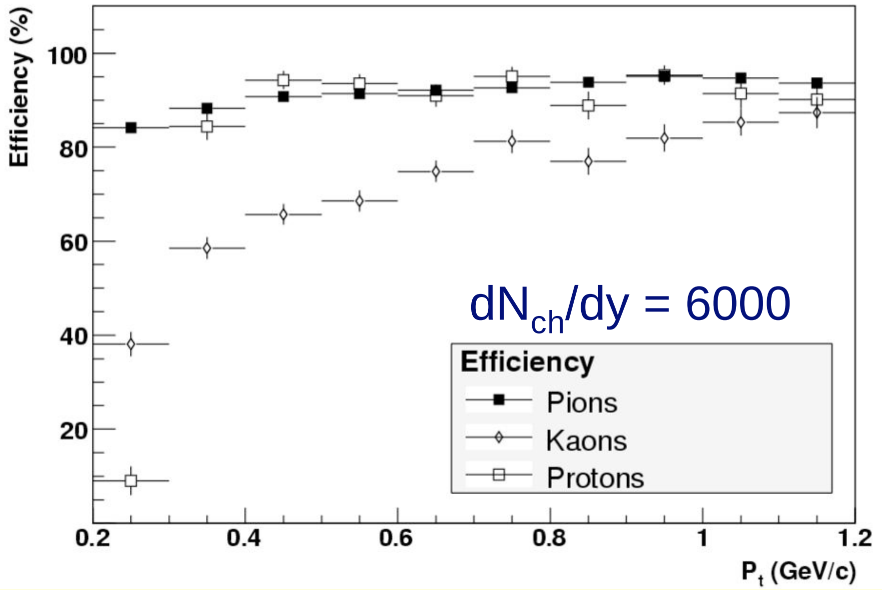


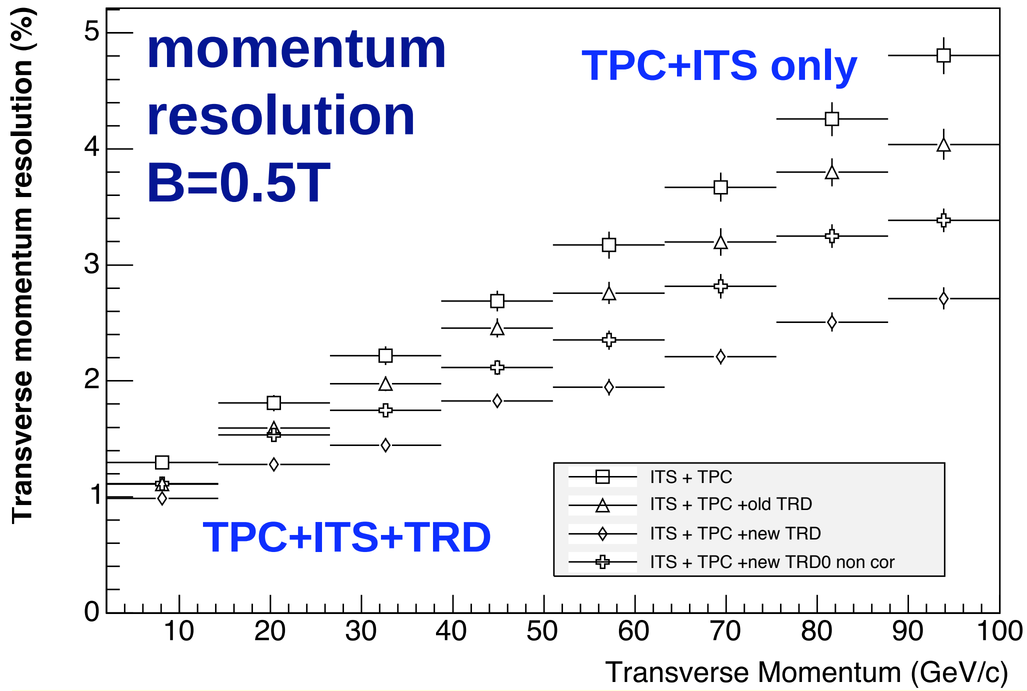
- radius: 85 cm – 247 cm
- length: 2x2.5 m
- gas: Ne/CO_2 (90/10) 88 m^3
- drift time: 88 μs (500 bins)

- #channels: 560,000
- 560 million pixels
- max. trigger rate: 200 Hz
- 180 space points/track ($\sigma_{x,y,z}$<500μm)
- can handle up 15000 tracks

ALICE Tracking Performance

tracking efficiency at small p

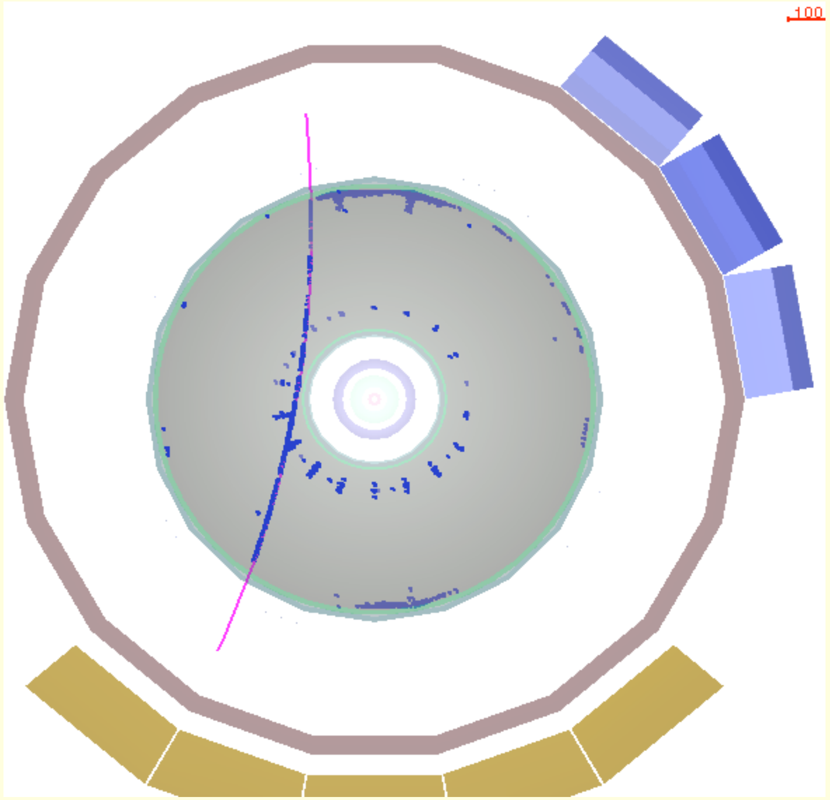




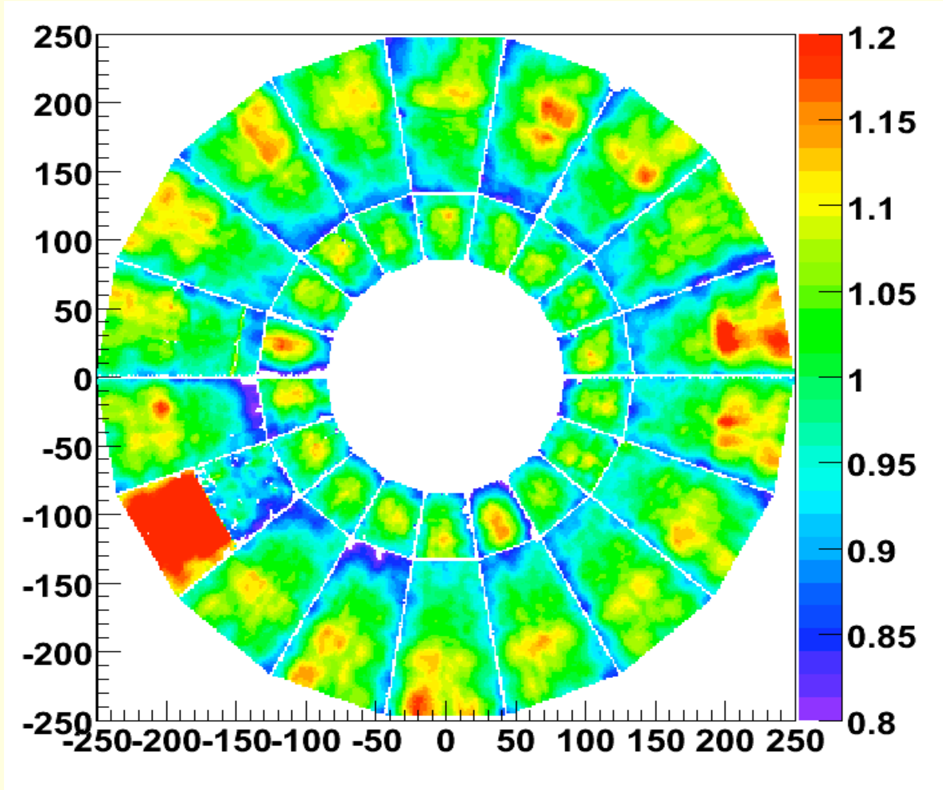
- robust and redundant tracking from ~100 MeV to 100 GeV
- $\delta p/p < 5\%$ at 100 GeV
- in conjunction with excellent particle ID

Actual TPC Performance (I)

C. Garabatos, M. Ivanov, A. Kalweit



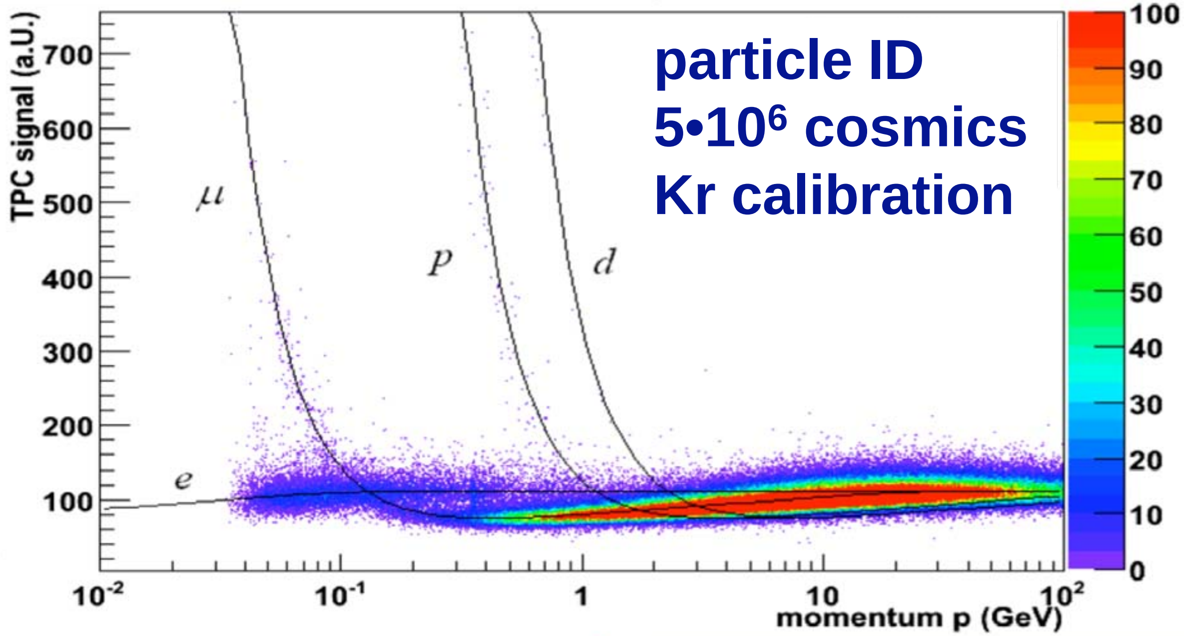
tracking cosmics in magnetic field

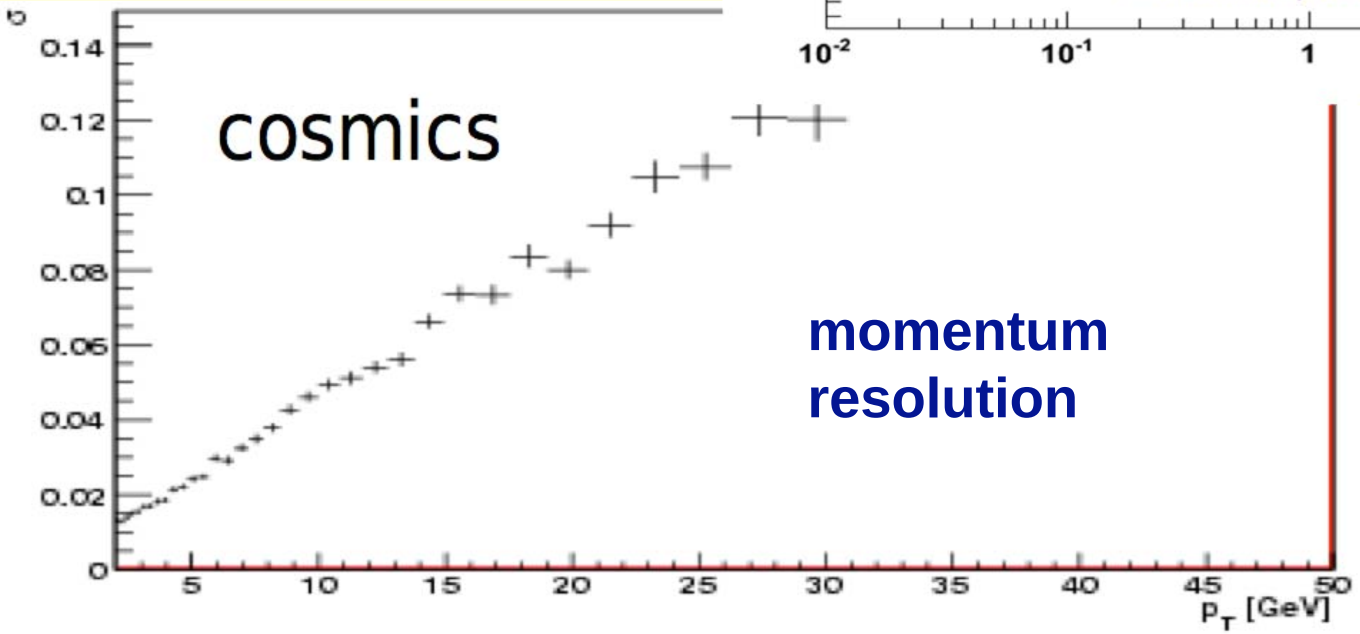


Krypton gain calibration

Actual TPC Performance (II)

M. Ivanov, A. Kalweit





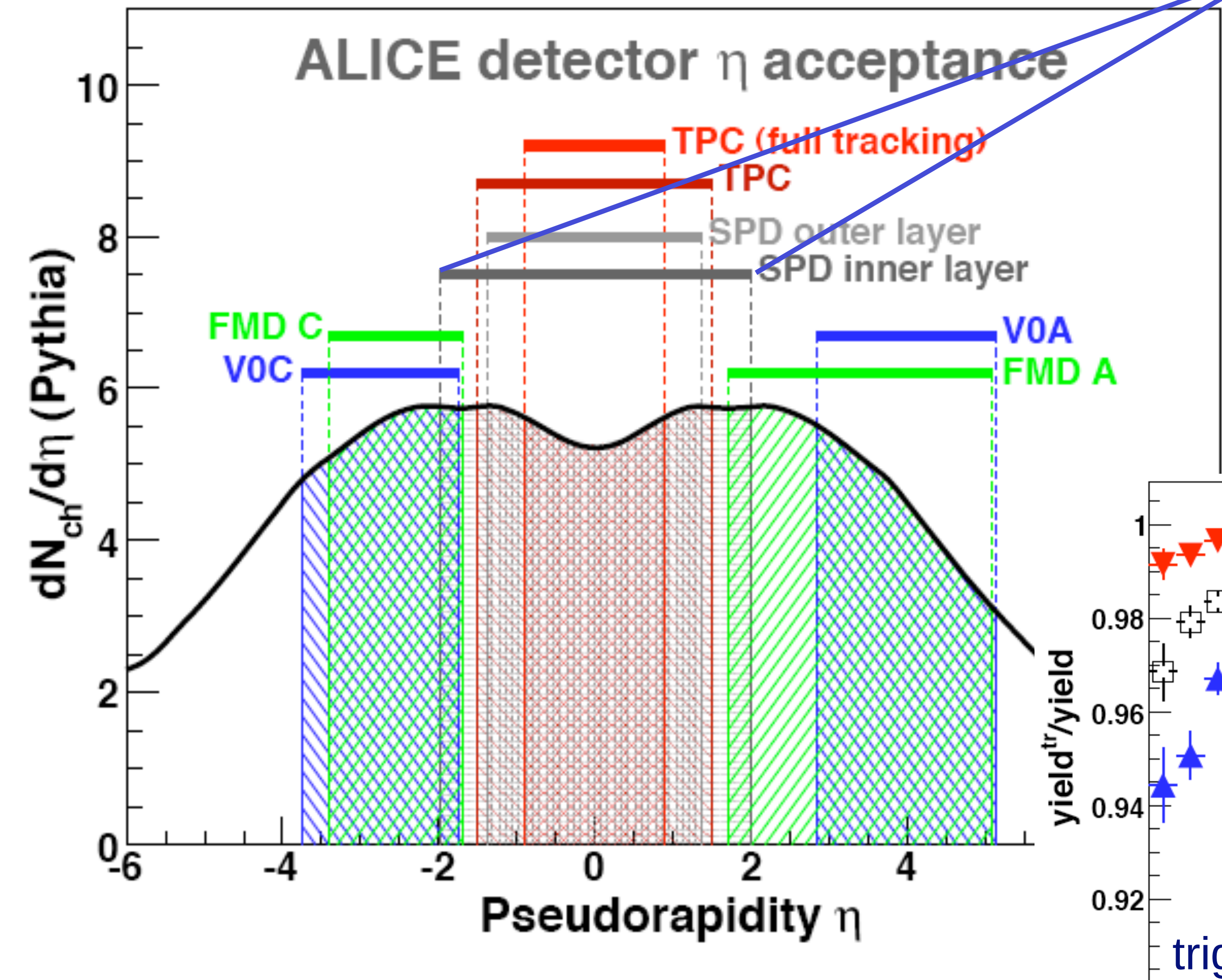
pp Physics with ALICE

- ALICE detector performs very well in pp
  - very low momentum cutoff (<100 MeV/c) new x_T-regime (10^{-5})
  - p_t-reach up to 100 GeV/c comparison to other experiments
  - excellent particle identification
  - efficient min. bias trigger

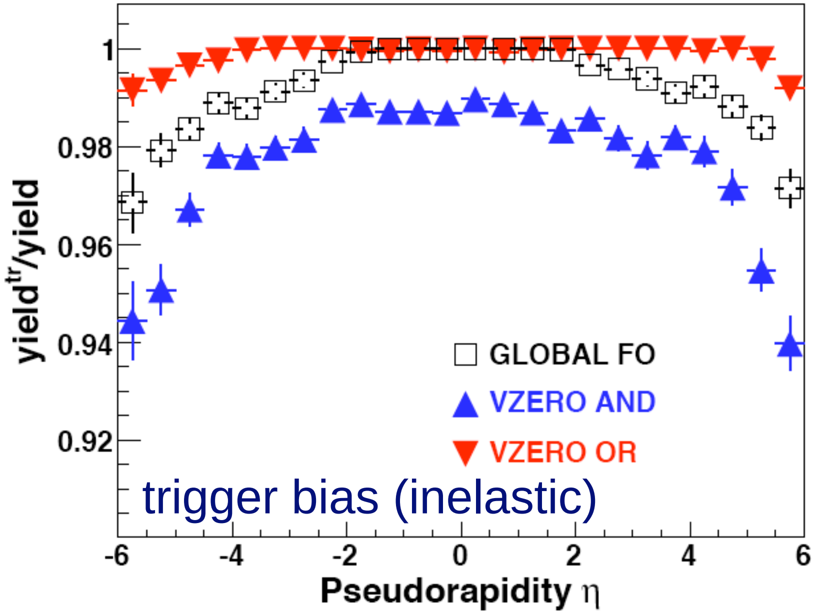
- first physics in ALICE will be pp
  - provides important "reference" data for heavy ion program
- unique pp physics in ALICE e.g.
  - multiplicity distribution
  - baryon transport
  - measurement of charm cross section major input to pp QCD physics

- **start-up**
  - some collisions at 900 GeV
    $\rightarrow$ connect to existing systematics
- **pp nominal run**
  - $\int Ldt = 3 \cdot 10^{30}\ cm^{-2}\ s^{-1} \times 10^7\ s$
    30 pb^{-1} for pp run at 14 TeV
    $N_{pp\ collisions} = 2 \cdot 10^{12}$ collisions
  - muon triggers:
    ~ 100% efficiency, < 1kHz
  - electron trigger:
    ~ 25% efficiency of TRD L1
  - min. bias triggers:
    20 events pile-up (TPC)
    $N_{pp\ minb} = 10^9$ collisions

Day 1 - Charged Particle Acceptance



- operating with fast multiplicity trigger L0 from Silicon Pixels
- efficiency studied for
  - single diffractive
  - double diffractive
  - non-diffractive events



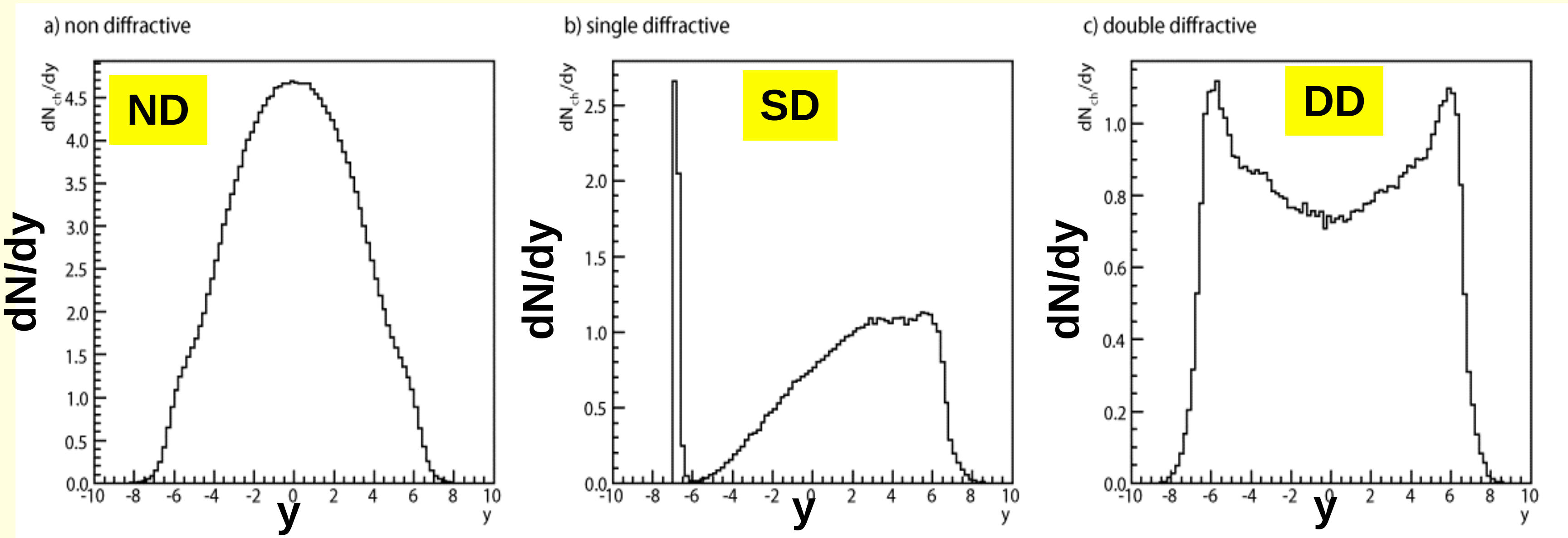
Inelastic Cross Section

J.F. Grosse-Oetringhaus

- previous experiments triggered on and published non-single-diffractive events (NSD)
- ALICE will measure full inelastic cross section

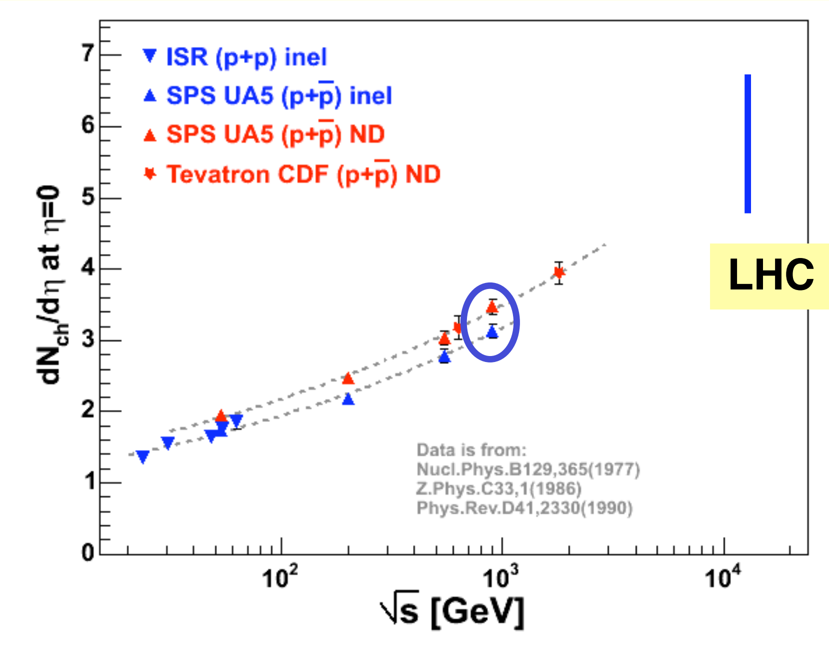
$$\sigma_{\text{total}} = \underbrace{\sigma_{\text{elastic}}}_{\text{insensitive}} + \underbrace{\sigma_{\text{non-diffractive}} + \sigma_{\text{single-diffractive}} + \sigma_{\text{double-diffractive}}}_{\text{ALICE trigger}}$$

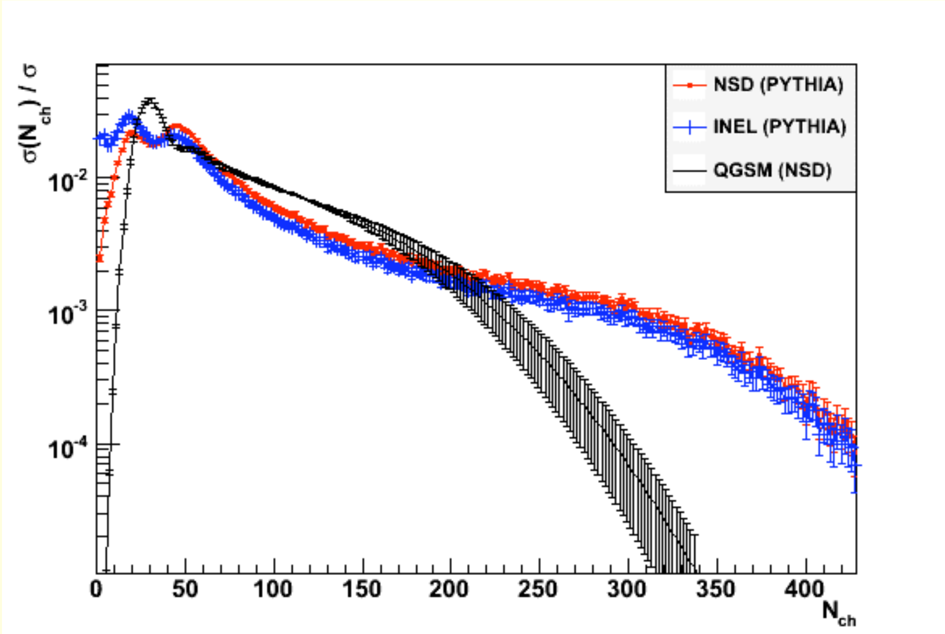
trigger efficiency	
ND-INEL:	98.2%
SD	: 55.4%
DD	: 58.4%



Charged Particle Multiplicity

J.F. Grosse-Oetringhaus

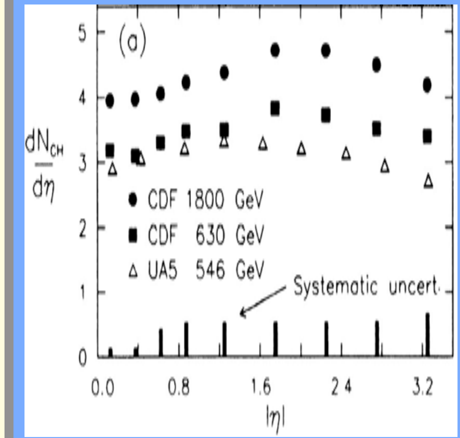




- extend existing energy dependence
- unique SPD trigger (L0) for
  min. bias precision measurement
- new look at fluctuations in pp
  (neg. binomials, KNO…)

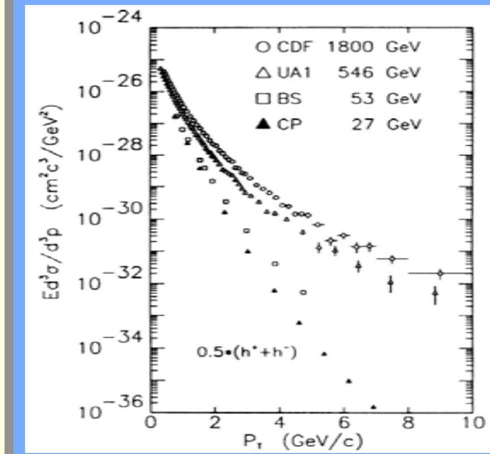
Few 10k Events

C. Jorgensen



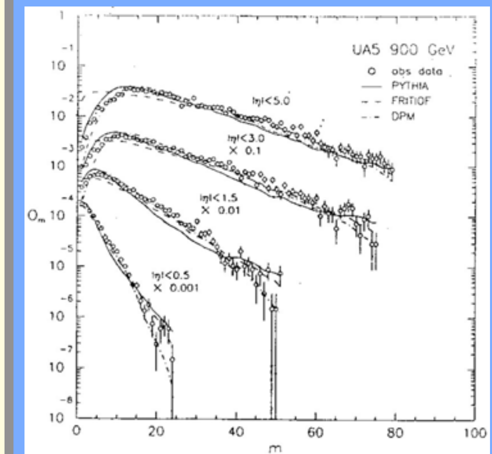
Pseudorapidity density $dN/d\eta$

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



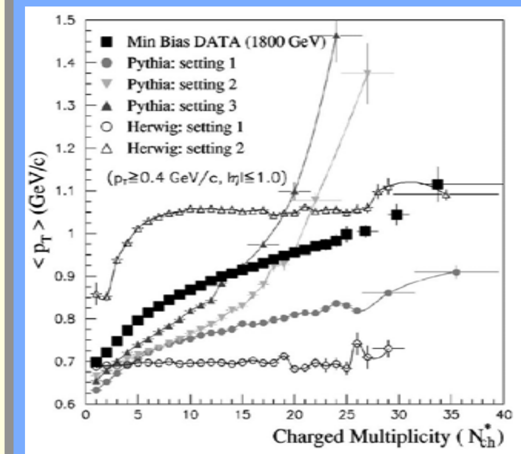
p_T spectrum of charged tracks

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



Multiplicity distribution

UA5:
Z. Phys
43, 357 (1989)



Mean p_T vs multiplicity

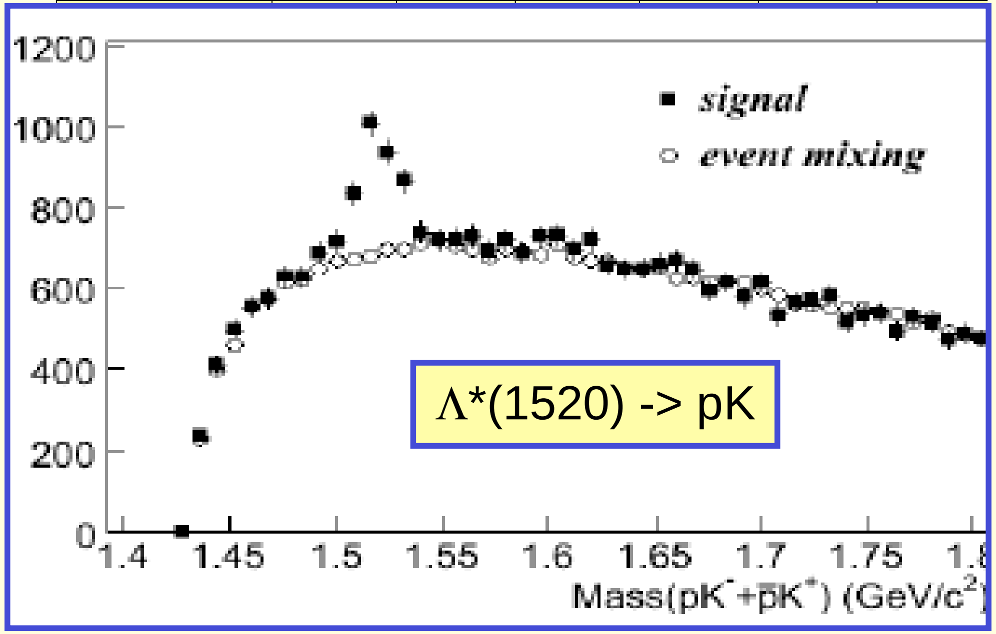
CDF:
Phys. Rev.
D65,72005(2002)

Only a few ten thousand events are necessary for these analyses

First Strange Particle Studies

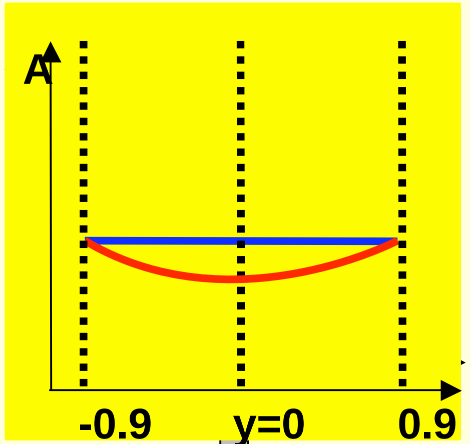
- based on Pythia for LHC
- significant samples of strange particles in 70 million minimum bias events:
- K^0 : $7x10^6$
- Λ: $7x10^5$
- Ξ: $2x10^4$
- Ω: 270
- detailed study of flavor composition

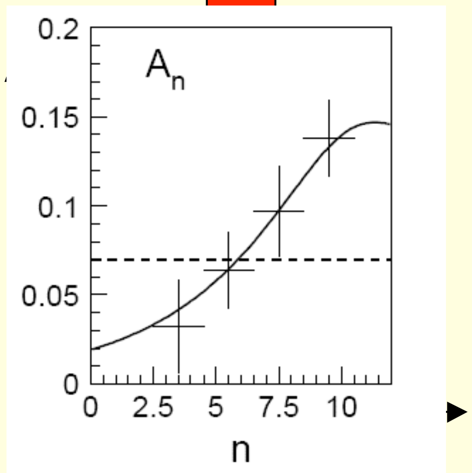
	K_S^0	Λ	Ξ	Ω	p	$\bar{p}$
yield per event	0.1	0.01	2×10^{-4}	10^{-5}	0.4	0.4



Baryon - Antibaryon Asymmetry

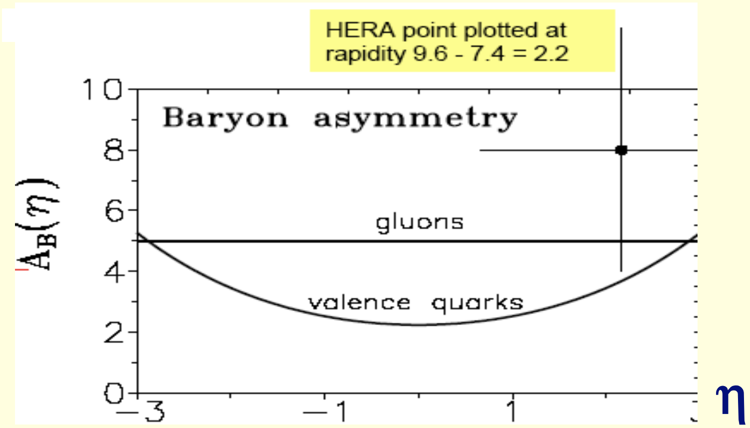
P. Christakoglu





- experimental challenge: distinguish between the two pictures
  baryon number transport via quark exchange
  baryon number transport via string junction exchange
  G.C. Rossi and G. Veneziano, Nucl. Phys B123 (1977) 507
  B.Z. Kopeliovich and B. Zakharov, Z. Phys. C43 (1989) 241
- large rapidity gap at LHC (> 9 units)
- predicted absolute value of the second case ~ 3-7%
- additional prediction: asymmetry multiplicity dependent

$$\boxed{A = 2 \cdot \frac{N_B - N_{\bar{B}}}{N_B + N_{\bar{B}}}}$$

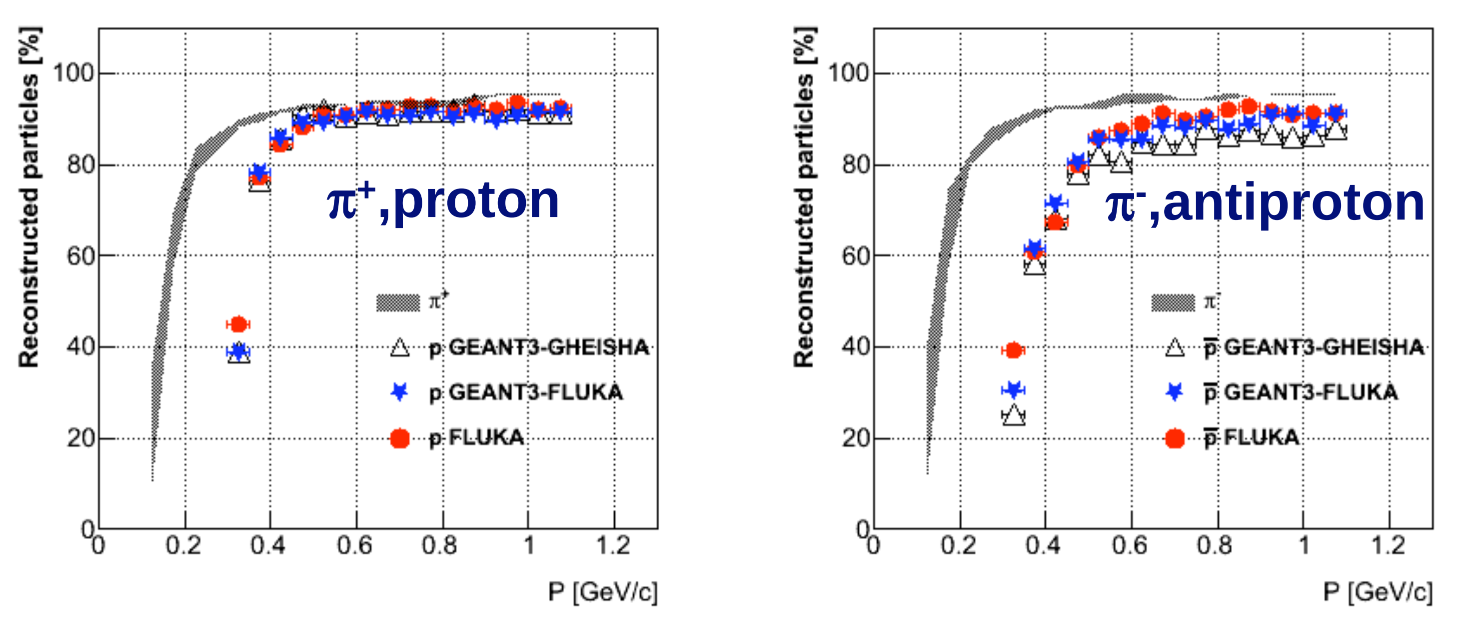


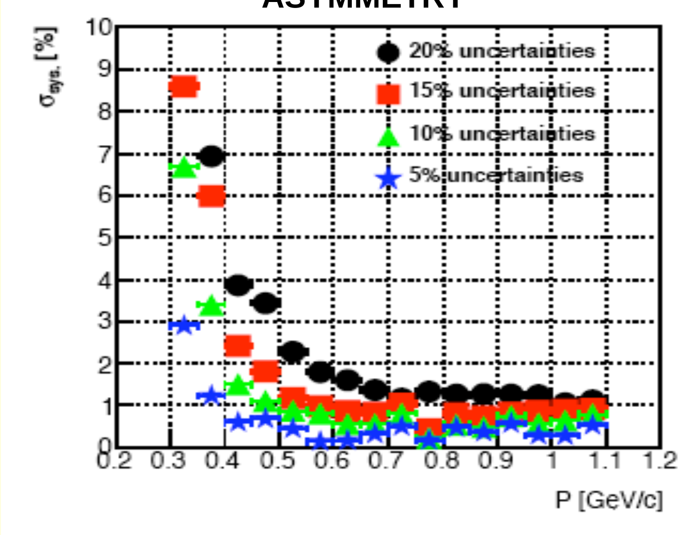
B.Z. Kopeliovich, B. Povh, Phys. Lett. B446 (1999) 321 with H1 data

Baryon - Antibaryon Measurement in ALICE

P. Christakoglu

reconstruction efficiencies



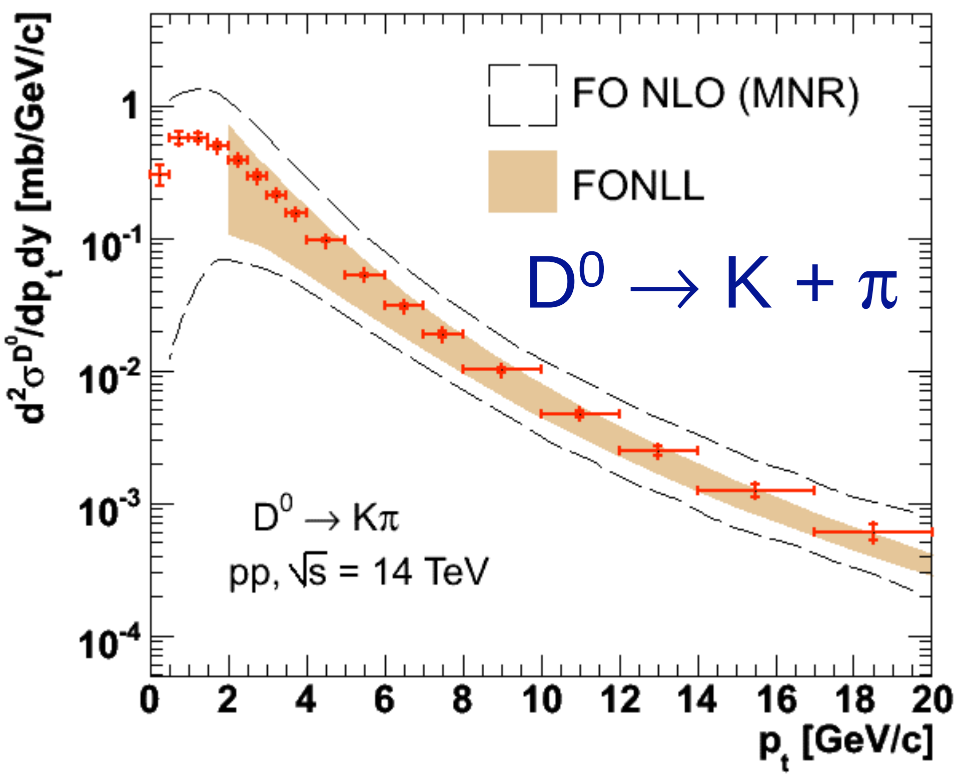


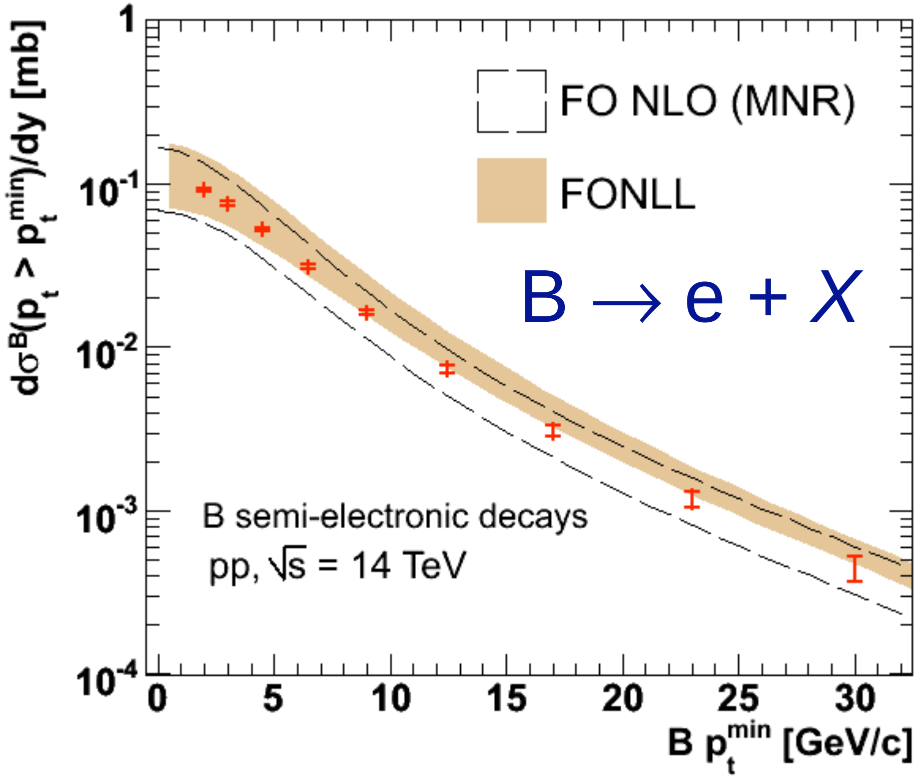
- systematic error of asymmetry below 1% for p > 0.5 GeV/c:
  contributions from uncertainties in the cross sections,
  material budget, beam gas events
- statistical error < 1% for 10^6 pp events (< 1 day)
- can be extended to $\Lambda,\bar{\Lambda}$ (asymmetry larger)

Heavy Flavor Precision Measurements

A. Daiinese

- $D^0 \rightarrow K + \pi$ in pp from reconstructed secondary vertices
- $B \rightarrow e + X$ in pp (depends on initial TRD overage)

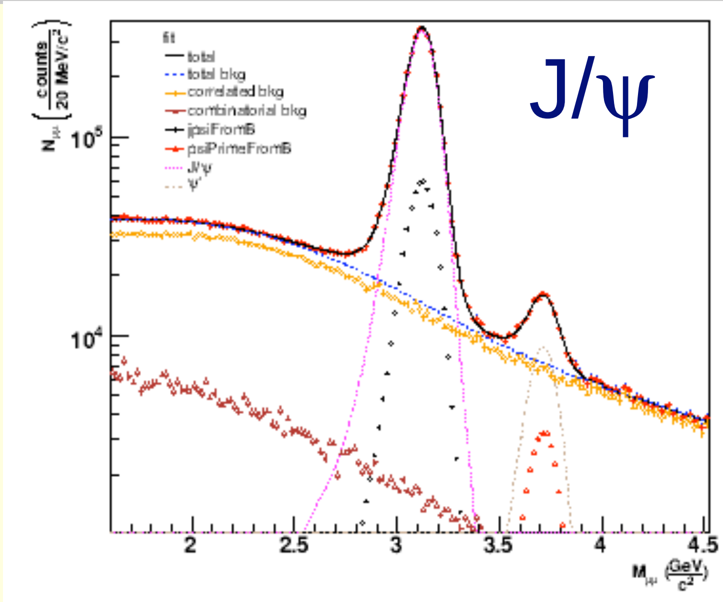




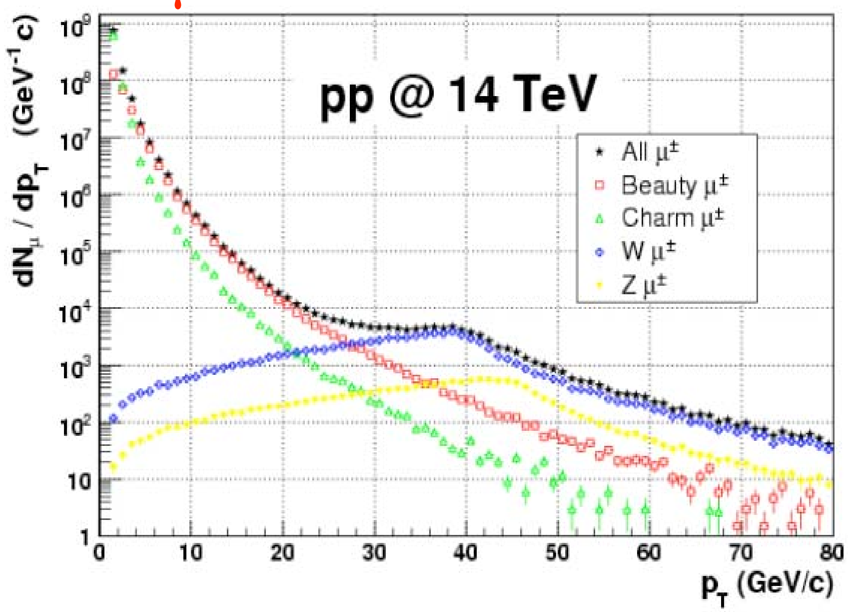
- expected sensitivity in comparison to different pQCD parameterizations (from 10^9 events)

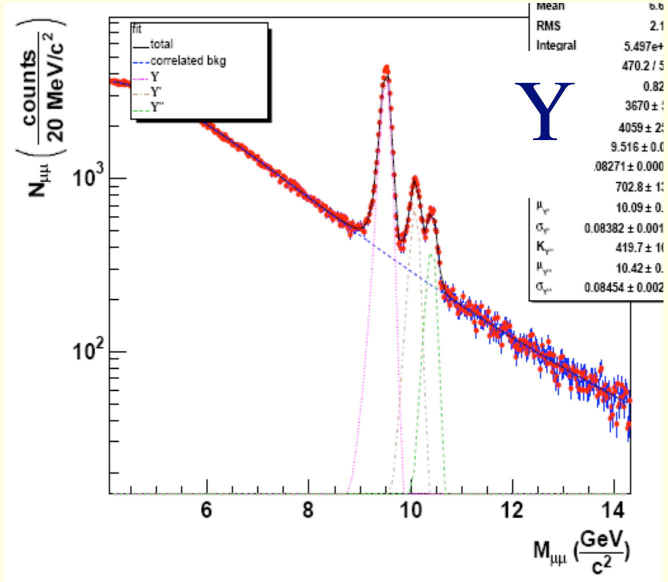
Heavy Flavor in Muon Channel

- **muon channel: J/ψ, Υ → $\mu^+\mu^-$**
  (2.5 <y< 4)
  60000 J/ψ and 2000 Υ
- initial sample sufficient to study production rates of J/ψ and Υ states in muon channel



- **b → μ**





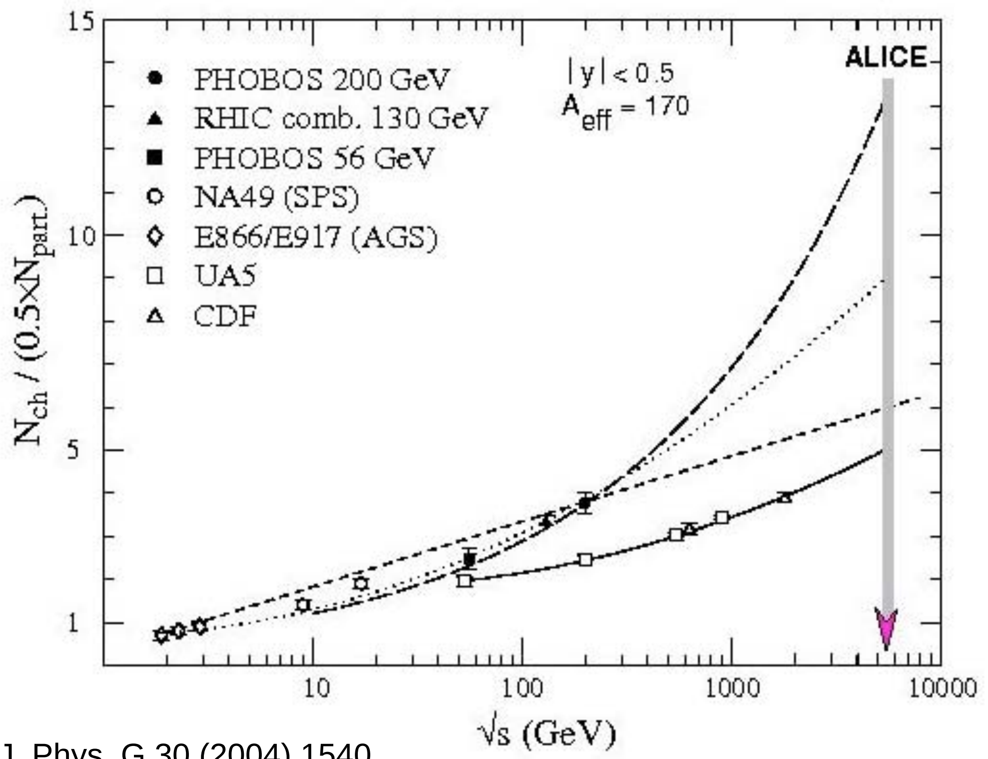
Heavy Ion Physics with ALICE

- fully commissioned detector and trigger
  - alignment and calibration available from pp
- **first 10^5 events:** global event properties
  - multiplicity, rapidity density
  - collective flow
- **first 10^6 events:** source characteristics
  - particle spectra, resonances
  - differential flow analysis
  - interferometry
- **first 10^7 events:** high p_t, heavy flavors
  - jet quenching, heavy flavor 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
    $N_{PbPb\ collisions} = 2 \cdot 10^8$ collisions (400 Hz)
  - muon triggers:
    ~ 100% efficiency, < 1kHz
  - centrality triggers:
    bandwidth limited
    $N_{PbPbminb} = 10^7$ events (10Hz)
    $N_{PbPbcentral} = 10^7$ events (10Hz)

Estimated Charged Particle Multiplicity Density

integrated multiplicity distributions from Au+Au/Pb+Pb collisions and scaled p+p collisions



J. Phys. G 30 (2004) 1540

$dN_{ch}/dy = 2600$

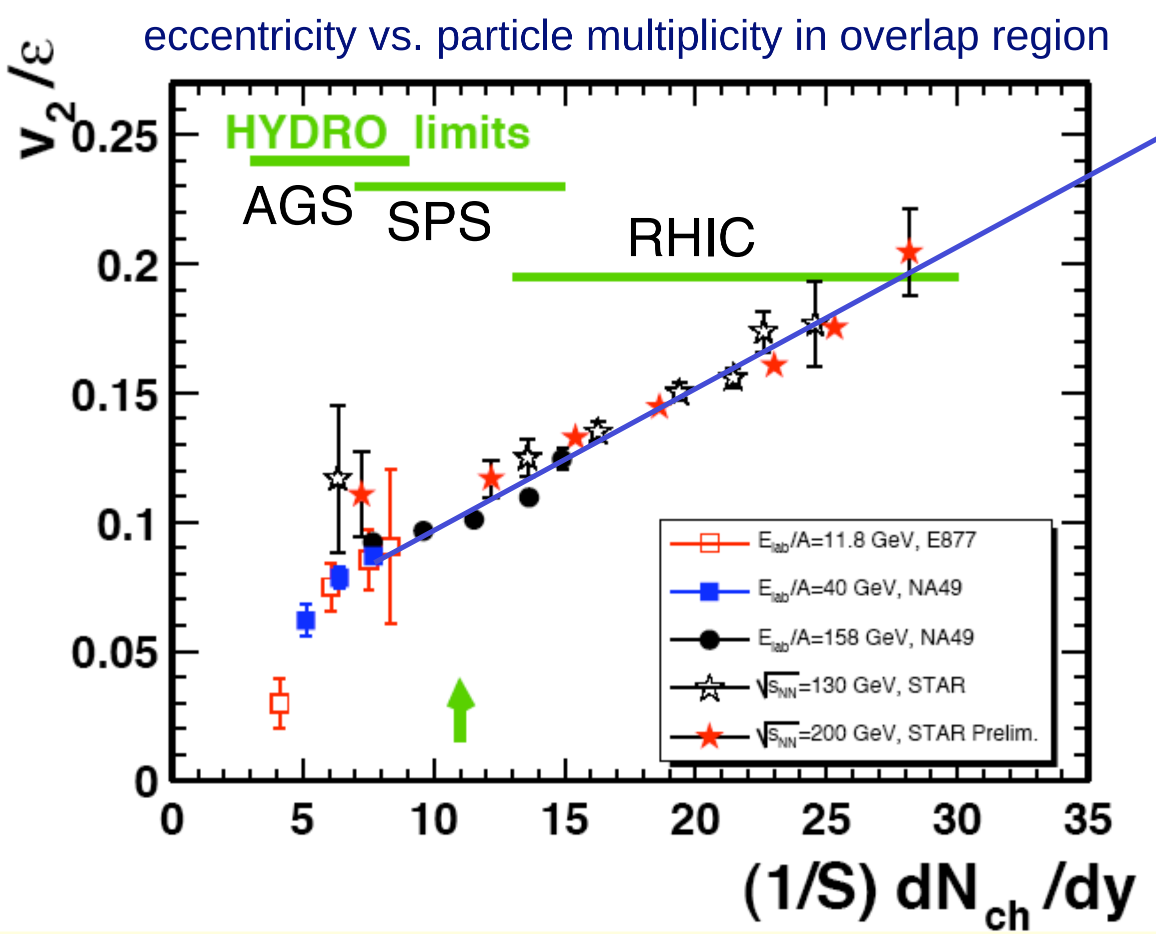
saturation model
Eskola hep-ph/050649

$dN_{ch}/dy = 1200$

ln($\sqrt{}$ s) extrapolation

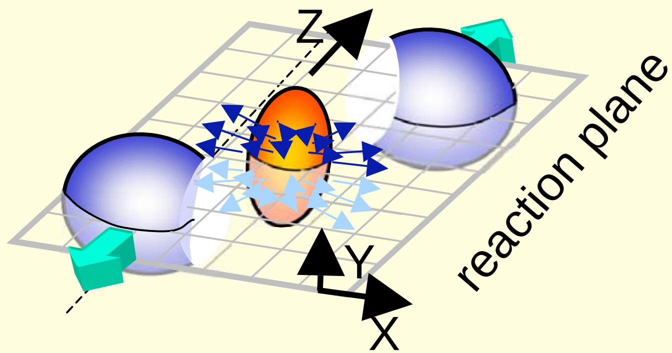
- **ALICE designed (before RHIC) for $dN_{ch}/dy = 3500$ design checked up to $dN_{ch}/dy = 7000$**

Elliptical Flow - Day 1 Physics



LHC

- data increase linearly
- hydrodynamical limit reached at RHIC → 'ideal fluid'
- clear predictions from hydrodynamics
- sensitive to equation-of-state

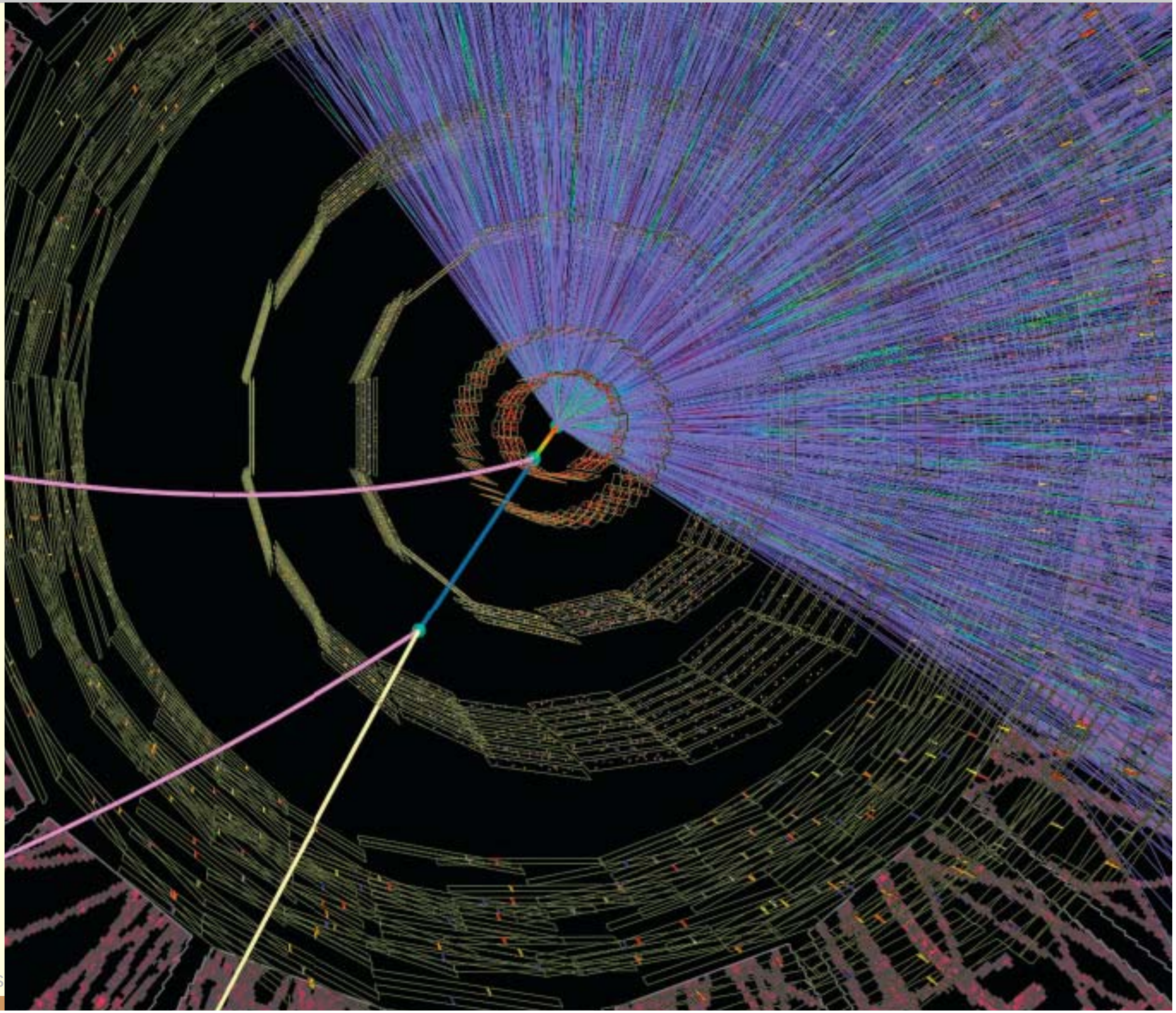


- **very robust signal - no PID necessary**
- **event plane resolution < 10º**

Tracking Challenge

with part of the event removed displaced vertices can be seen

$$\Xi^- \rightarrow \Lambda\pi^-$$



Reconstruction of Resonances ($\rho,\phi,K^*,K^0_s,\Lambda,\Xi,\Omega\ldots$)

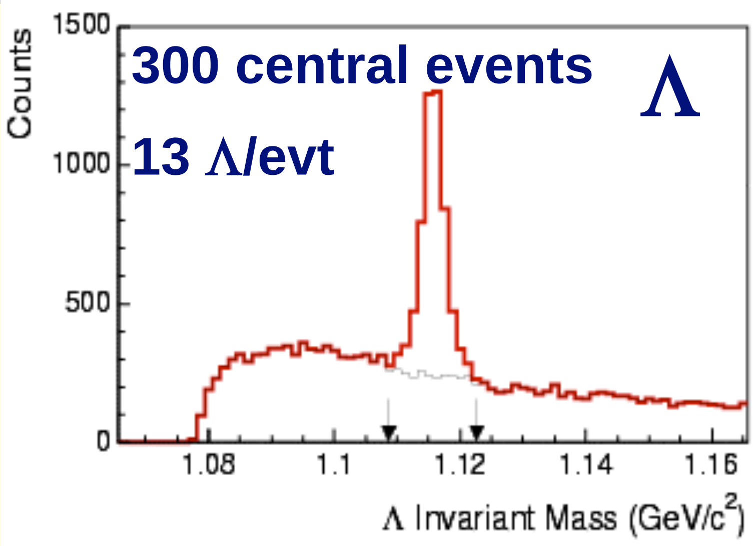
10^7 events:

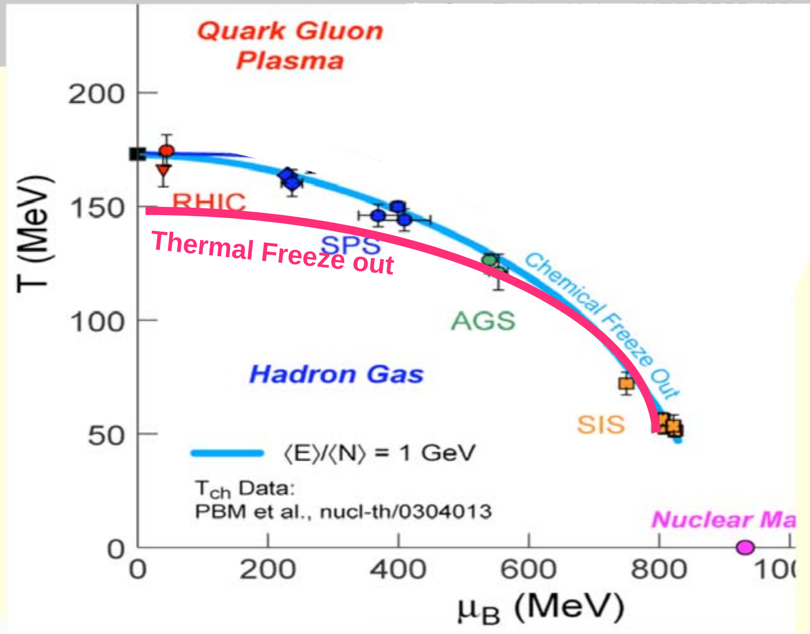
p_t reach ϕ,K,Λ

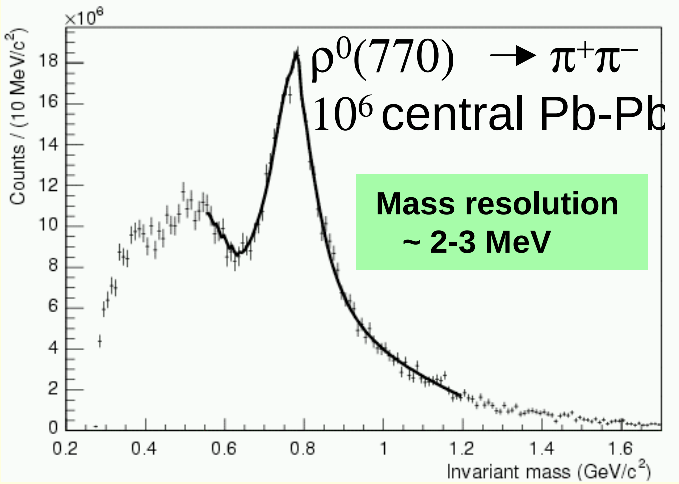
~ 13-15 GeV

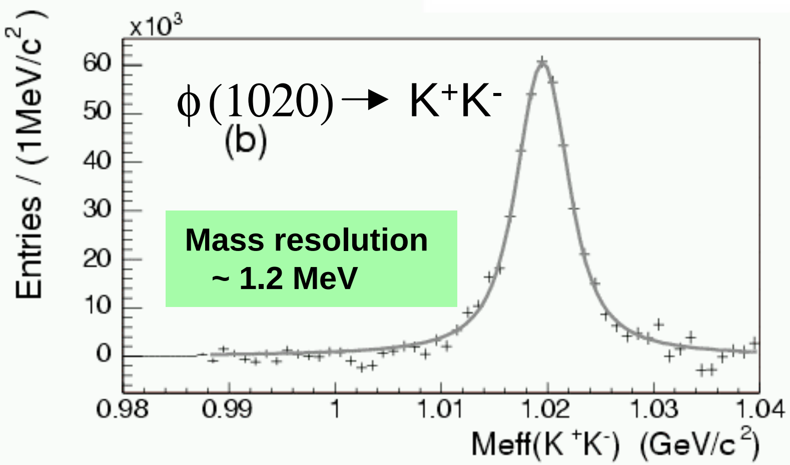
p_t reach ρ,Ξ,Ω

~ 9-12 GeV









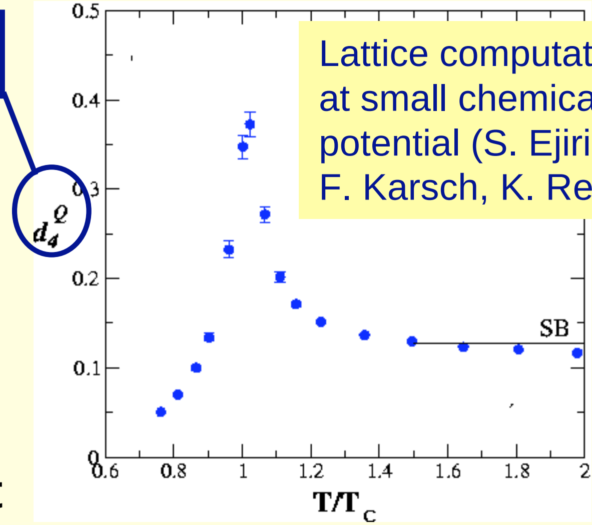
- **hadrochemical analysis**
- **chemical / kinetic freeze-out**

- **medium modifications of mass, widths**

Event-by-Event Fluctuations

4th moment of the net charge

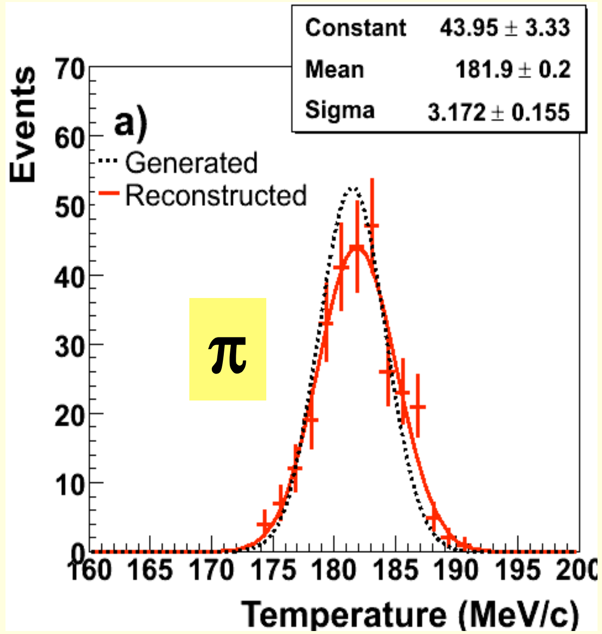
Fluctuations are associated with phase transition



Lattice computations at small chemical potential (S. Ejiri, F. Karsch, K. Redlich)

Multiplicities at LHC allow for measurement of event-by-event fluctuations

$<p_T>$, T, multiplicity, particle ratio, strangeness, azimuthal anisotropy, long range correlations, balance function, …



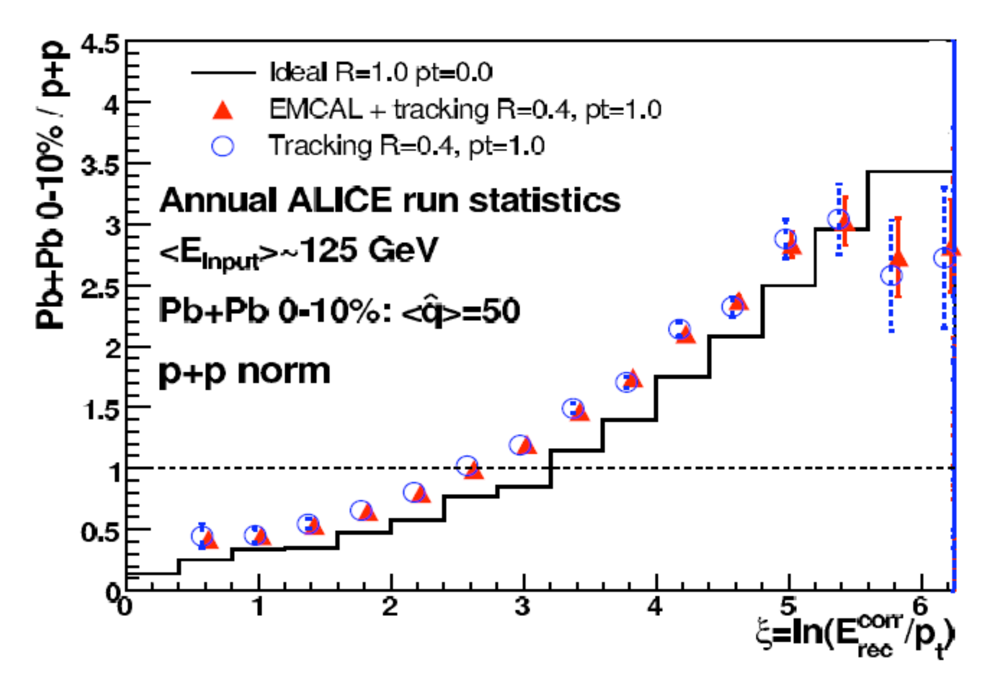
Resolution σ_T/T: 0.5 % for π

Jet Production at LHC

10^7 events

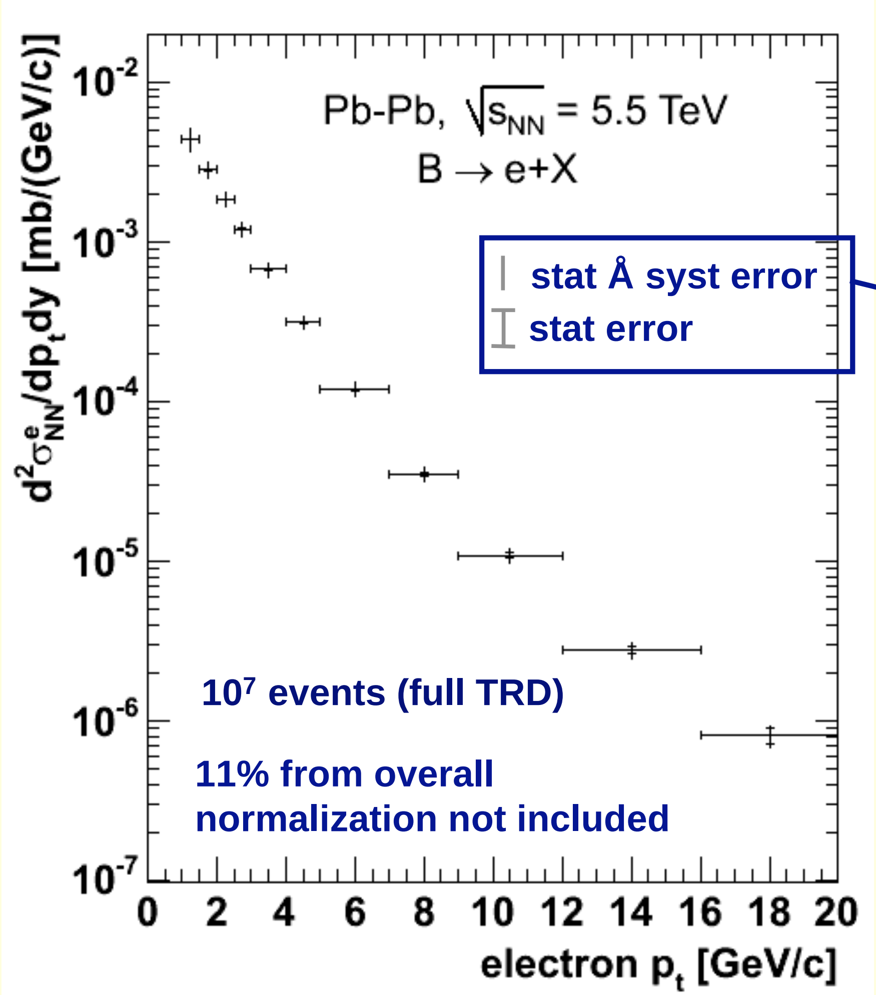
- first measurement up to 100 GeV (untriggered charged jets only)
- detailed study of fragmentation possible
- sensitive to energy loss mechanism
- accuracy on transport coefficient <^q> ~20%

p_t jet > (GeV/c)	jets/event Pb+Pb
5	**$3.5\ 10^{2}$**
50	**$7.7\ 10^{-2}$**
100	$3.5\ 10^{-3}$
150	**$4.8\ 10^{-4}$**
200	**$1.1\ 10^{-4}$**

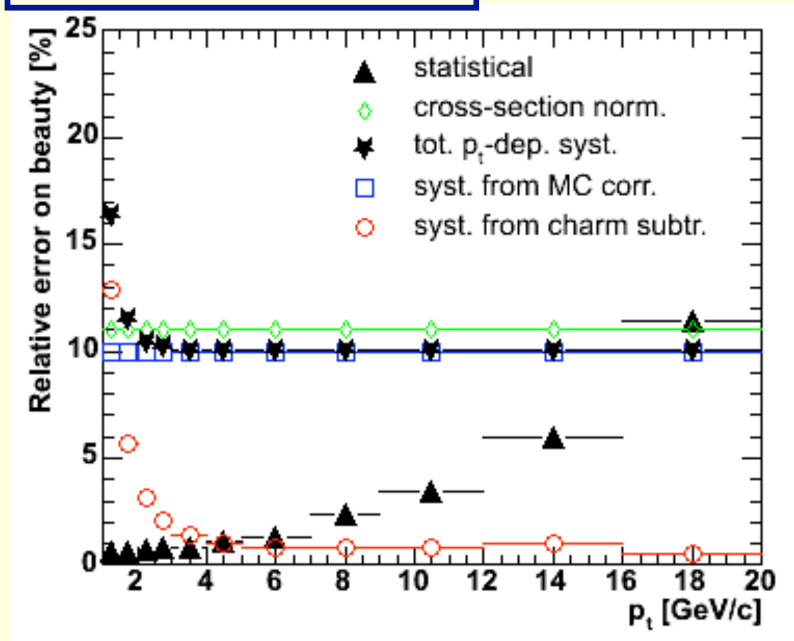


$B \rightarrow e + X$

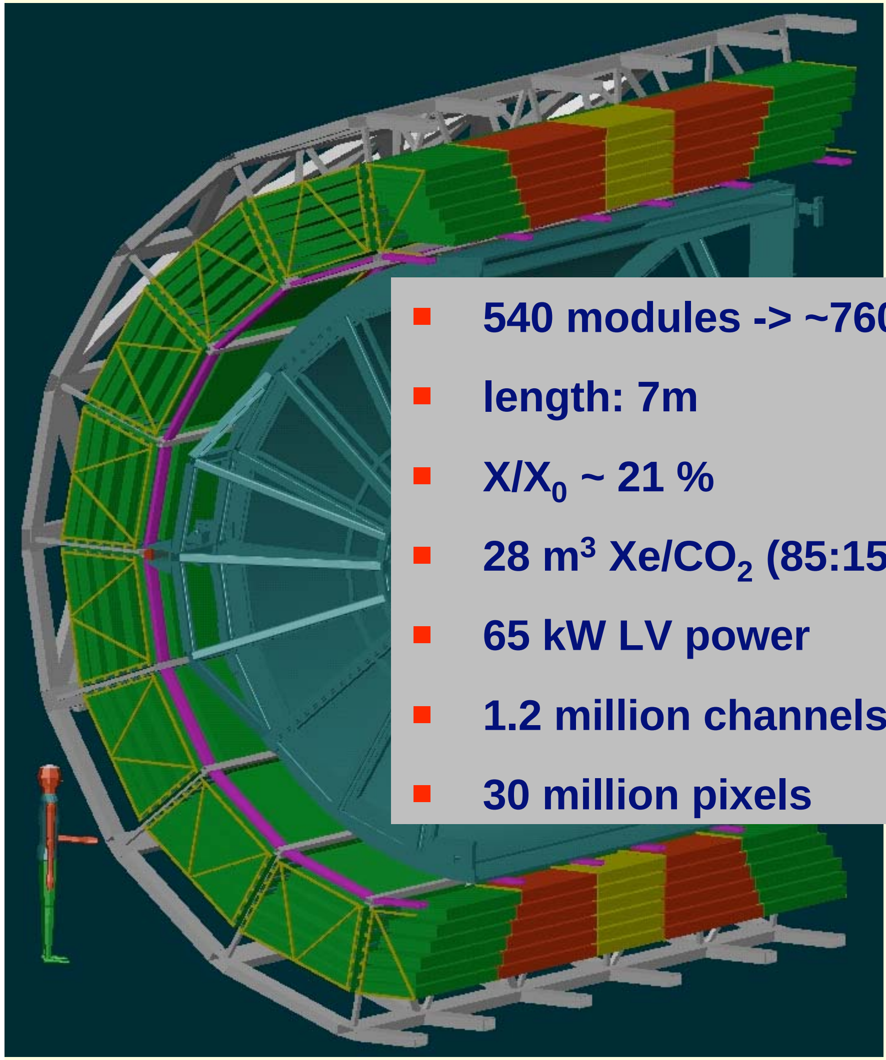
- compare these cross sections to pp cross sections $\rightarrow R_{AA}$
- energy loss of c,b quarks in medium



error decomposition



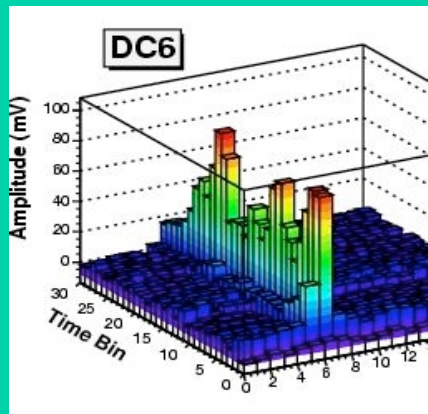
Transition Radiation Detector (TRD)

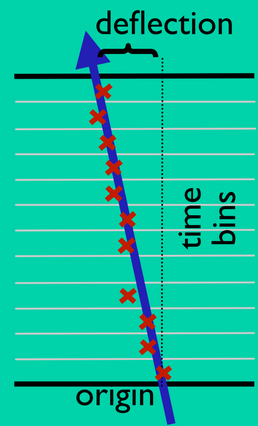


- **540 modules -> ~760m^2**
- **length: 7m**
- **X/X_0 ~ 21 %**
- **28 m^3 Xe/CO_2 (85:15)**
- **65 kW LV power**
- **1.2 million channels**
- **30 million pixels**

- **electron ID in central barrel p>1 GeV/c**
- **fast trigger for high momentum particles**

processing of track segments
local tracking on each chamber:



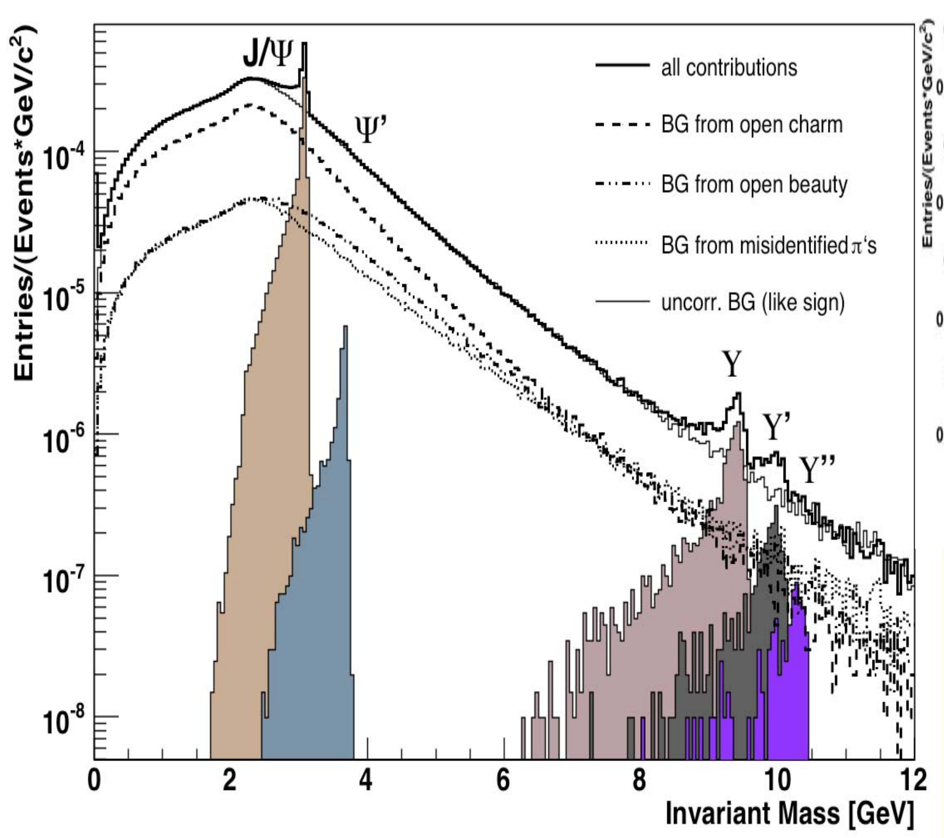


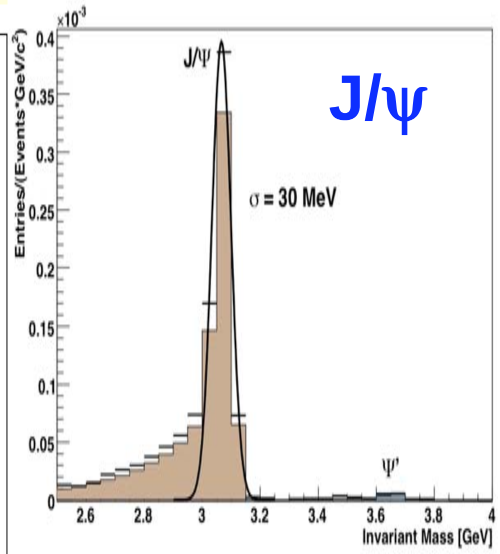
- 275000 CPUs process 65 MB of data from track segments within 6.5 μs
- search electron pairs

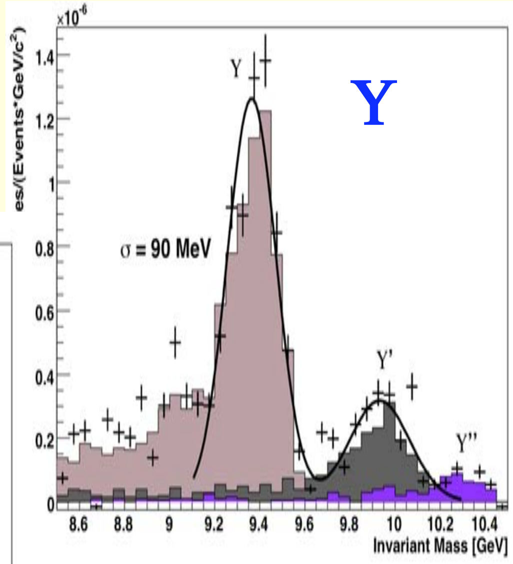
Charmonia via Di-Electron Measurement

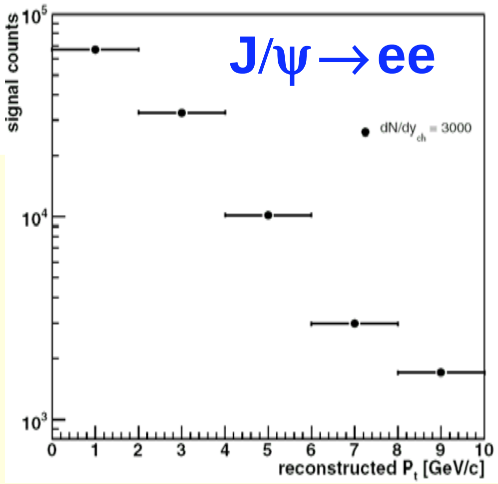
W. Sommer

- electron ID with TPC and TRD
- expect 2500 ϒ per PbPb year
  with good mass resolution and S/B



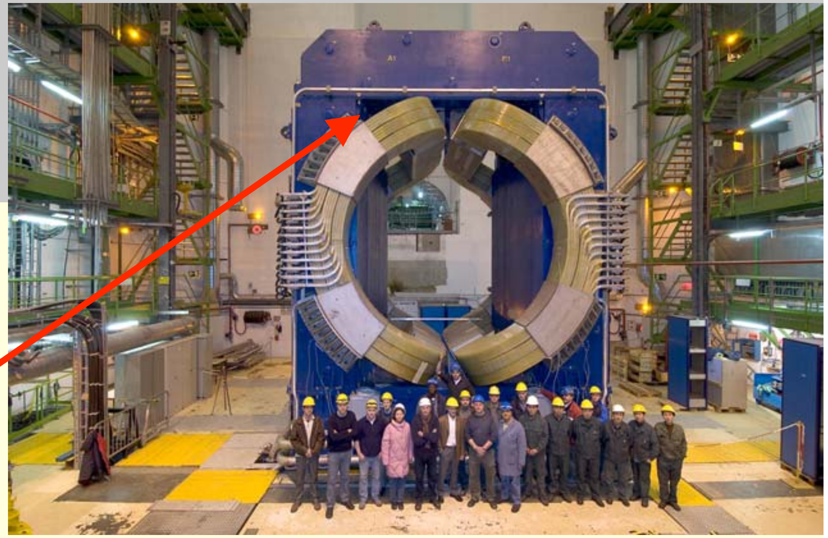




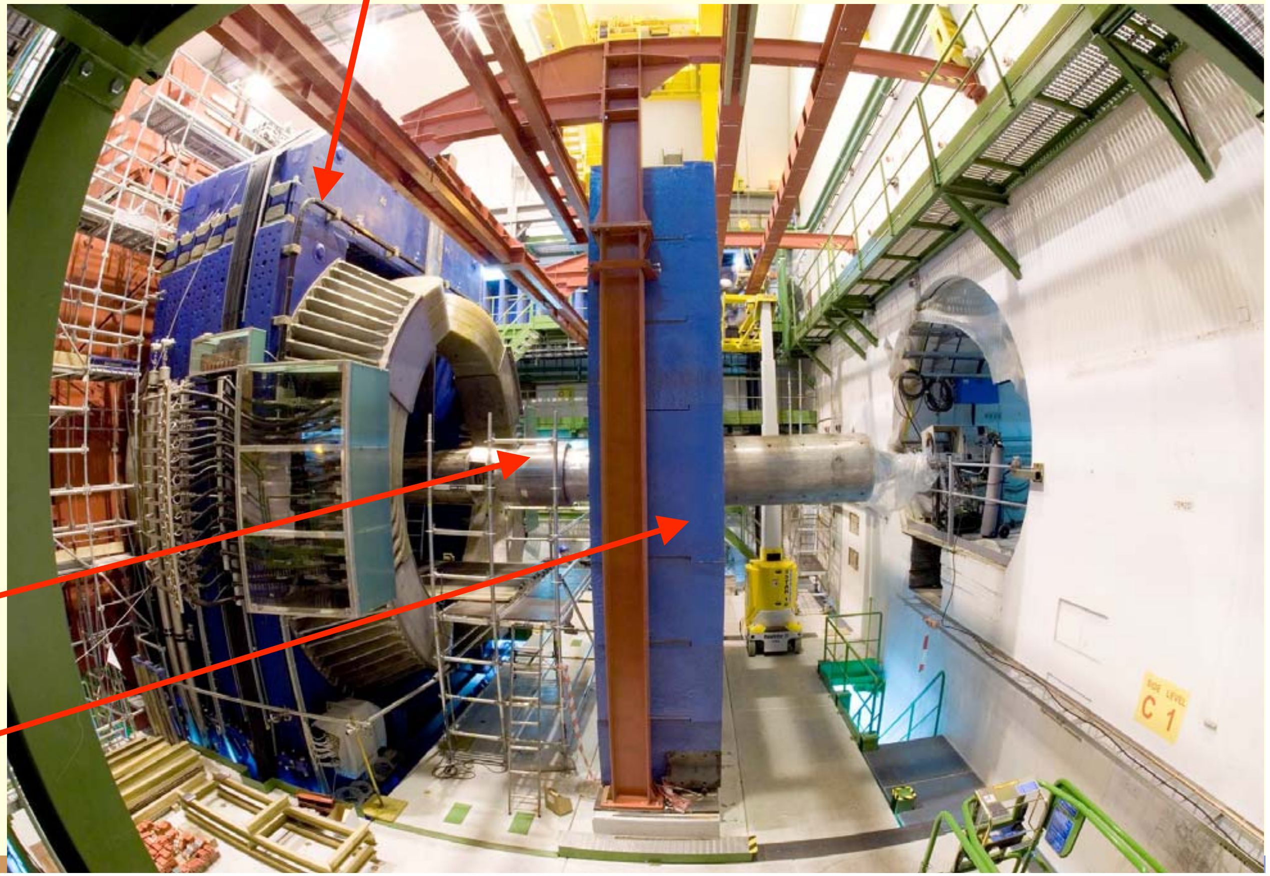


Simulation: $2 \cdot 10^8$ central PbPb collisions

ALICE (Di)-Muon Spectrometer



dipole magnet



muon chambers

muon absorber

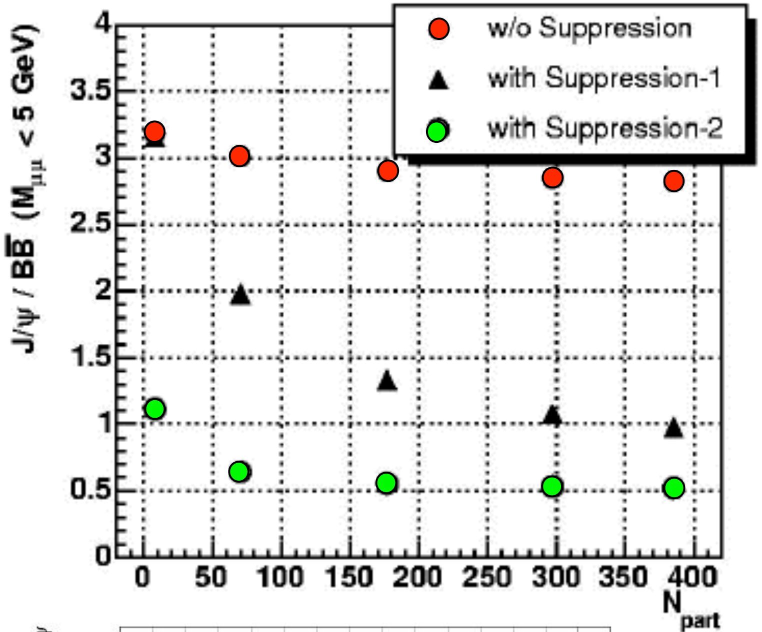
muon filter

Quarkonia Suppression (μ-Channel)

suppression depends on T_D/T_C

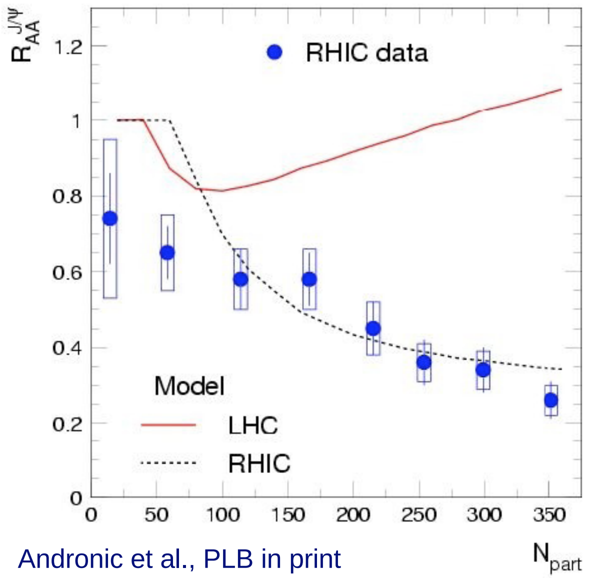
suppression 1
quenched QCD T_C=270 MeV

suppression 2
unquenched QCD T_C=190 MeV



J/Ψ:
excellent sensitivity to different suppression scenarios stat. err~5%

- **if production enhanced compared to pp**
direct signal for deconfinement
J/ψ produced via stat. hadronization



Andronic et al., PLB in print

Summary & Outlook

- **commissioning phase**
  - fully commission trigger, DAQ, ECS
  - align and calibrate the entire system
  - further use of beam gas interactions
- **first pp run**
  - important pp reference data for heavy ions
  - unique physics to ALICE
    - minimum bias running
    - fragmentation studies
    - baryon number transport
    - heavy flavor cross sections
- **first few heavy ion collisions**
  - establish global event characteristics
  - important bulk properties
- **first long heavy ion run**
  - quarkonia measurements
  - jet suppression studies
  - flavor dependences

Outlook

- **high luminosity heavy ion running ($1 nb^{-1}$)**
  - dedicated high p_t electron triggers
  - jets > 100 GeV (EMCAL)
  - Y - states
  - γ - jet correlations
  - …
- **pA & light ion running**