Study of charmonium production at central rapidity with the ALICE experiment at LHC

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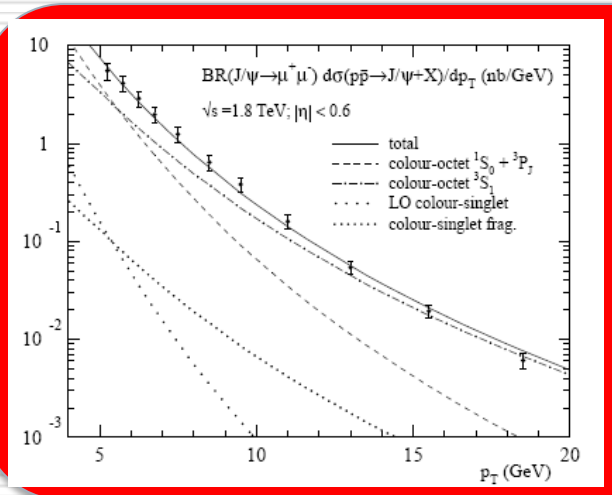
for the ALICE collaboration

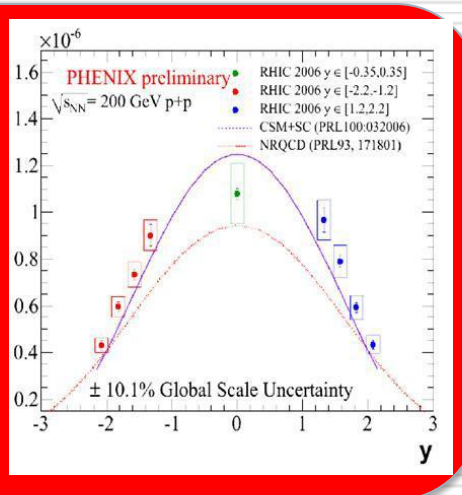
Outline:

- motivations
- detectors used for charmonium measurement
- performance in first runs
- expectations for pp and PbPb
- conclusions

Quarkonium production in p-p collisions: motivations

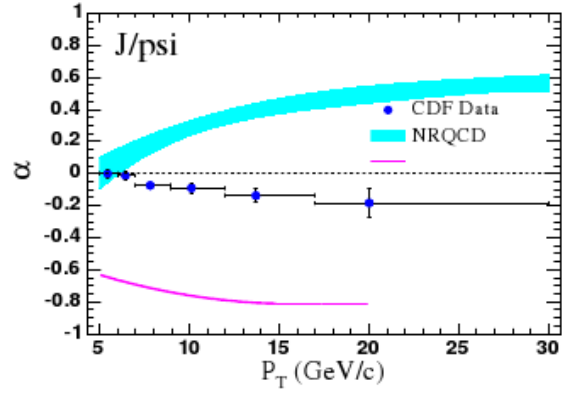
- Several production mechanisms: CEM, CSM, NRQCD (COM)

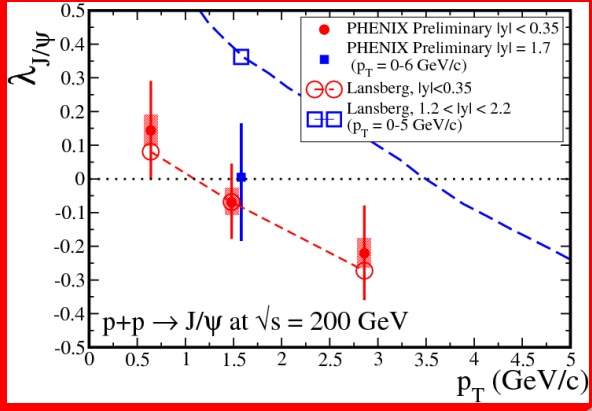




- NRQCD well reproduces CDF data
- PHENIX preliminaries of dσ/dy are better reproduced by CSM (+s-channel cut) at forward rapidities

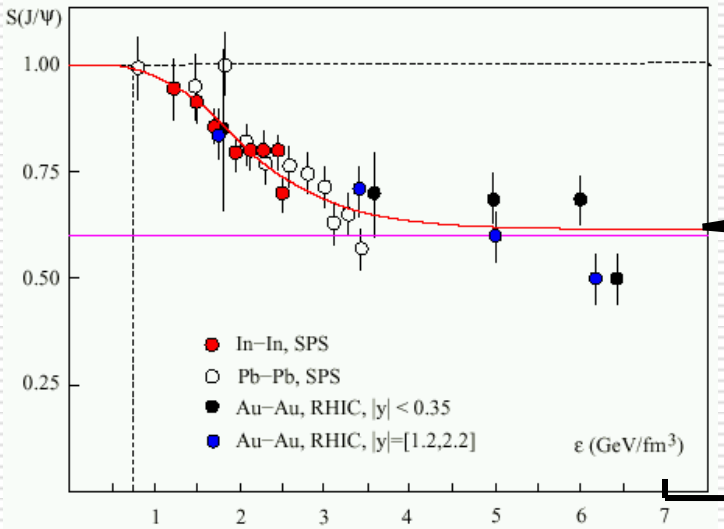
- NRQCD fails in predicting polarization (CDF Run II).
- At mid-rapidity PHENIX preliminaries are well reproduced by CSM + s-channel cut (still problems at high y)



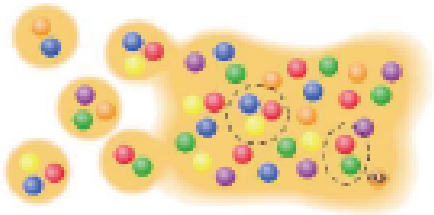


Quarkonium production in Pb-Pb collisions: motivations

- J/ψ suppression & regeneration?
- χ_c, ψ′ suppression (J/ψ T_D ~ 1.5-2 T_c)?



enhanced regeneration



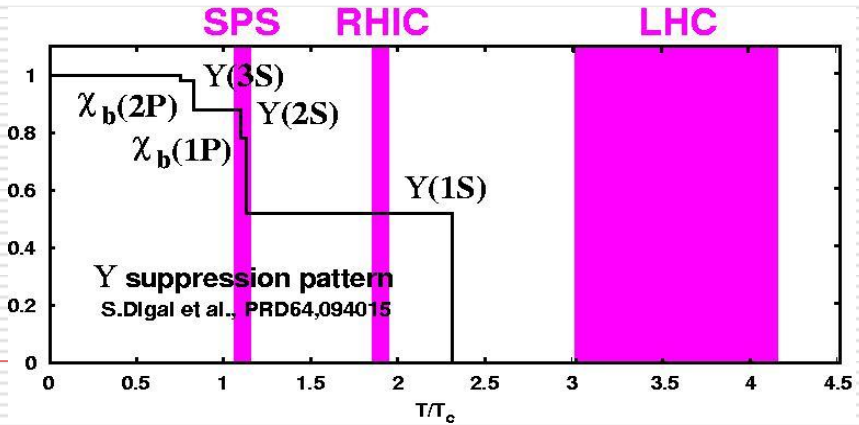
enhanced suppression

T_{LHC} >> J/ψ T_D

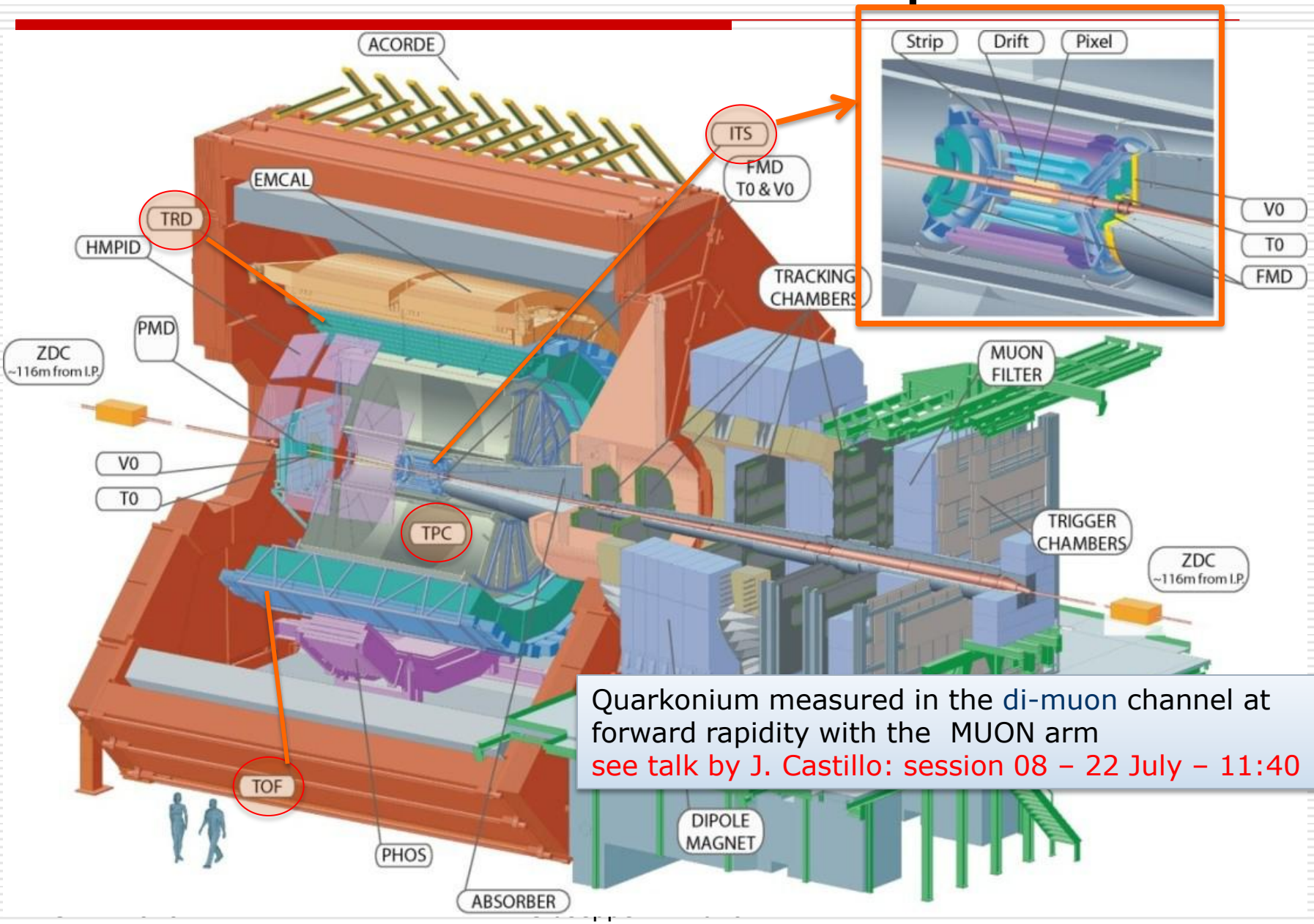
30

SPS
RHIC
LHC

- ϒ melts only at LHC
- ϒ′ T_D ~ J/ψ T_D
- Small ϒ regeneration
  - → ϒ′ can unravel J/ ψ suppression VS regeneration



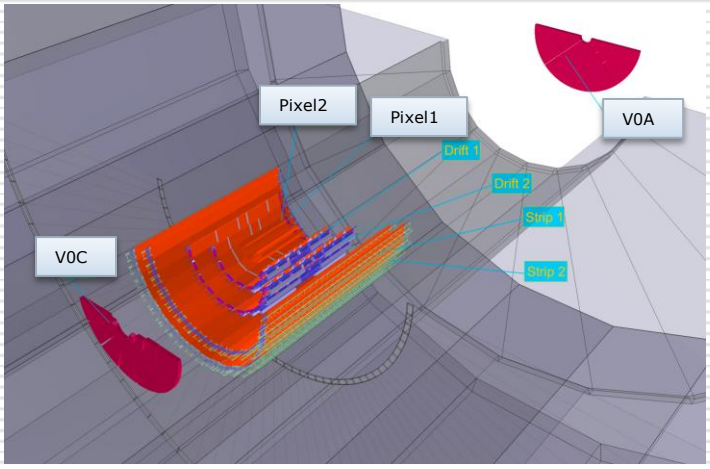
ALICE schematic setup



Quarkonium measured in the di-muon channel at forward rapidity with the MUON arm

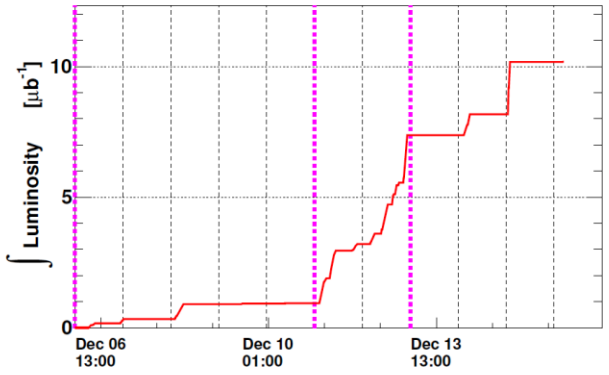
see talk by J. Castillo: session 08 – 22 July – 11:40

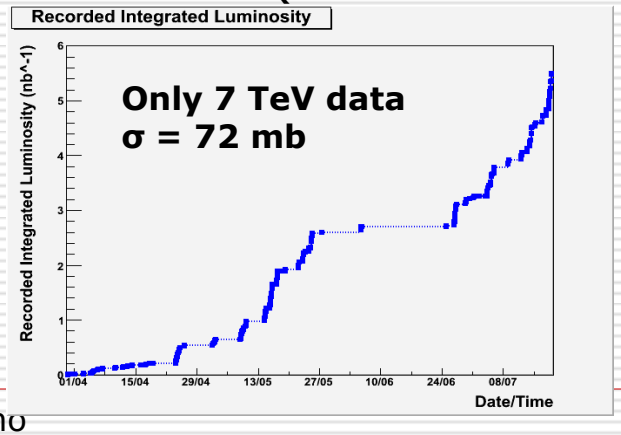
Trigger & Data samples so far



- "**Minimum bias**", i.e. interaction **trigger**:
  - SPD or V0-A or V0-C
    - at least one charged particle in 8 η units
- **single-muon trigger:**
  - forward muon in coincidence with Min Bias
  - read out MUON, SPD, V0, FMD, ZDC
- Activated in coincidence with the BPTX beam pickups

- 2009 (0.9 and 2.36 TeV)
  - ~10.3 μb^{-1} (5×10^5 min bias)
- 2010 to July 20th (0.9 and 7 TeV)
  - ~5.5 nb^{-1} (4×10^8 min bias)



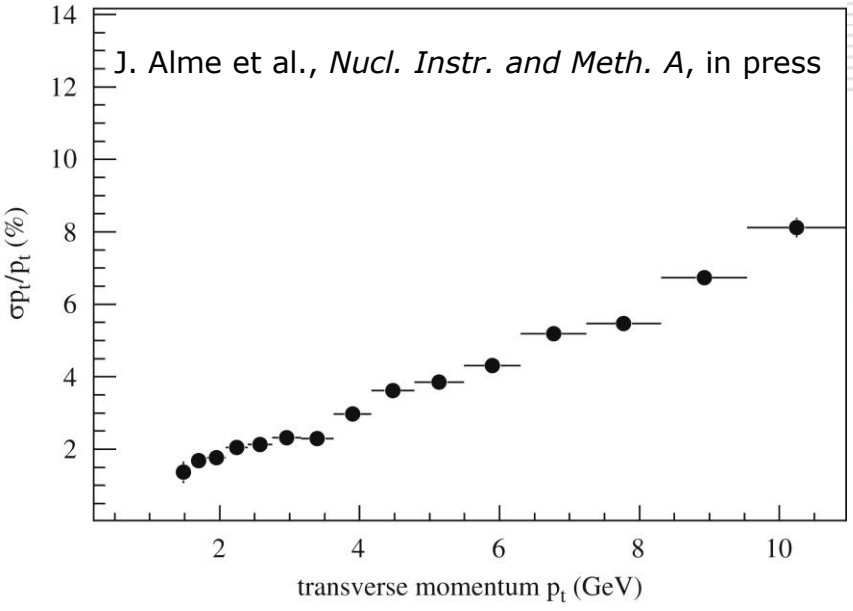


Analysis strategy for quarkonium in the ALICE barrel

- good tracks from the primary vertex
  - tracking with ITS + TPC (+ TRD)
- electron identification
  - dE/dx in TPC
  - time-of-flight for low momentum electrons from TOF
  - transition radiation signature from TRD
- cuts to maximize the peak significances
- determination of combinatorial background
- J/□ from B-decay: secondary vertexing with ITS

Tracking with TPC: 3D reconstruction of up to 15 000 charged tracks per event

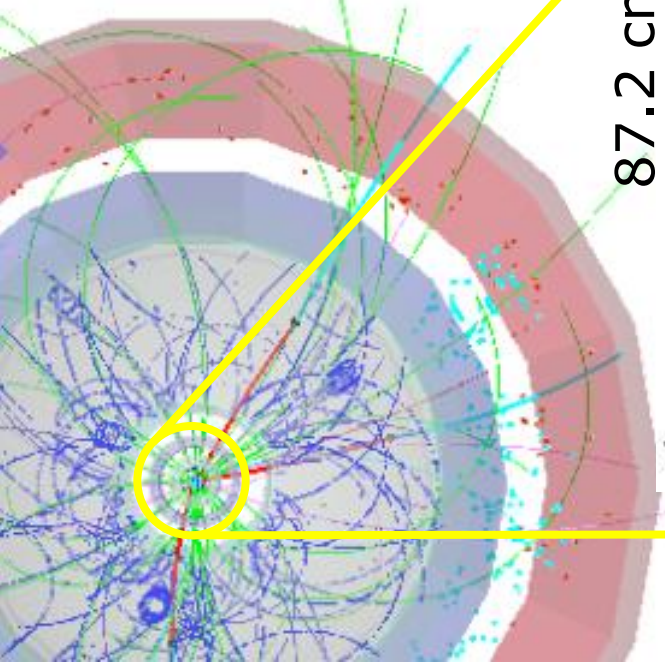
- with 95 m^3 the largest TPC ever
- precision better than 500 □m in all 3 dim.
- 160 space and charge points per track

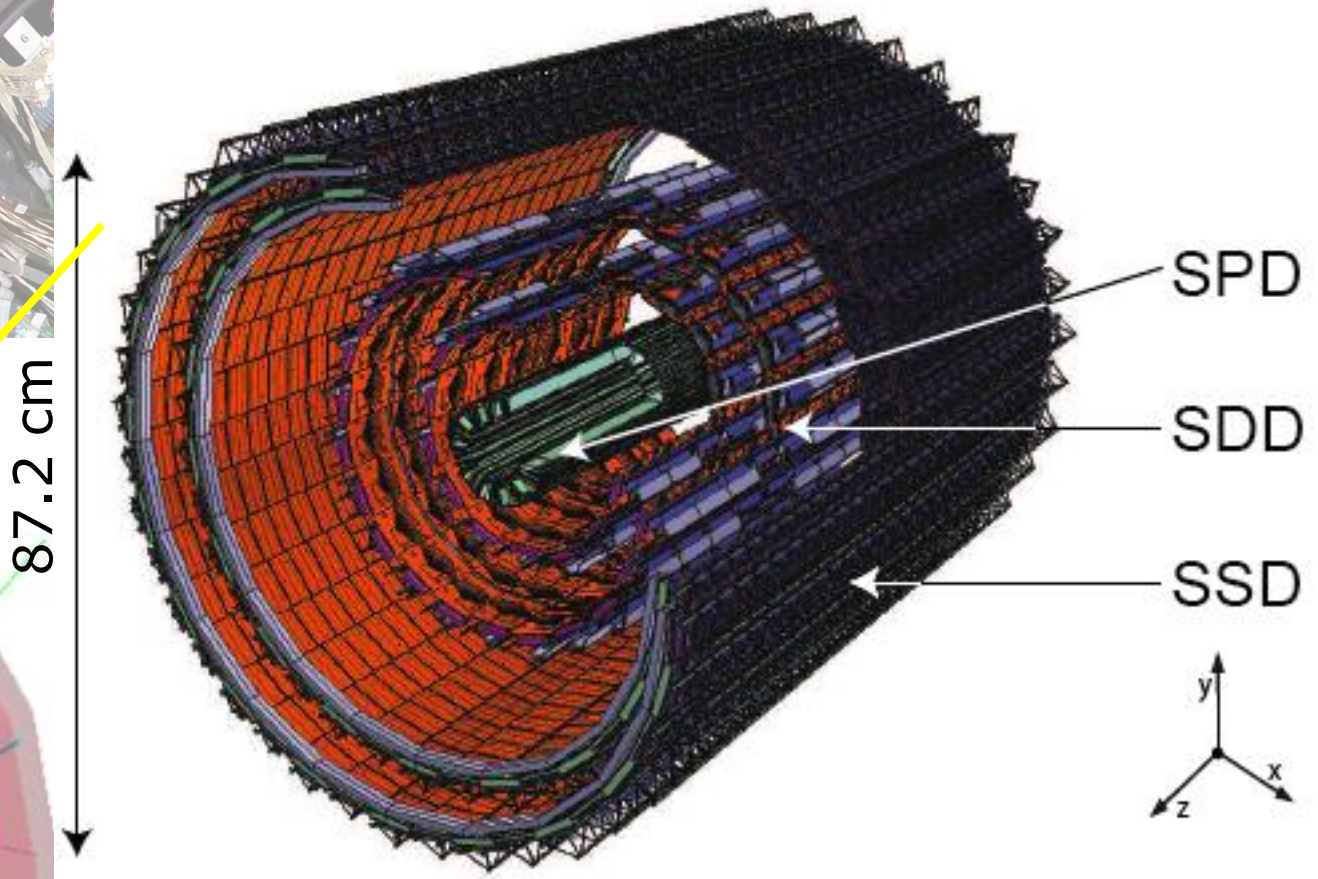


- match two segments of cosmic tracks
- momentum resolution very close to detector design:
  - 7% at 10 GeV/c
  - < 1% at p_T< 1 GeV/c confirmed from K^0_s measurement

The inner tracking system

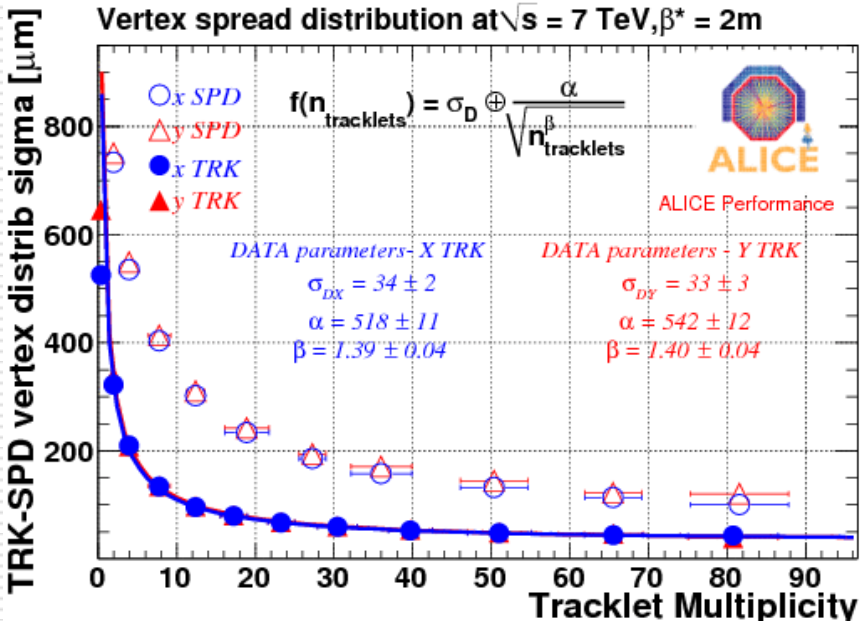
- Six layers of silicon detectors
- Three technologies
  - Pixels (SPD)
  - Drift (SDD)
  - Strips (SSD)





ITS performance

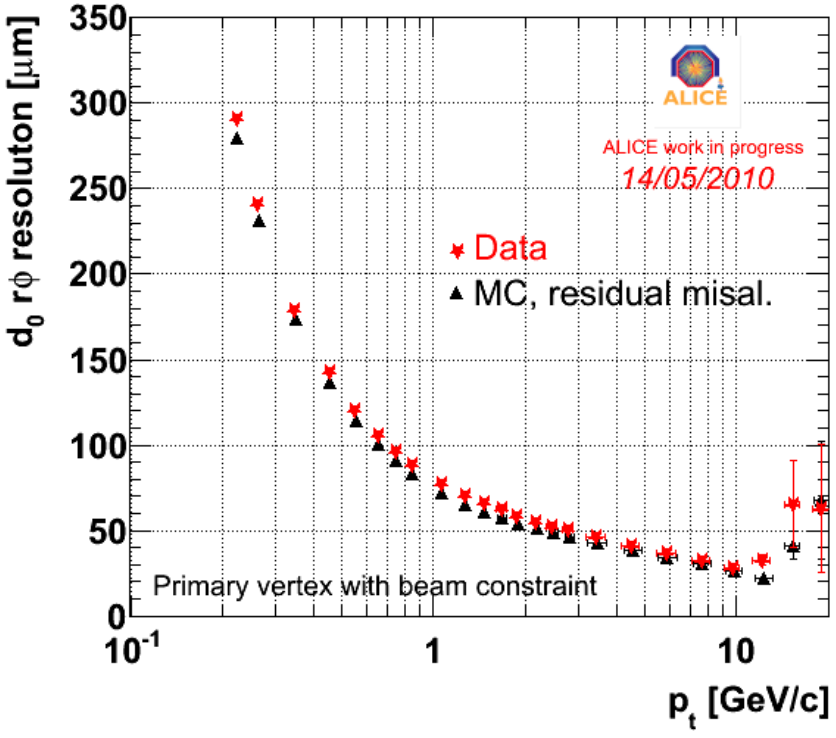
- Vertex resolution



Primary vertex from tracks with at least 4 points in ITS

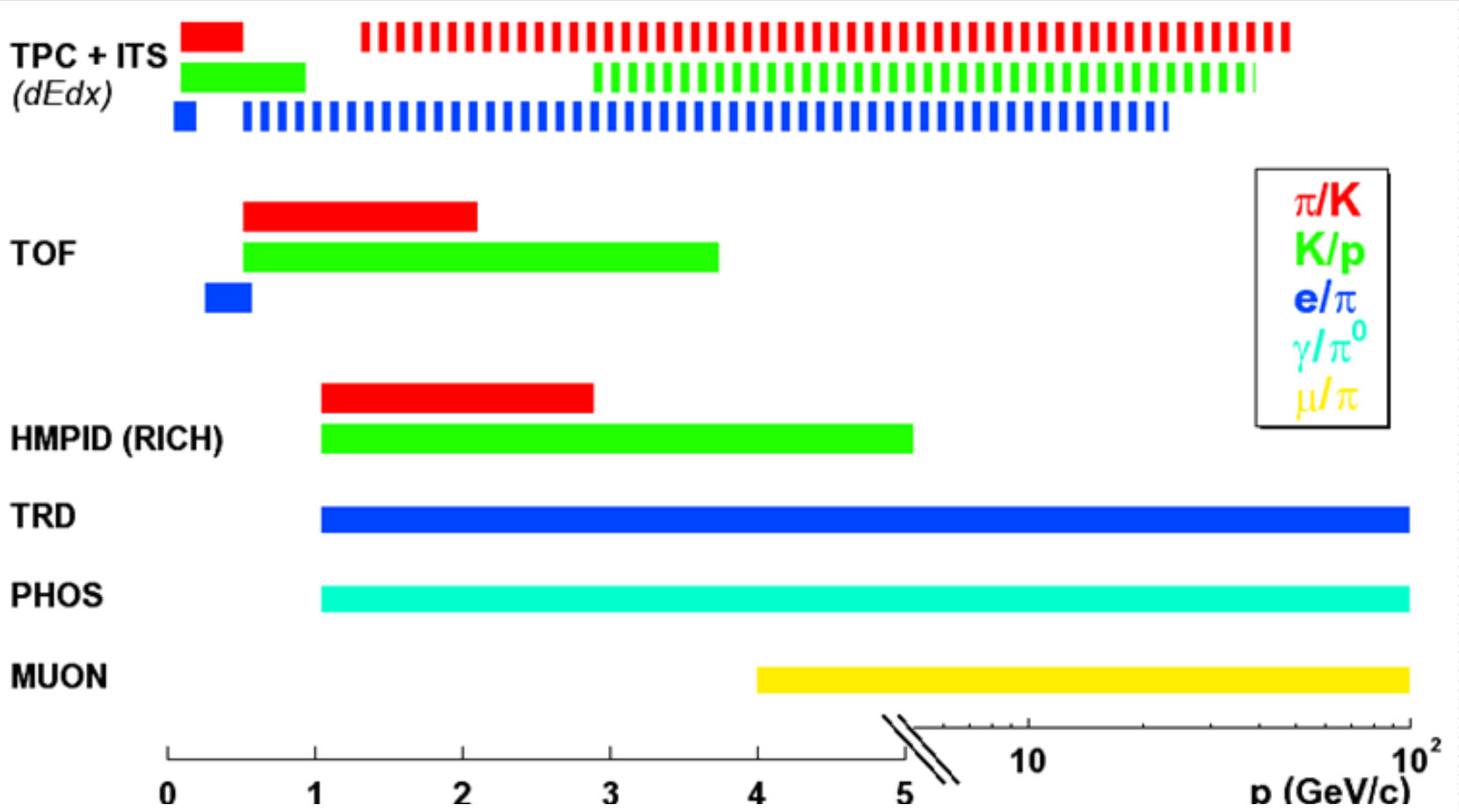
- Impact parameter resolution

ITS aligned with cosmic and first pp colllisions (still to be improved)



- Already very close to design figures

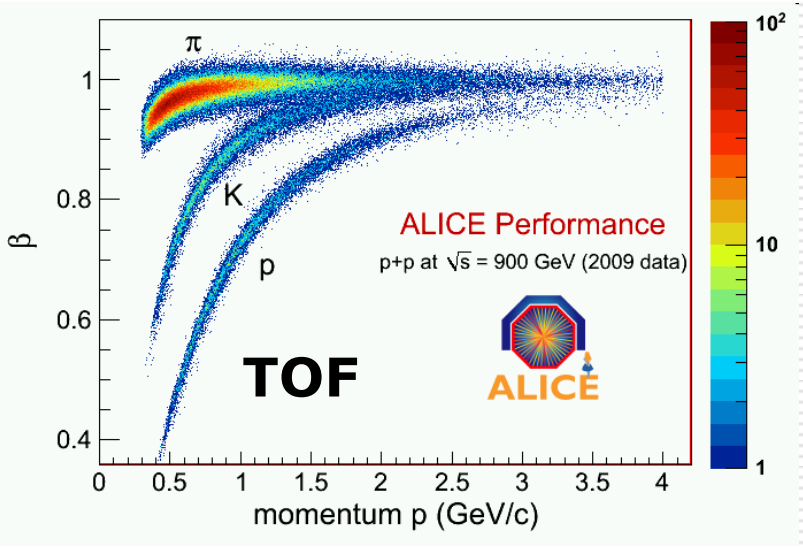
PID: one of ALICE's strengths

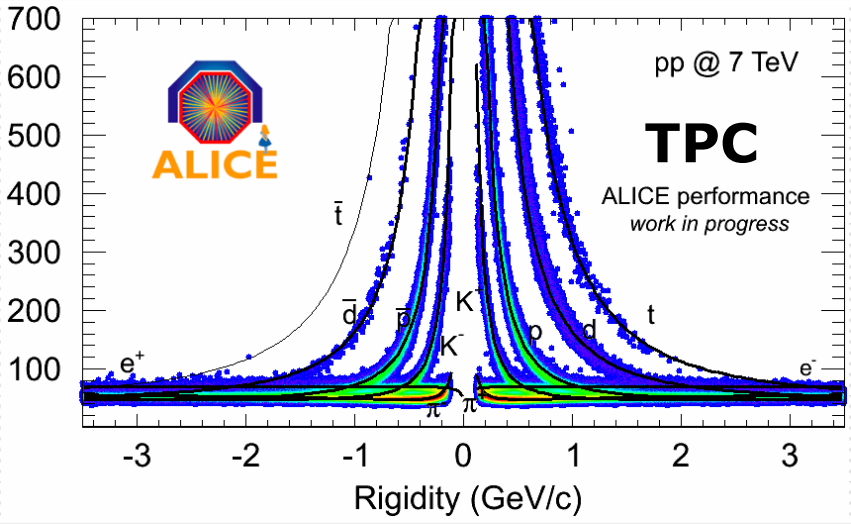


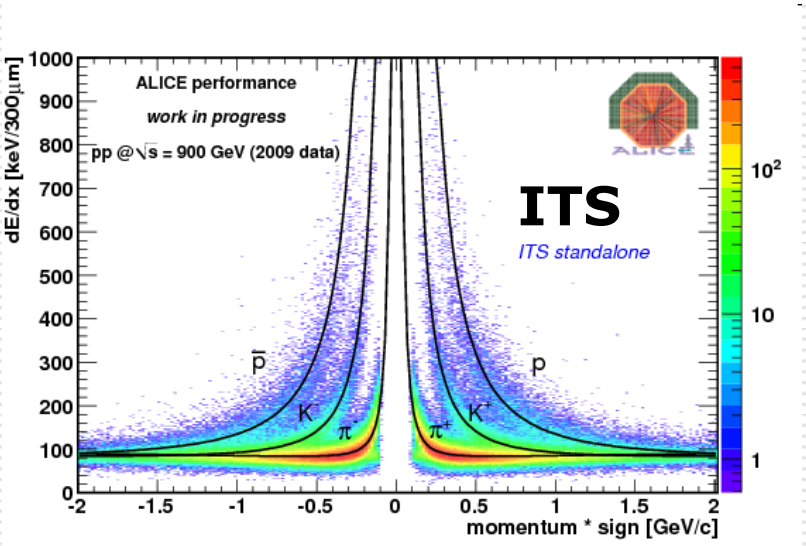
EMCAL adds electron/pion separation via shower shape

- ALICE has PID over large momentum range

PID performance

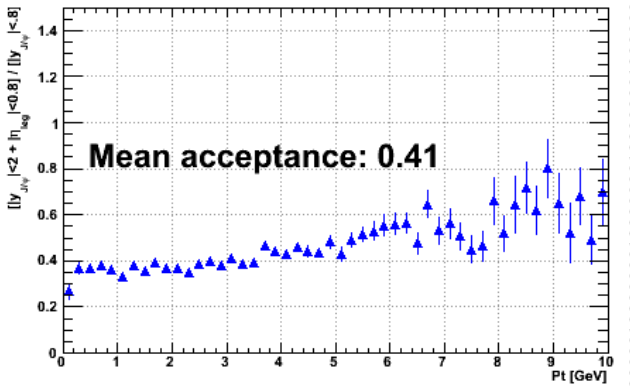


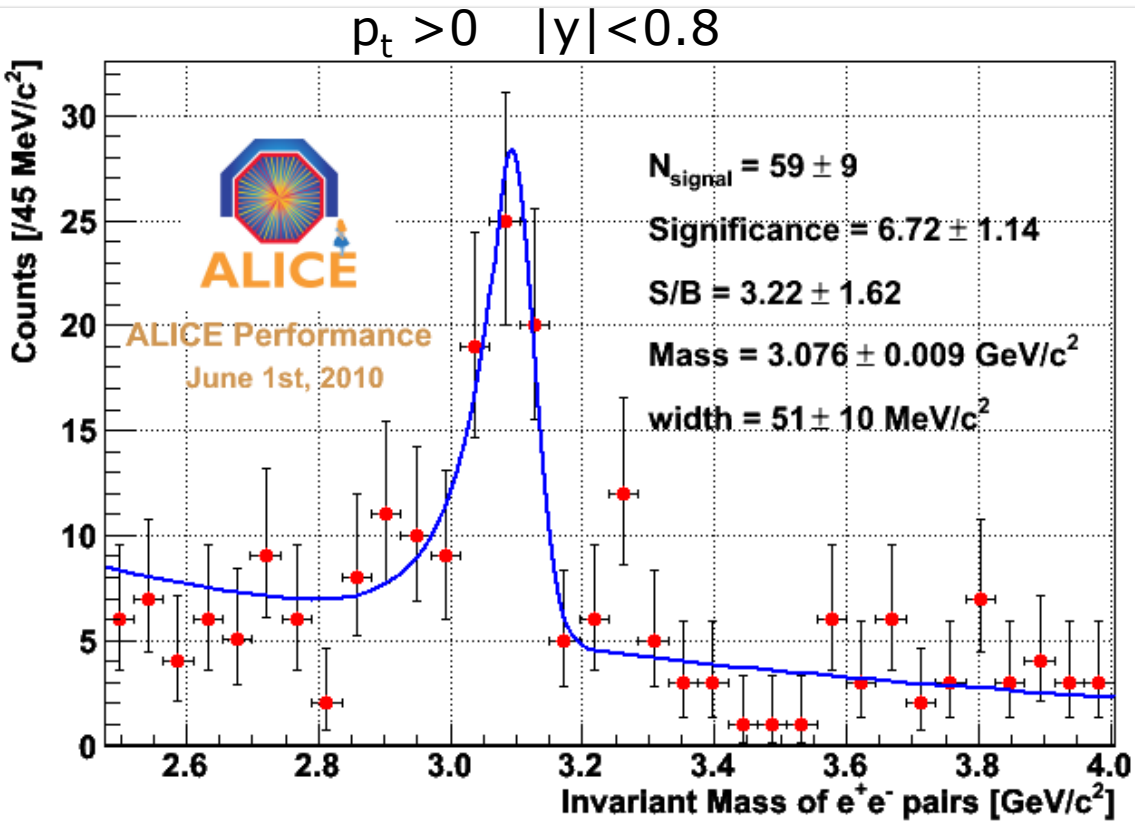




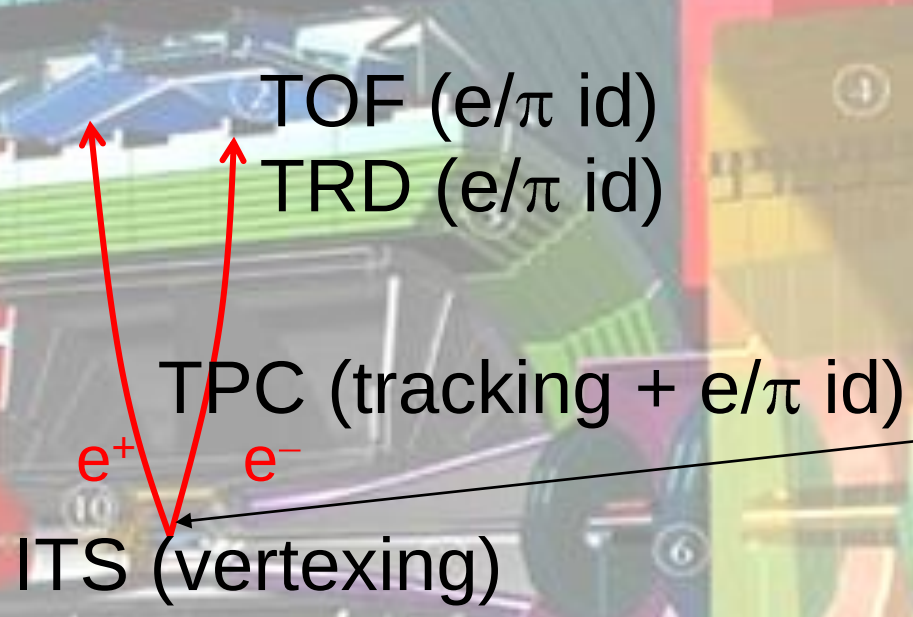
J/ψ mass peak

- 110M min. bias events
  - (~1/4 of actual statistics)
- TPC+ITS tracks:
  - $n_{clus\ TPC} > 120$
  - inner pixel layer
  - $p_t(e^{\pm}) > 1$ GeV
- PID: TPC only
  - 2 σ bands for:
    - electron inclusion
    - pion rejection
  - TRD will come soon



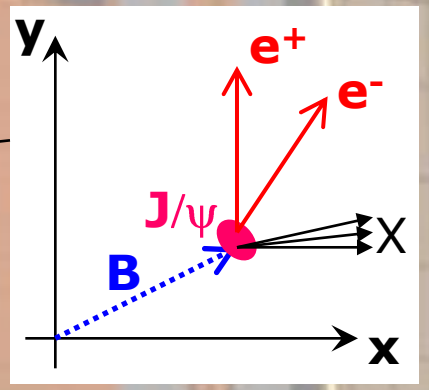


Displaced J/ψ (from Beauty)



B→J/ψ+X

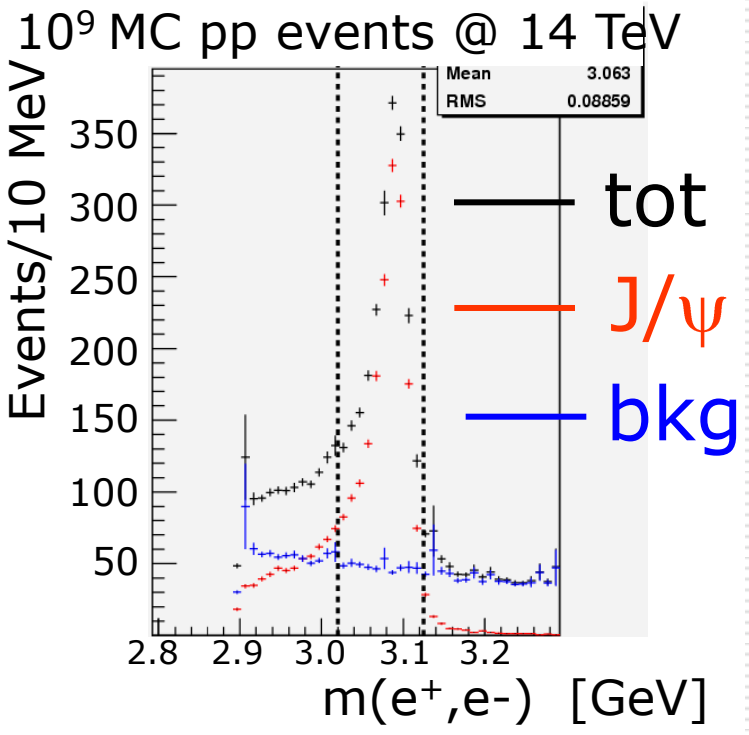
↳ **e⁻e⁺**



J/ψ from Beauty is a large fraction: about 30 %

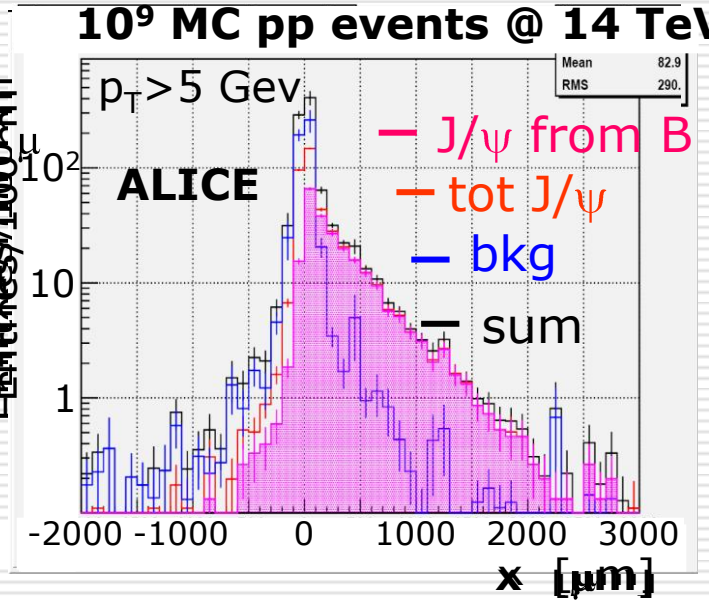
Displaced J/ψ (from Beauty)

- Analysis based on a simultaneous fit of
  1. the invariant mass spectrum



Displaced J/ψ (from Beauty)

- Analysis based on a simultaneous fit of
  1. the invariant mass spectrum
  2. an "impact parameter" to separate prompt from detached J/ψ, e.g. pseudo-proper decay time (à la CDF)
     D.Acosta et al Phys. Rev. D 71 (2005) 032001

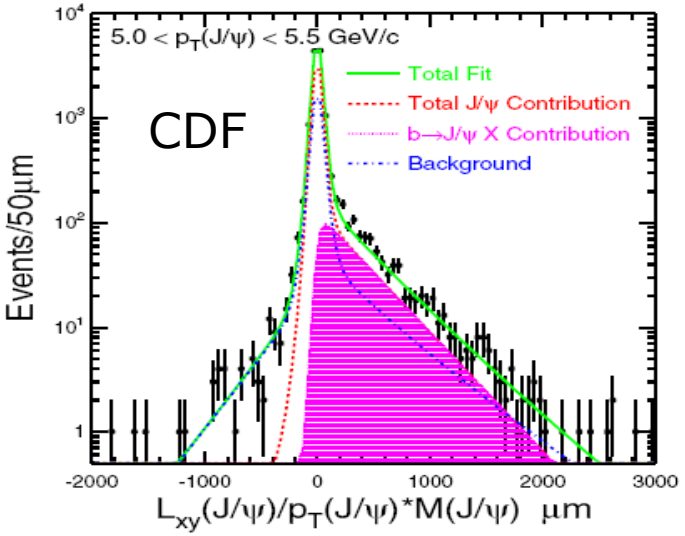


$$x = L_{xy}(J/\psi) \cdot \frac{M_{J/\psi}}{p_T(J/\psi)}$$

$$L_{xy}(J/\psi) = \frac{\vec{L}\,\vec{p}_T(J/\psi)}{\left|\vec{p}_T(J/\psi)\right|}$$

$$\vec{L} = \vec{r}^{\,\mathrm{sec}}_{\mathrm{vtx}} - \vec{r}^{\,\mathrm{prim}}_{\mathrm{vtx}}$$

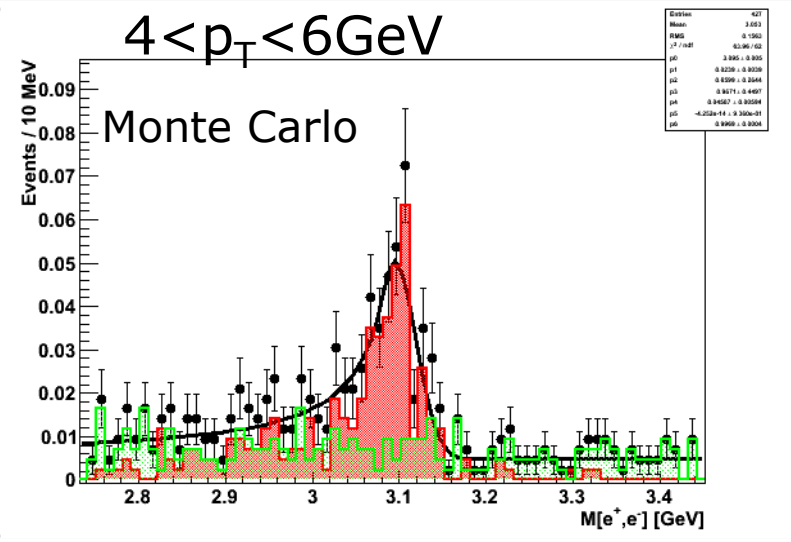
- This measurements can allow a deter
  $d\sigma^{b\bar{b}}/dp_T$ cross
  to



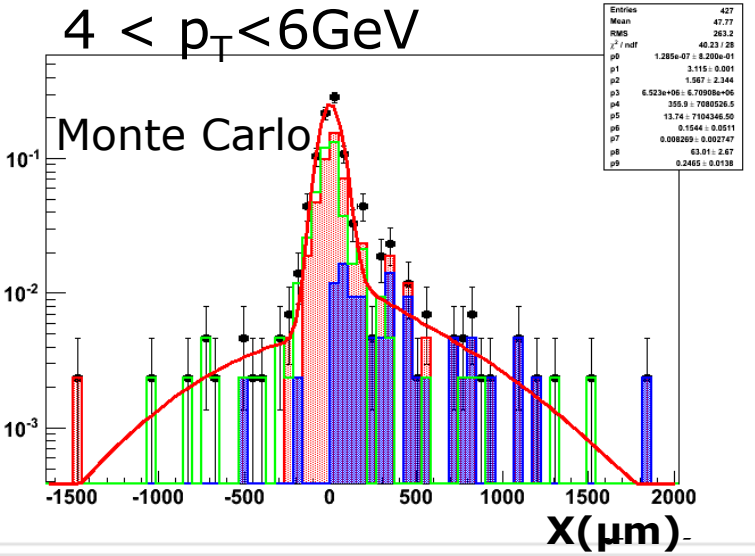
Performance plot in the first year

- assuming □ 1000 final J/□ in pp @ □s = 7 TeV

- Invariant mass:

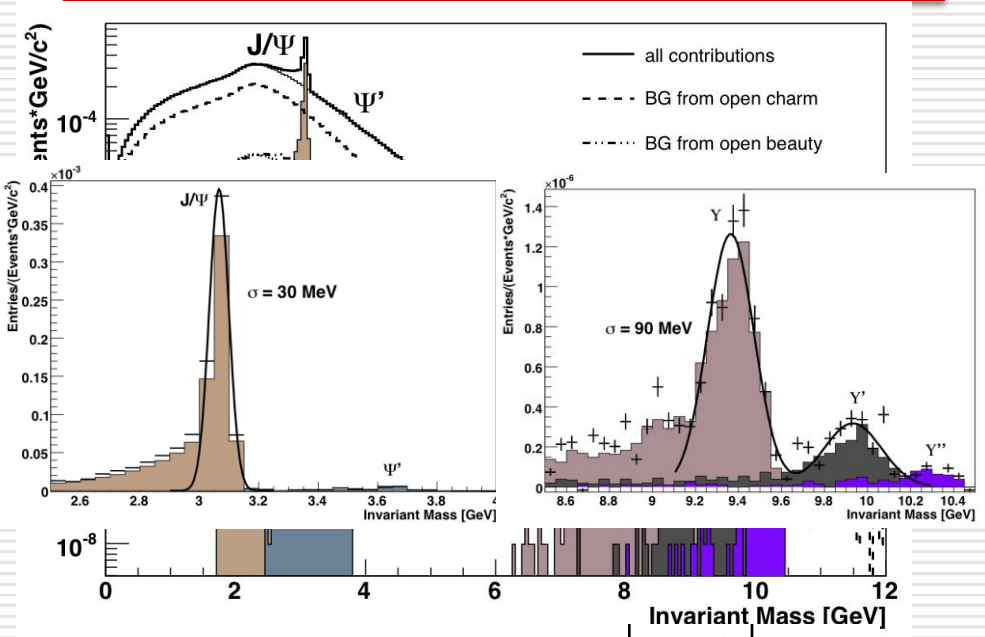


- Pseudo-proper decay time



Expectations in Pb-Pb

- $\sqrt{s_{NN}}$=5.5 TeV @ nominal L_0



	J/ψ	Υ
Mass resolution (Mev/c^2)	~30	~90
Signal/Noise	1.2	1.0
Counts (most central 10%) for nominal Pb-Pb year	120 k	*900*

- Prospects for Pb-Pb in 2010

- $\sqrt{s_{NN}}$ = 2.75 TeV
- luminosity for Pb-Pb in 2010 expected to be of order 10^{25} $cm^{-2}s^{-1}$
  - about 100 Hz min bias interaction rate
- → 10^7 central collisions possible
- assuming 1 J/ψ per 10^4 collisions (factor 200 more than pp)
  - we can reconstruct 1000 J/ψ for central collisions
  - centrality dependence of yield possible

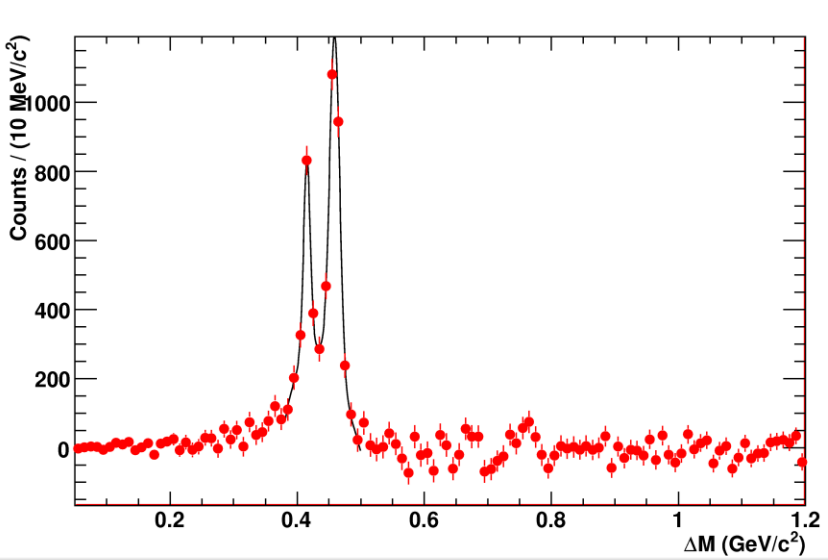
Summary

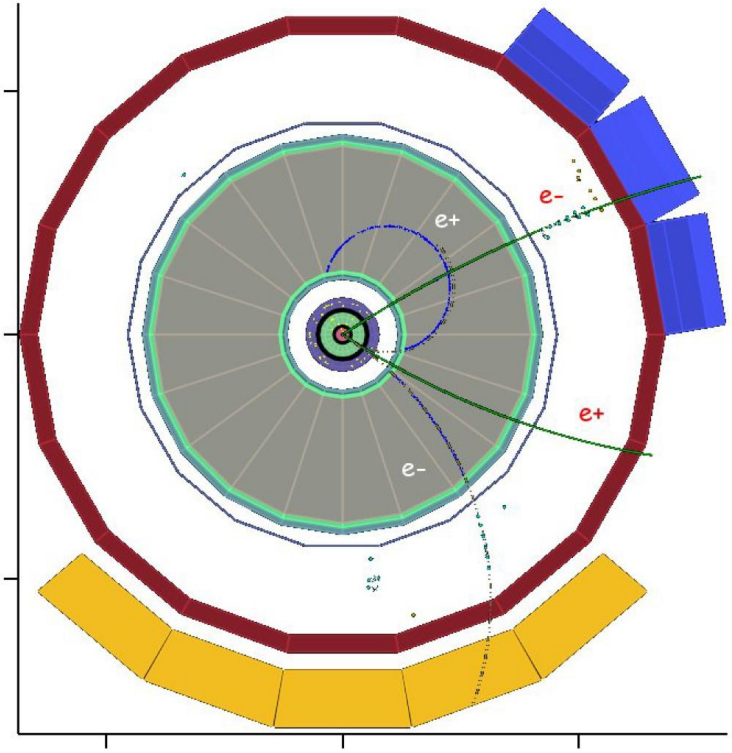
- Measurements of J/ψ production at central rapidity in pp collisions at √s=7 TeV ongoing
- Measurements in the first Pb-Pb run (end of this year) is feasible
- ALICE has good capabilities to disentangle the component from beauty particle decays

Extra slides

J/ψ from χ_c

- χ_c: contribution ~30%
  - $\chi_c \rightarrow J/\psi+\gamma$
    - J/ in dielectron channel
    - © in ©-conversion



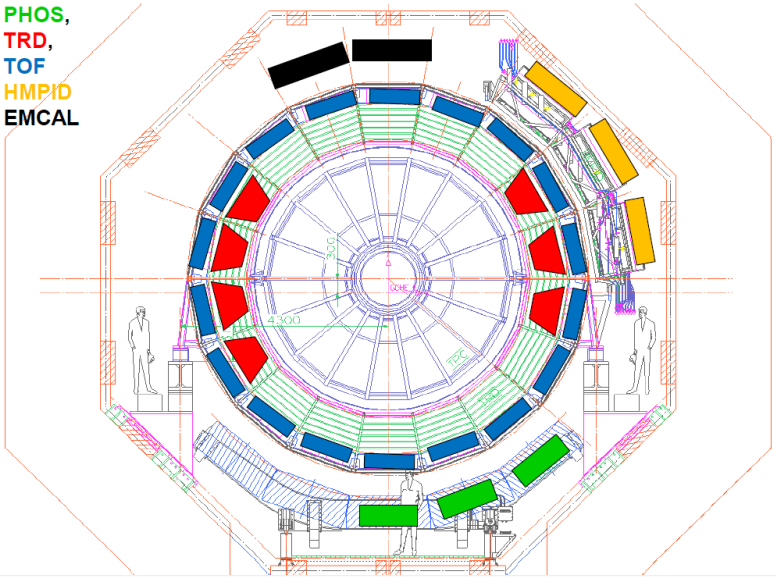


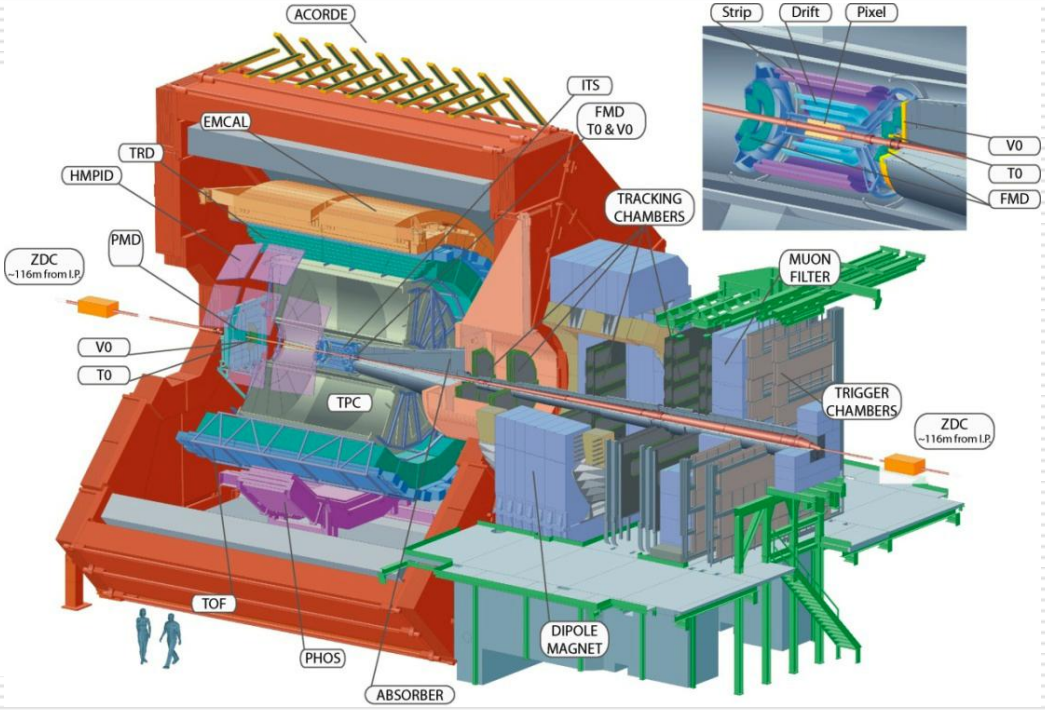
- feasible in pp collisions
  - ~7k χ_c but requires a trigger

Detector configuration 2009/2010

- ITS, TPC, TOF, HMPID, MUON, V0, T0, FMD, PMD, ZDC (100%)
- TRD (7/18)
- EMCAL (4/12)
- PHOS (3/5)
- HLT (60%)

full hadron and muon capabilities
partial electron and photon capabilities





Expected J/□ statistics in 7 TeV pp collisions

- acceptance in -0.8 < y < 0.8 : 0.4
- typical reconstruction efficiency (track quality + first layer ITS): 0.5-0.6
- typical PID efficiency (e.g. TPC only, pion exclusion): 0.6
- long tail due to bremsstrahlung, integrate typically 50%

→ combined acceptance/efficiency about 0.05 (no TRD yet)

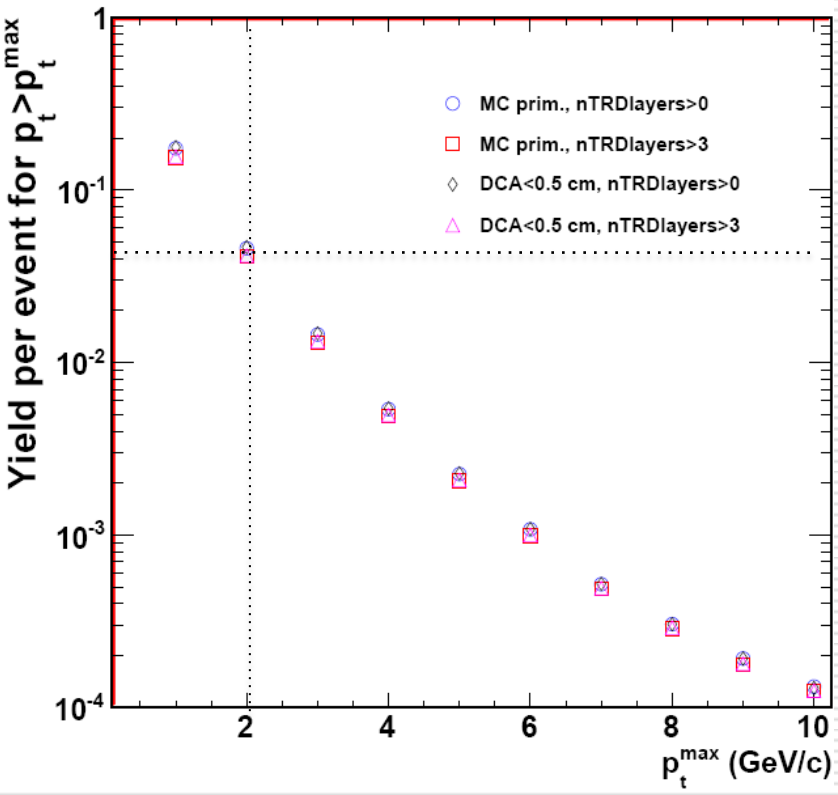
→ expect about 0.6 reconstructed J/psi per 10^6 events (with currently installed TRD about 0.1 J/psi per 10^6 events)

600 J/□ for 10^9 events → ok to measure yield

more refined differential measurements need triggered sample

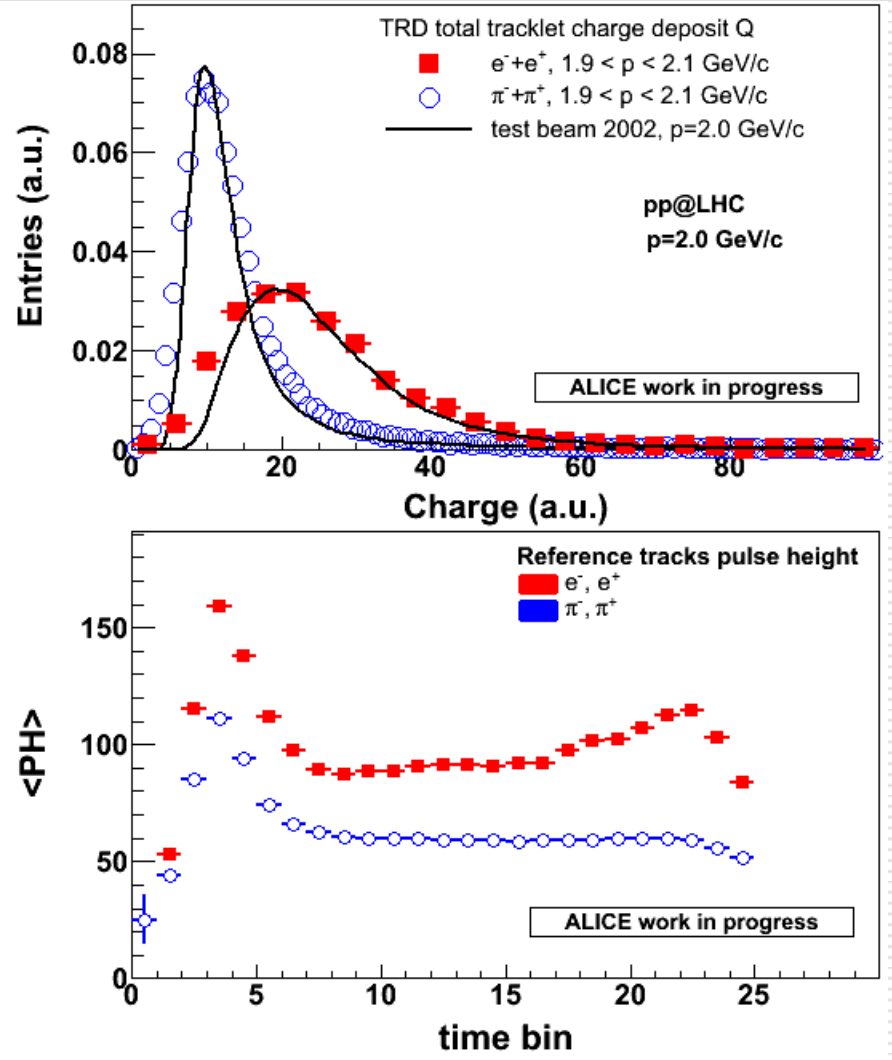
J/□ trigger in pp

- Level1 trigger with TRD (7 □s):
  - single track with $p_t > p_t^{min}$
    - p_t^{min}=2 GeV → reduction by factor 30
  - electron signature (online pion suppression factor 10)
  - → reduction by factor 300
- HLT:
  - e^+e^- pair including better electron id from TPC
  - invariant mass cut



electron pion separation in TRD: first evidence from 7 TeV pp collisions

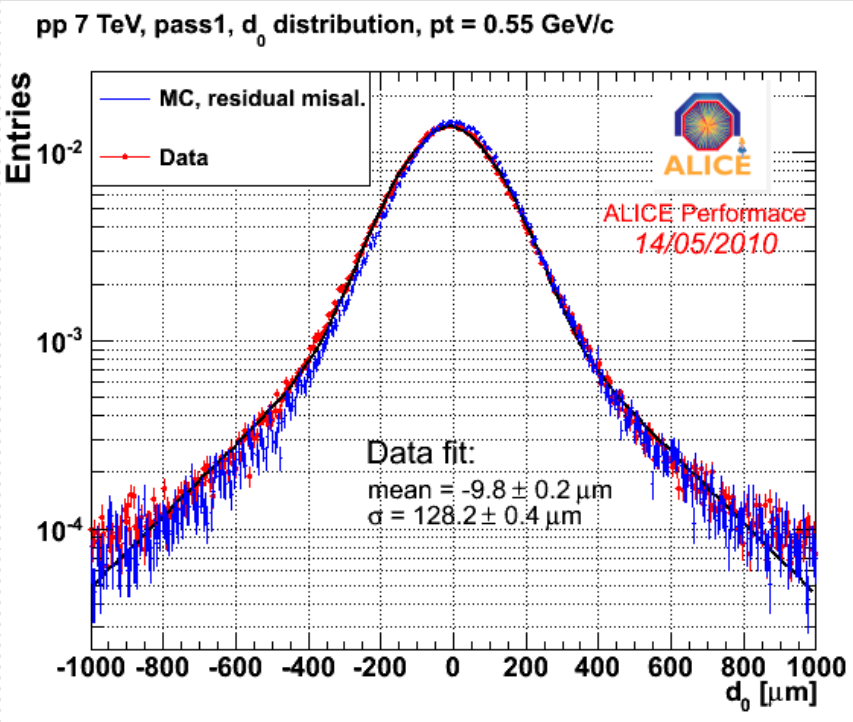
- response of TRD to π identified by K^0_s decay and electrons from pair conversion
- clear TR signature visible
- already good consistency with test beam data



Track impact parameter resolution

- Track selection: standard TPC cuts + **both SPD points**

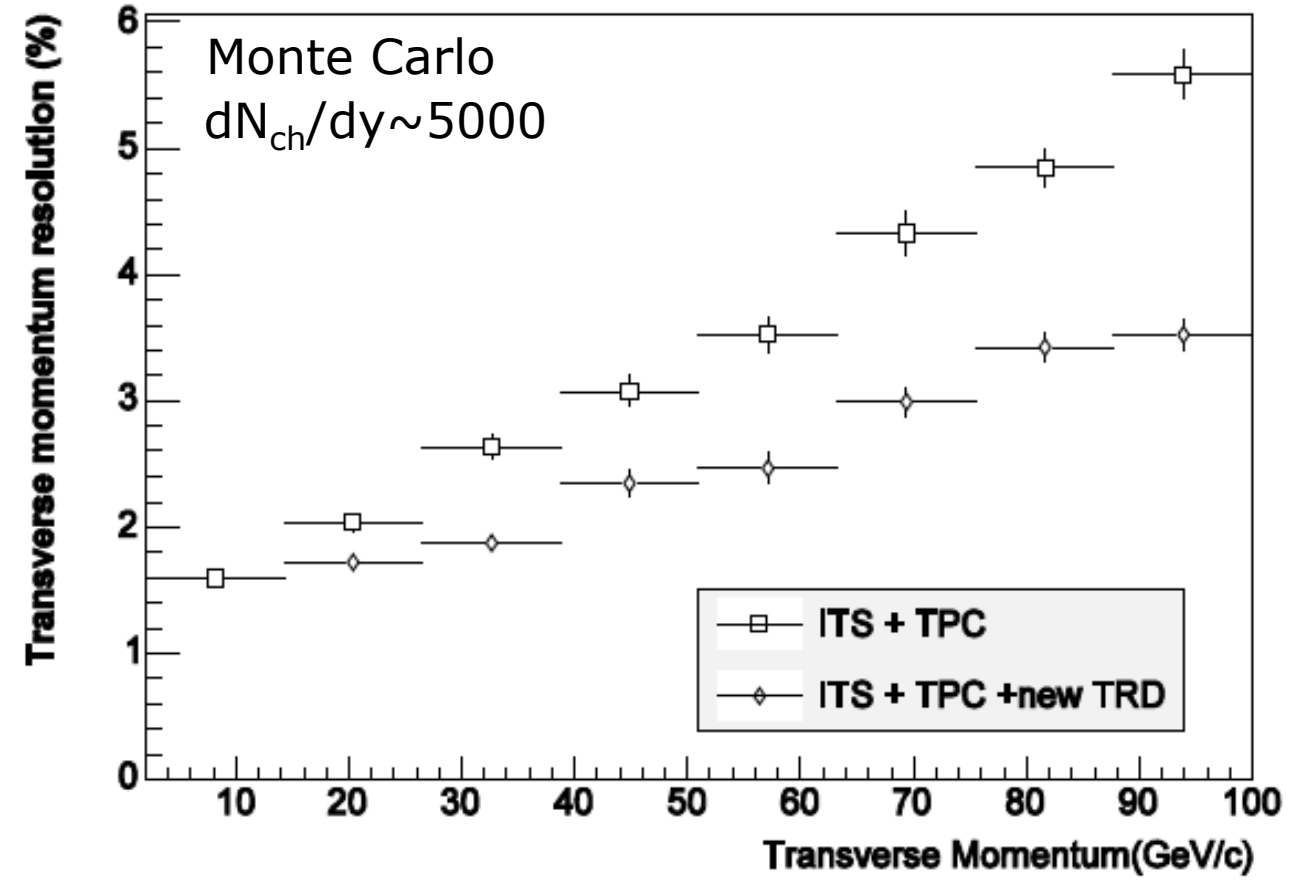
- Method:
  - d_0 distribution w.r.t. primary vertex from tracks without the current track
  - Gaussian fit distribution in ± 2 RMS (negligible contribution of secondaries)
    - *Gaussian+Exp-tails fit under study (looks more stable)*
  - Check sigma and mean



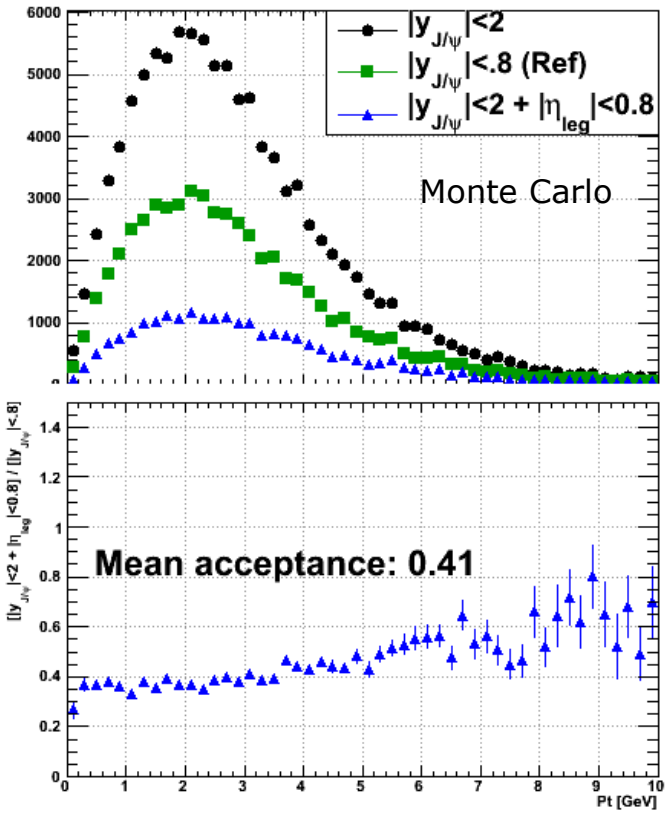
The resulting resolution is the convolution of the track-position and the primary-vertex resolutions

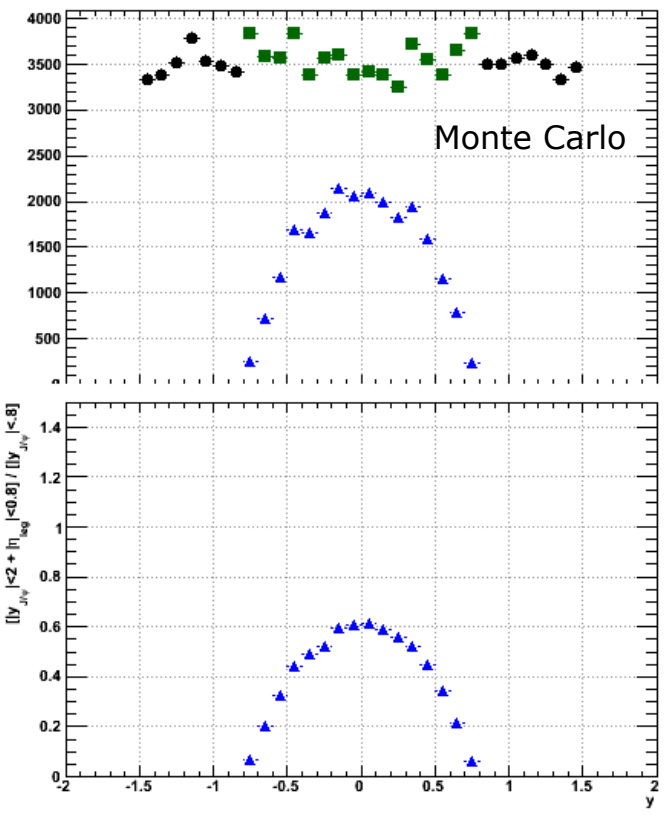
Combined Momentum Resolution in ALICE Central Barrel in Pb-Pb collisions

- resolution ~ 3% at 100 GeV/c
- still excellent performance in hard region!



J/ψ acceptance





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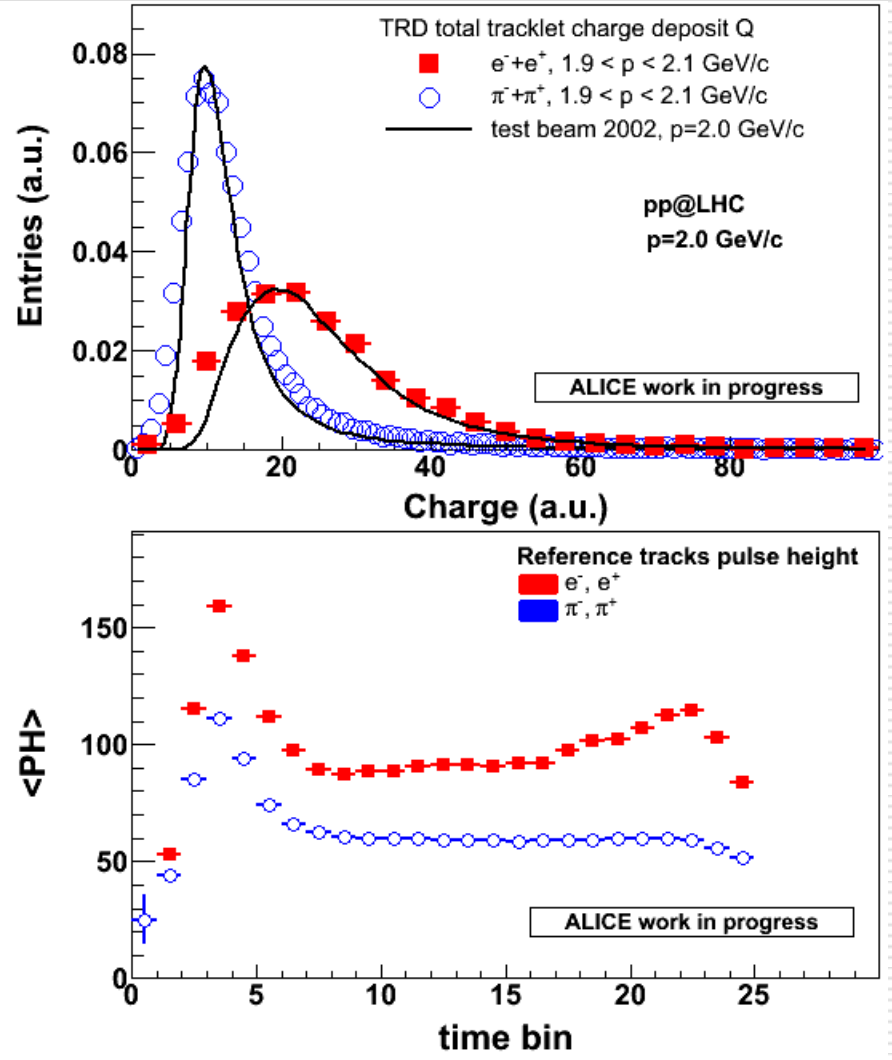


LHC

- Running conditions:

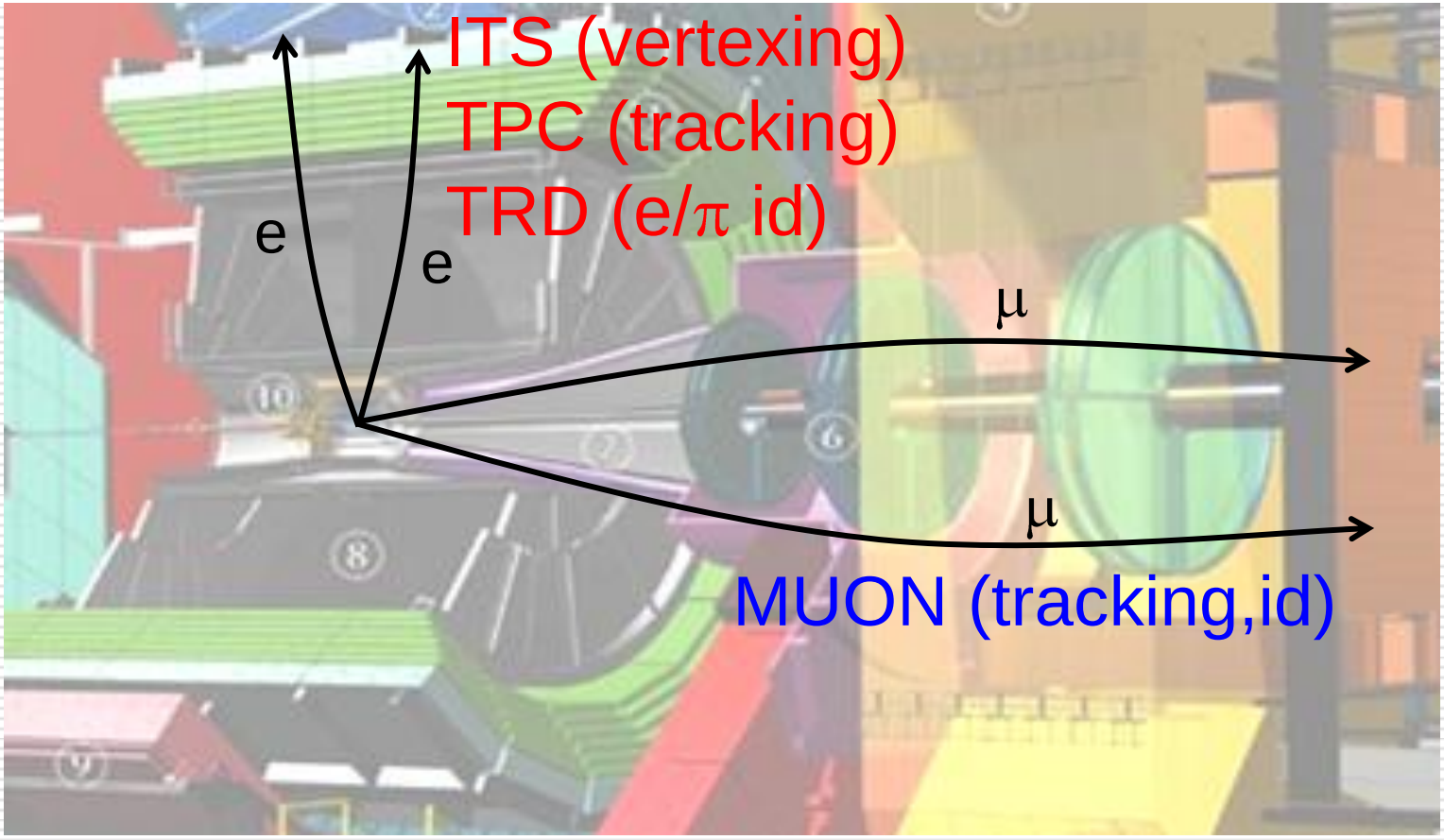
Collision system	$\sqrt{s_{NN}}$(TeV)	L_0 ($cm^{-2}s^{-1}$)	Run time (s/year)	σ_{geom} (b)
pp	14.0	10^{34} *	10^7	0.07
PbPb	5.5	10^{27}	10^6 **	7.7
pPb	8.8	10^{29}	10^6	1.9
ArAr	6.3	10^{29}	10^6	2.7

*$\mathcal{L}_{max}$ (ALICE) = 10^{31} **$\mathcal{L}_{int}$ (ALICE) ~ 0.5 nb^{-1}/year

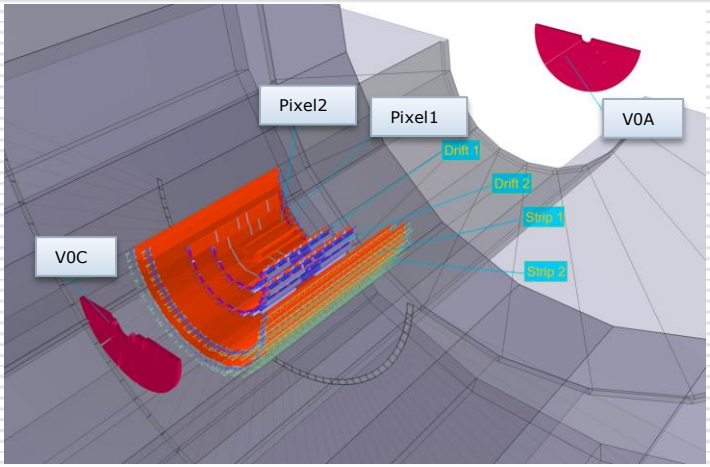
- + other ions (Sn, Kr, O) & energies (e.g.: pp @ 5.5 TeV)

Quarkonia

- Measured both in the di-electron (midrapidity, TRD) and di-muon (forward rapidity, MUON) channel



Trigger & Data samples so far



- "**Minimum bias**", i.e. interaction **trigger**:
  - SPD or V0-A or V0-C
    - at least one charged particle in 8 η units
- **single-muon trigger:**
  - forward muon in coincidence with Min Bias
  - read out MUON, SPD, V0, FMD, ZDC
- Activated in coincidence with the BPTX beam pickups

- 2009 (0.9 and 2.36 TeV)
  - ~10.3 μb^{-1} (5×10^5 min bias)
- 2010 to July 13th (0.9 and 7 TeV)
  - ~4.1 nb^{-1} (3×10^8 min bias)