Single Muon and J/Ψ yield in forward rapidity as a function of the particle multiplicity at mid-rapidity in the ALICE experiment.

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For the ALICE Collaboration.

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Outline

- **Introduction**
- **Charged particle multiplicity**
- **Single Muons as a function of the tracklet multiplicity**
- **J/ψ as a function of the tracklet multiplicity**
- **Conclusions and Outlooks**

Outline

Introduction

- Physics motivations.
- The ALICE experiment.
- The Inner Tracking System.
- The Muon Spectrometer.

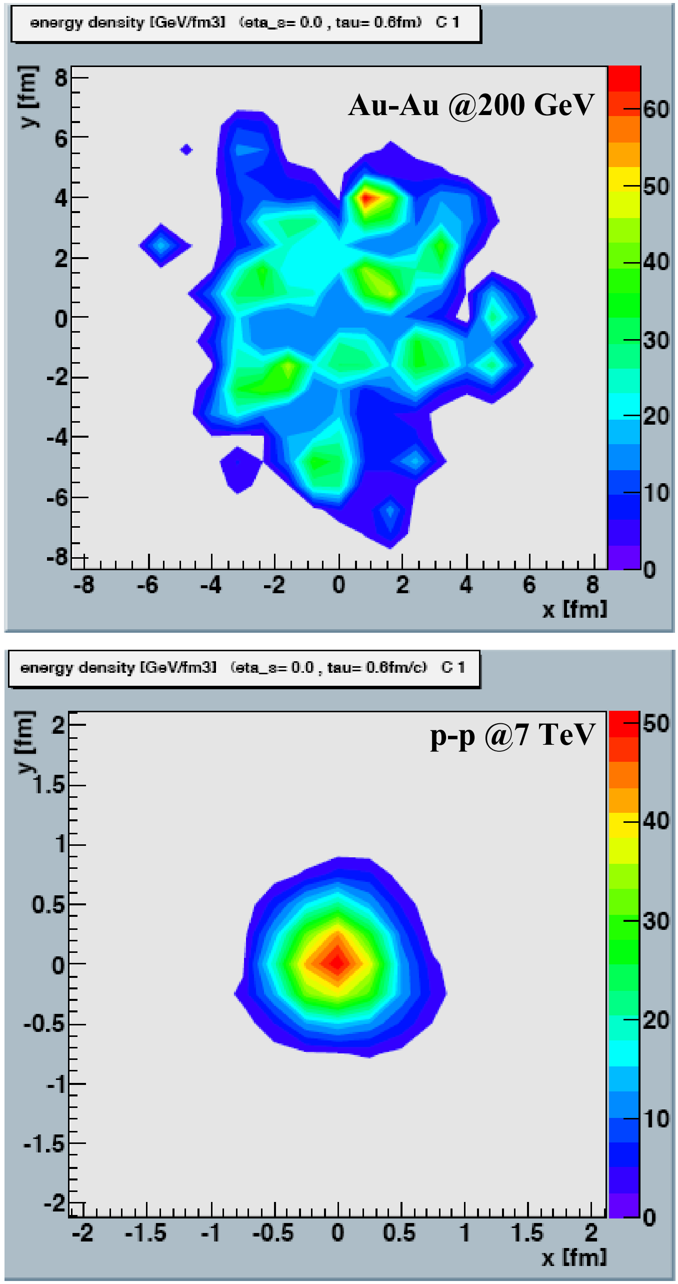
Physics Motivations

The results on the two-particles angular correlation ($\Delta\eta$, $\Delta\phi$) in p-p collisions by the CMS collaboration[1], in particular the presence of a "ridge" around $\Delta\phi = 0$ can be interpreted as an hydrodynamic effect [2].

This may imply the apparition of phenomena in the probes of the QGP in p-p collisions that were only observed in A-A collisions at lower energies.

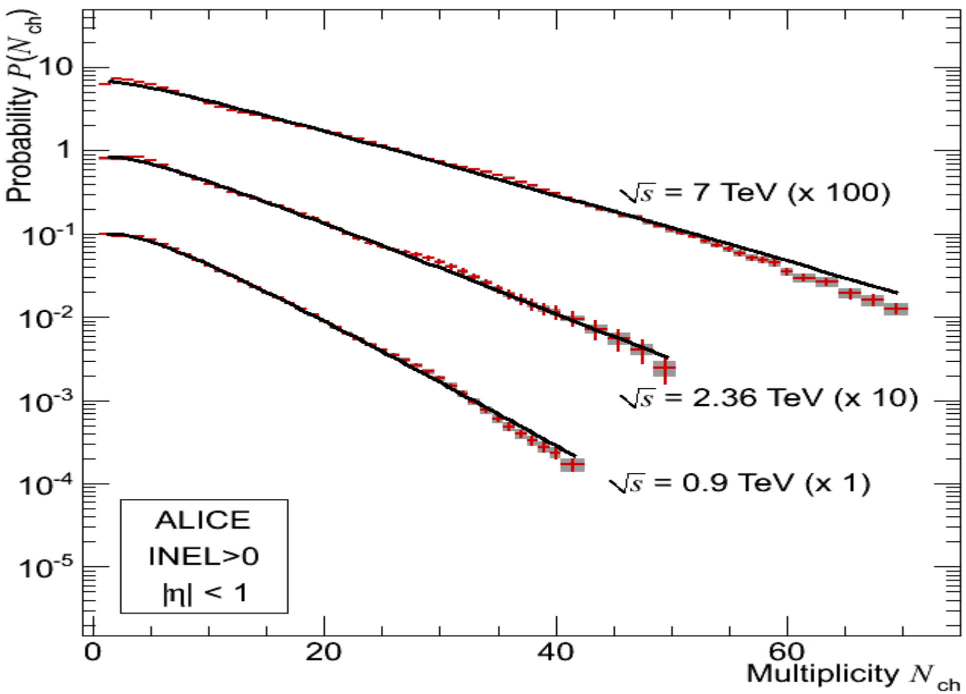
In p-p collisions, the centrality variable is the charged particles multiplicity of the collision.

Energy density ($GeV.fm^{-3}$) computed with EPOS simulations [3]



[1] CMS Collaboration, JHEP 1009:091, 2010
[2] K. Werner *et al.*, Phys. Rev. Lett. **106**, 122004 (2011)
[3] T. Pierog *et al.*, arXiv:1005.4526

Charged particle multiplicity measured by ALICE in p-p collisions at 0.9, 2.36 and 7 TeV, in the $|\eta| < 1.0$ range [4].



Measured average charged particles density :

$$<dN_{ch}/d\eta> = 6.01 \pm 0.01(stat.)^{+0.20}_{-0.12}(syst.)$$

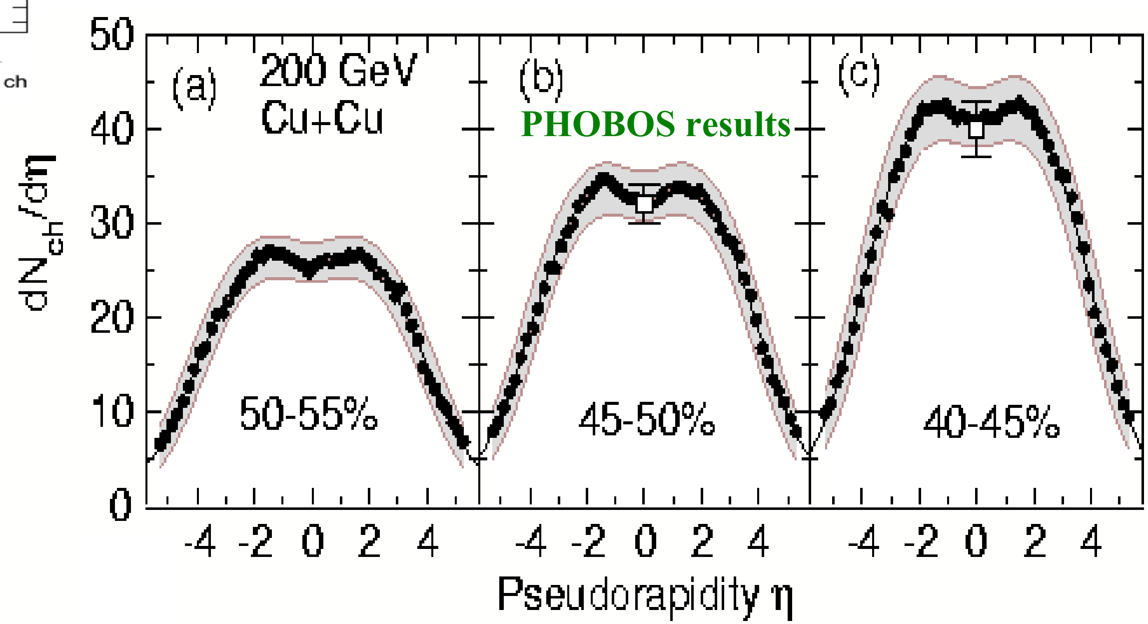
Maximum particle multiplicity reached in p-p collisions at 7 TeV in ALICE : $N_{ch} \approx 60$.

Corresponding charged particle density :
$dN_{ch}/d\eta = 0.5{*}N_{ch} \approx 30$

Comparison with RHIC [5] :

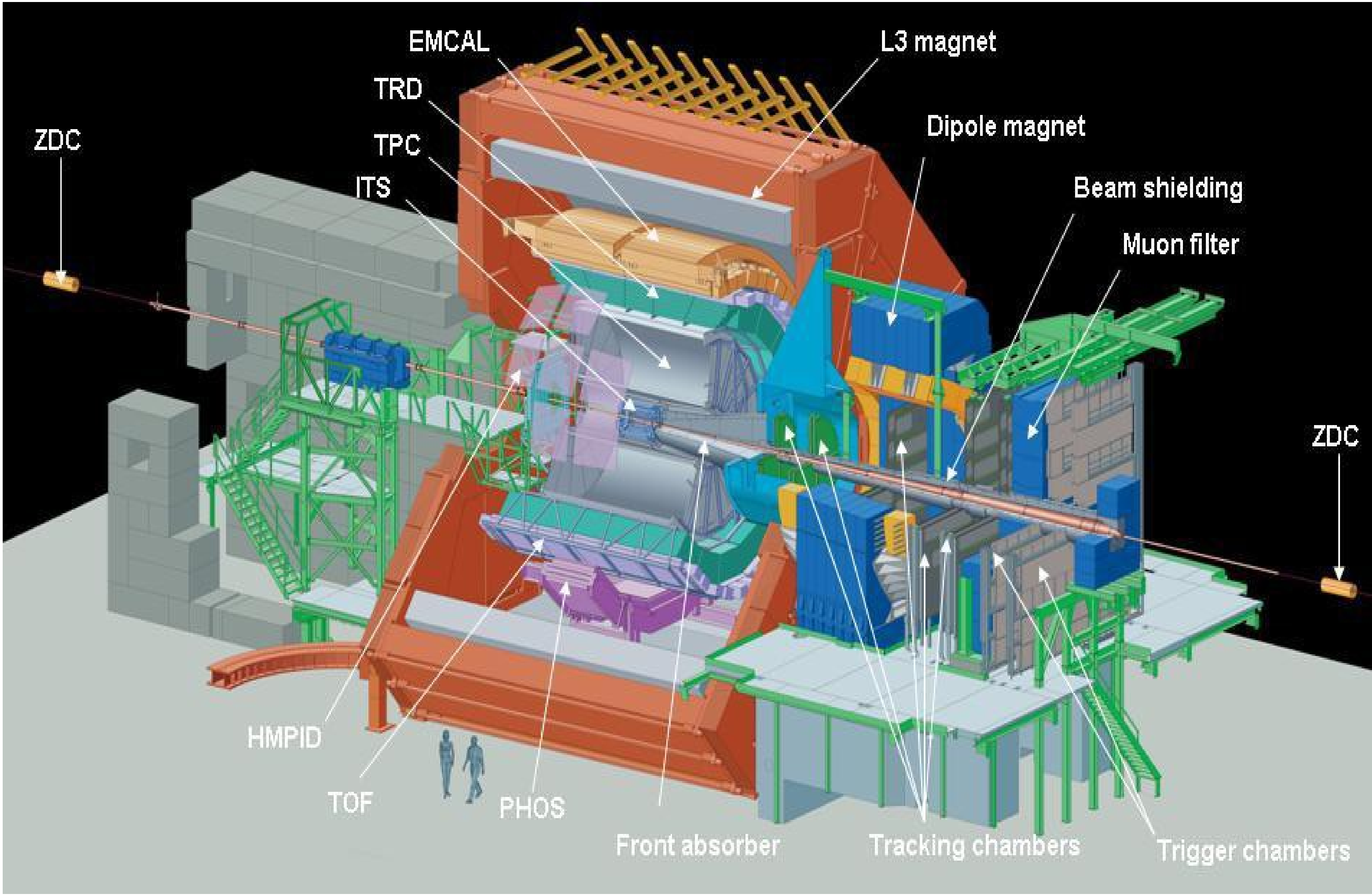
$dN_{ch}/d\eta$ (p-p 7 TeV) ≈

$dN_{ch}/d\eta$ (Cu-Cu; 50-55% 200 GeV)

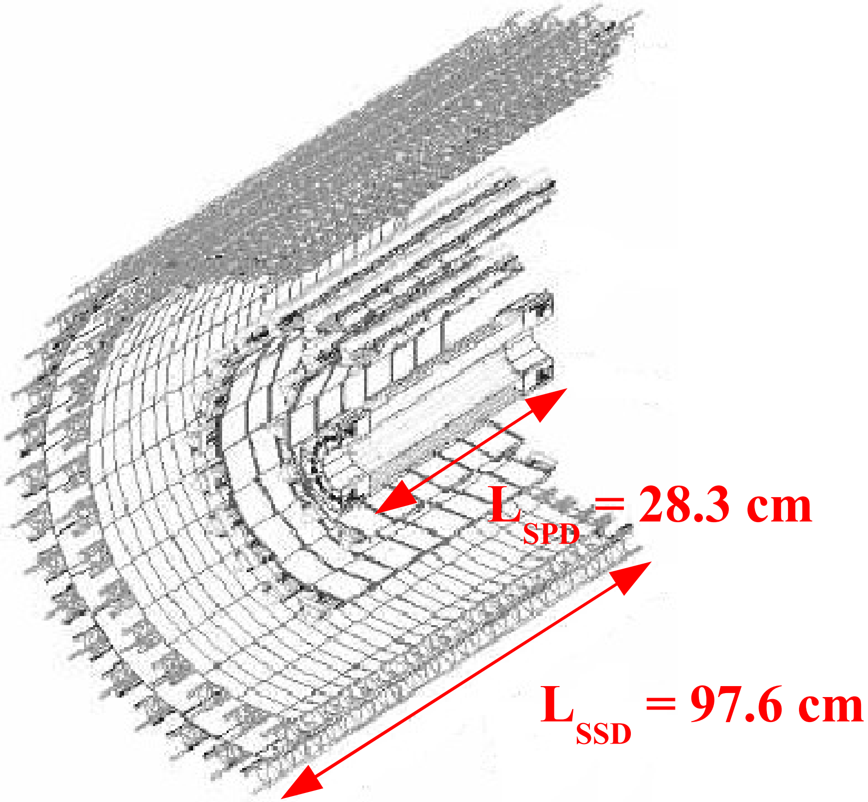


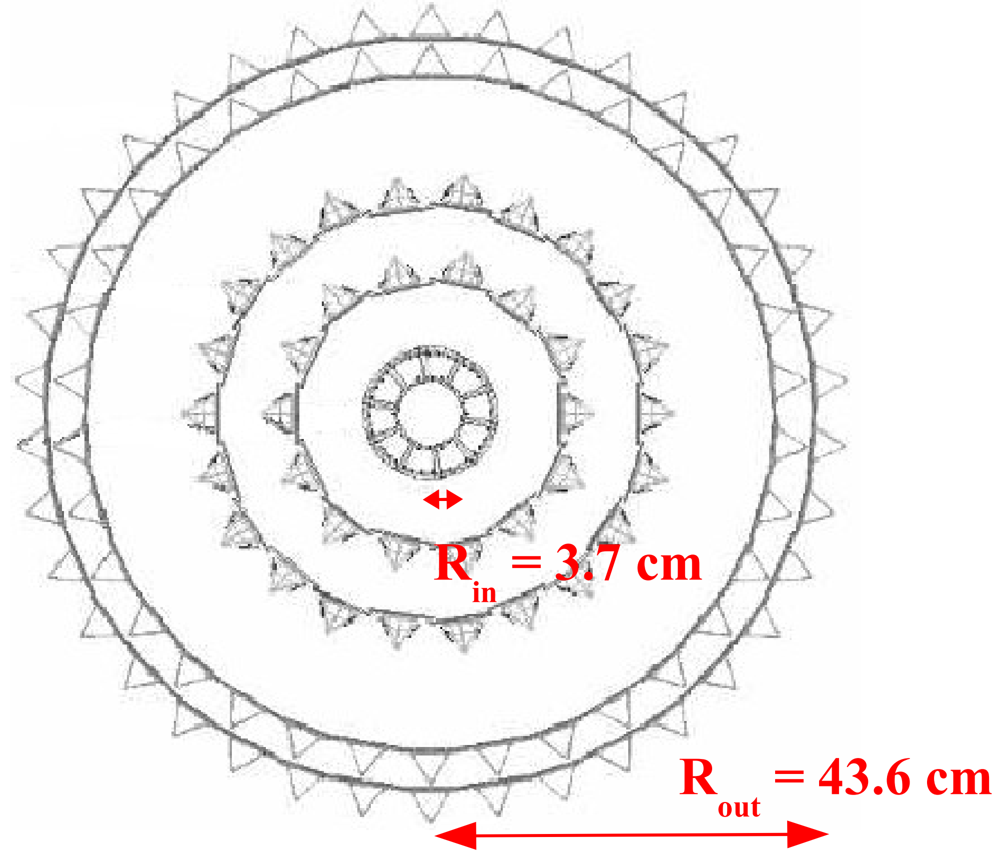
[4] ALICE Collaboration, EPJC: Vol. 68 (2010) 345
[5] PHOBOS Collaboration, Phys. Rev. C **83**, 024913 (2011)

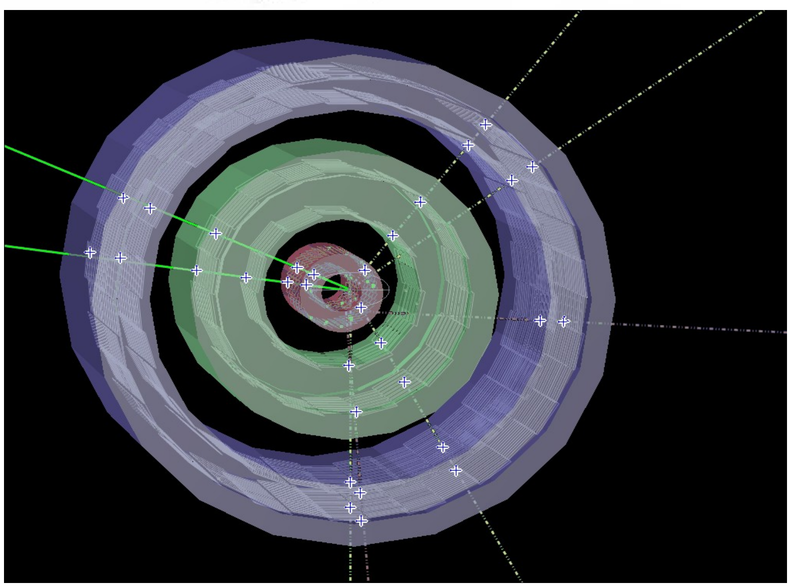
ALICE experiment



Inner Tracking System







The SPD is :

- Our multiplicity detector.
- Our vertex detector.

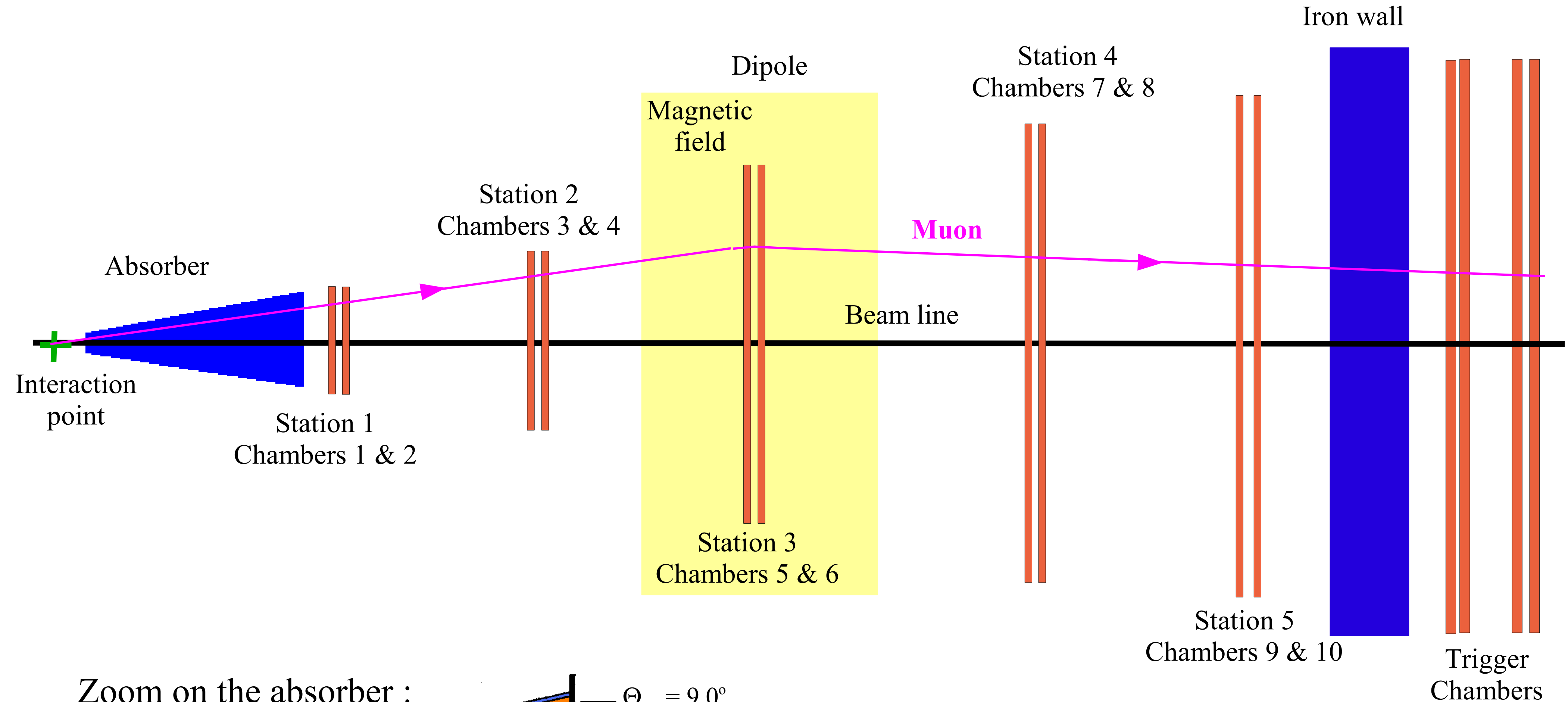
Acceptance of the SPD :

- $|\eta| < 2.0$

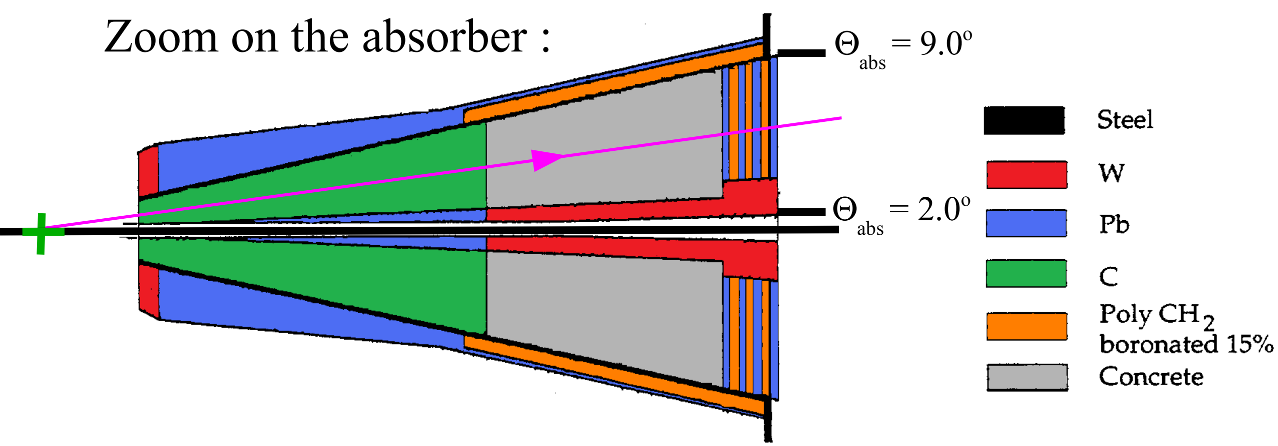
Our cuts on the SPD tracklets :

- $|\eta| < 1.6$
- $|z| < 10.0$ cm

Muon Spectrometer



Zoom on the absorber :



Acceptance :

- $-4.0 < \eta < -2.5$
- $2.0^o < \theta_{abs} < 9.0^o$

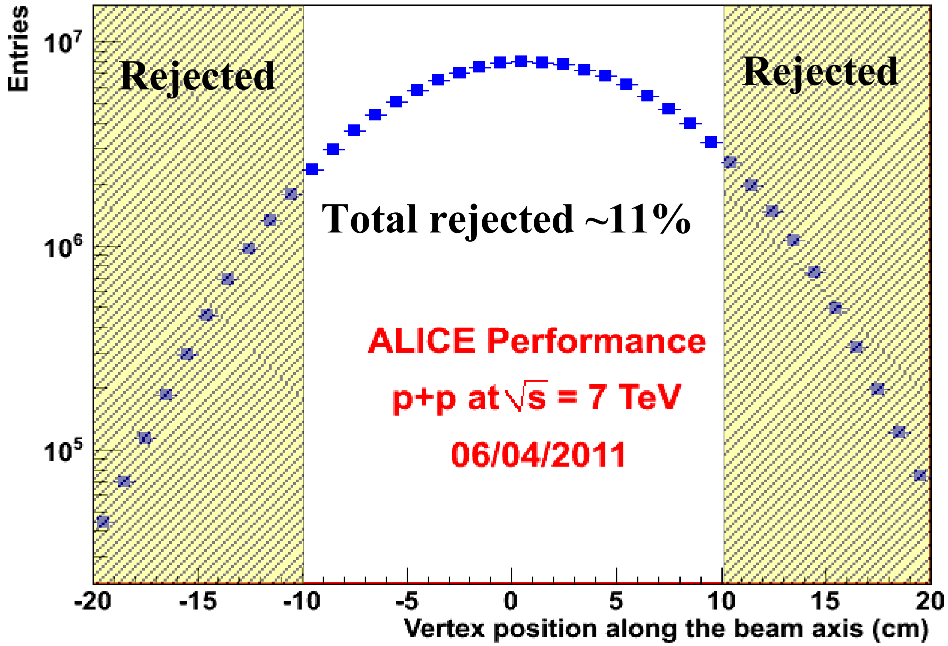
Outline

Charged particle multiplicity

- Tracklet multiplicity in ALICE.
- Pile up in ALICE.
- Estimation of Pile up from data.
- Estimation of Pile up from MC

Tracklet multiplicity in ALICE

Our multiplicity variable will be the SPD tracklet multiplicity.

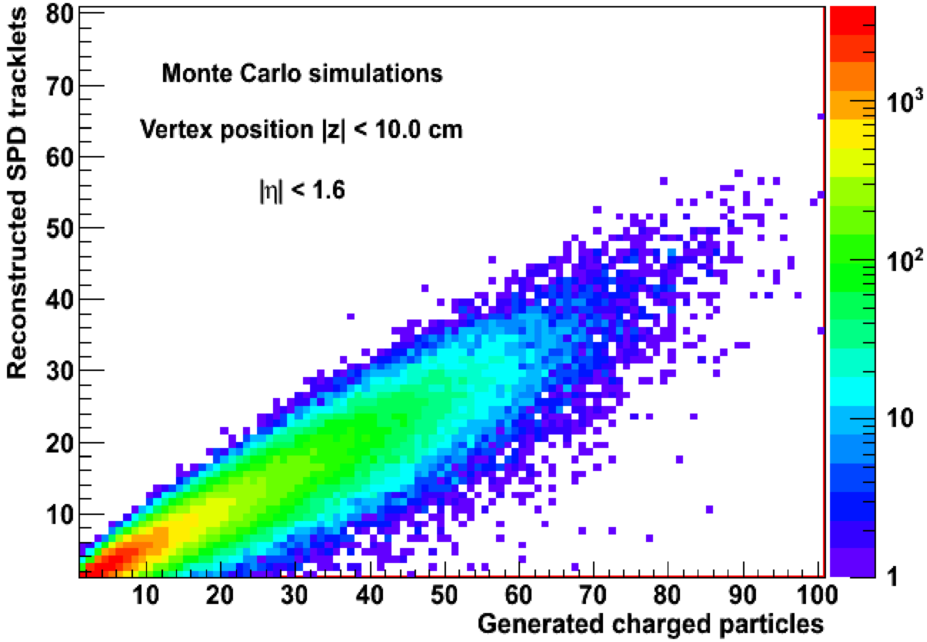


Cuts on the events and the tracklets :

- Events with a position along the beam axis $|z| > 10.0$ cm are rejected (~11% of events).
- Only tracklets with $|\eta| < 1.6$ are counted.

To obtain $dN_{ch}/d\eta$ from the Tracklet multiplicity :

- Correction for the SPD efficiency in $|\eta| < 1.6$, obtained from MC simulations.
- Correction for the rapidity range $-1.6 < \eta < 1.6$



In the end, the total correction factor is 0.56 :

$$\frac{dN_{ch}}{d\eta} \approx 0.56\ N_{tracklets}$$

Pile up in ALICE

When two bunches cross each other at the interaction point of ALICE, more than one pair of protons can collide. Those events are called pile up events.

In this data sample, ALICE MB trigger rate was 10kHz, with 48 crossing bunches in each beam.

Estimation of the rate of pile up events :

- Probability to have n p-p collisions in an event, given by the Poisson distribution :

$$P(n) = \frac{\mu^n e^{-\mu}}{n!}$$

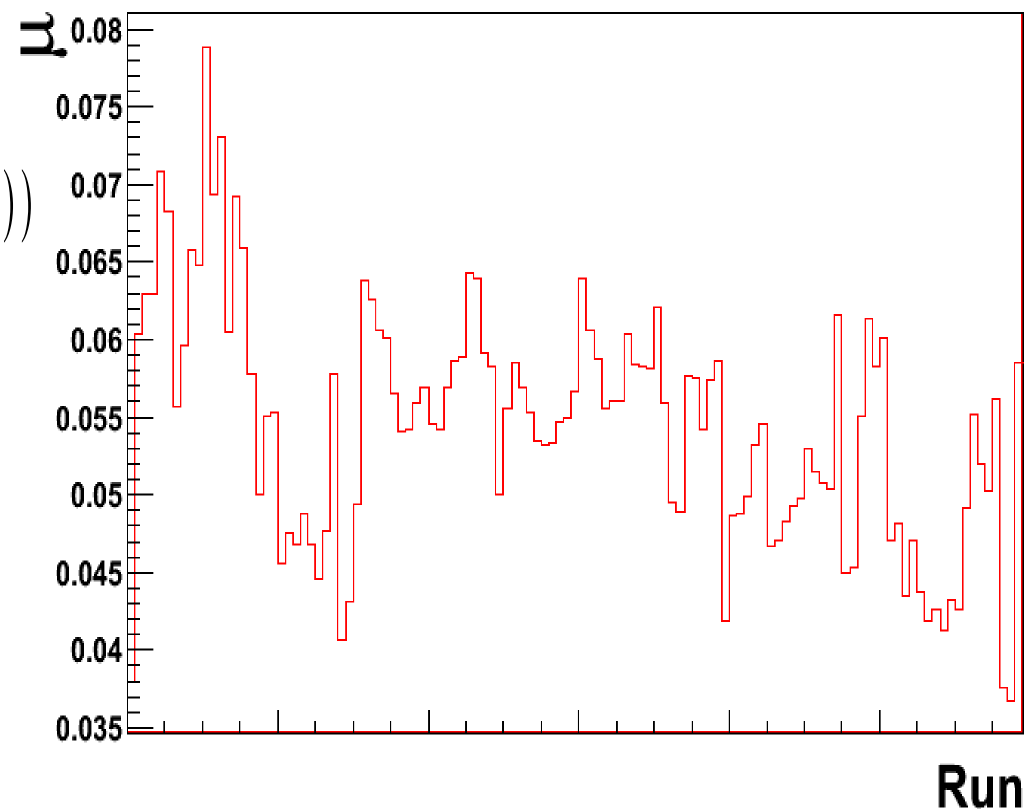
where μ is the average number of collision per events.

- Choosing n = 0 : $\mu = \ln(P(0)) = \ln(1 - P(n>0))$

- And : $P(n>0) = \frac{N_{Trigger}}{N_{cross\ bunch} f_{rev}}$

  - $N_{Trigger}$: number of events triggered.
  - $N_{cross\ bunch}$: number of crossing bunches in the beam (48).
  - f_{rev} : frequency of revolution of the LHC (11 245 Hz).

In the data period, $<\mu>$ = 0.0572



Estimation of Pile up from data

If more than one vertex reconstructed with the SPD

↓

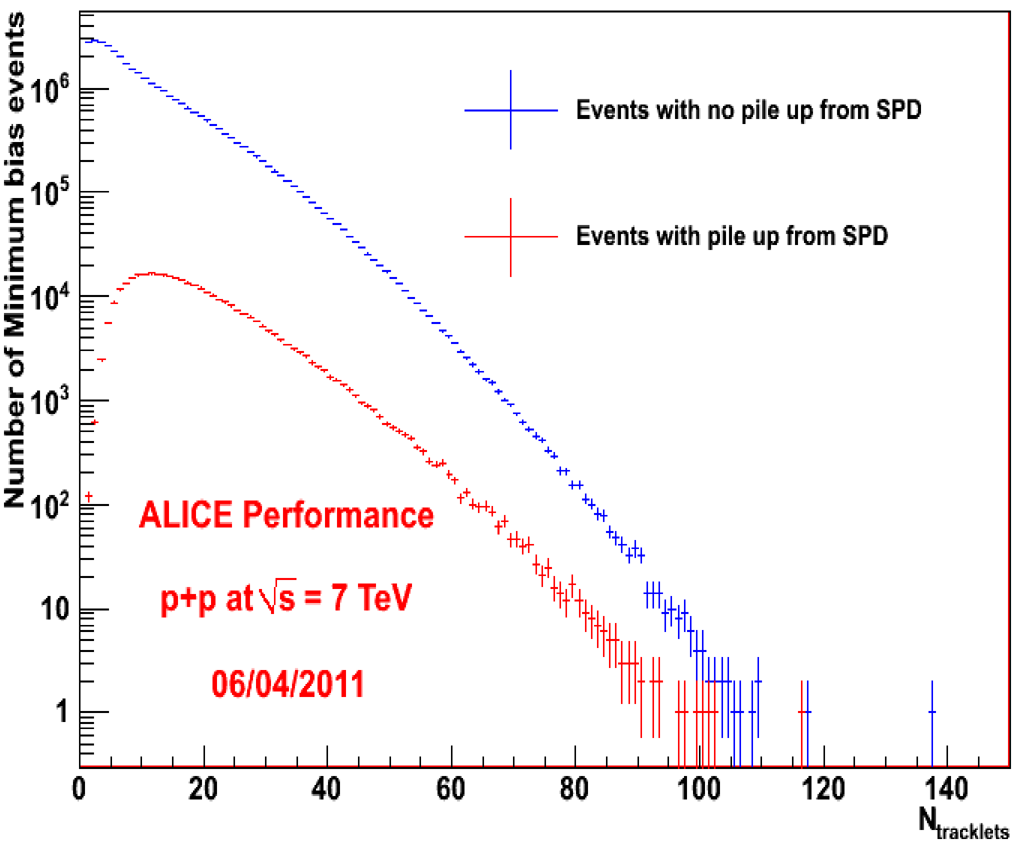
More than one pp collisions took place

Conditions on second vertexes :

- Distance to the primary vertex along the beam axis must be > 0.8 cm.
- Second vertex must have at least 3 tracklets associated.

Corrections to apply on pile up distribution from SPD :

- Efficiency of vertex reconstruction.
- Efficiency of pile-up reconstruction.
- Selection of the characteristics of the pile-up vertex.



Evolution of the correction factor with $N_{tracklets}$ under progress.

For now, global correction factor ≈ 3.7

Estimation of Pile up from MC

Determination of the pessimistic pile up scenario using a MC model.

If pile up : $N_{tracklets}(event) = N_{tracklets}(coll1) + N_{tracklets}(coll2)$

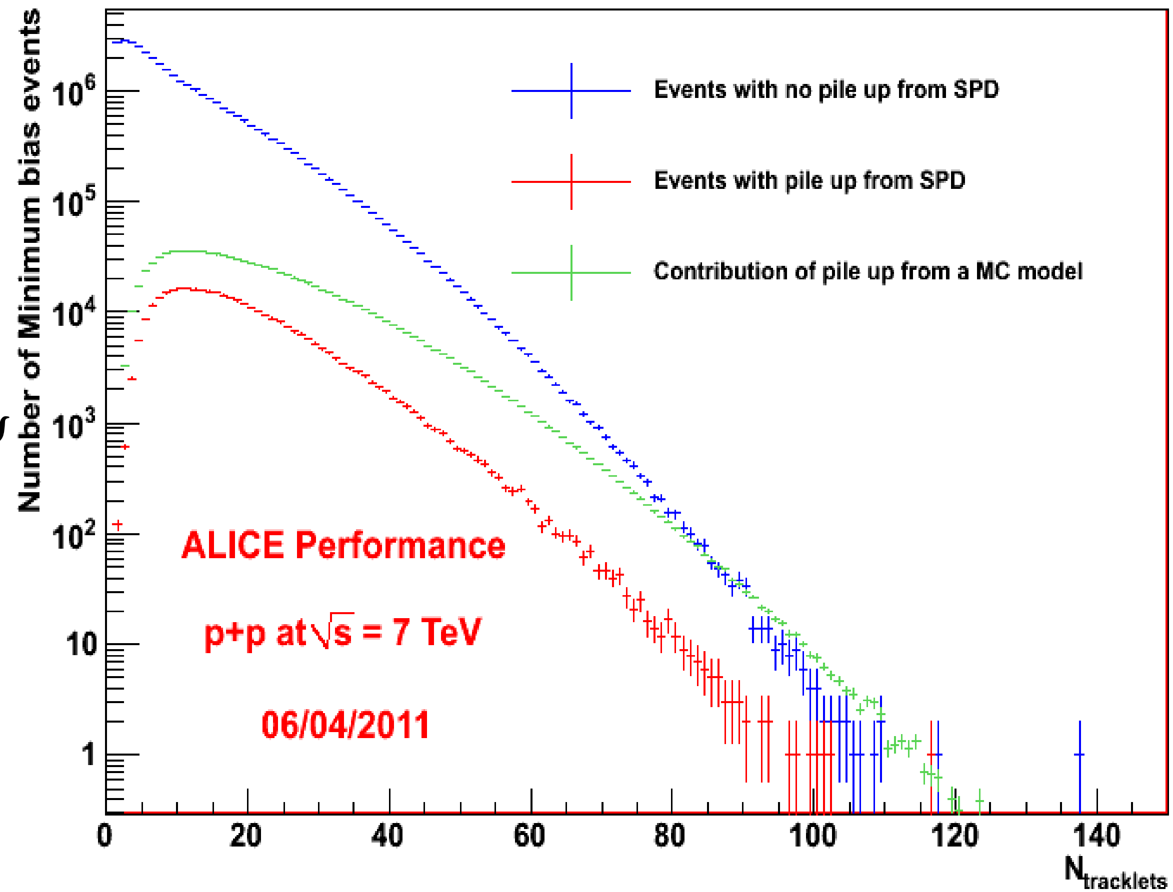
From MC, pile up events not dominant before $N_{tracklets} > 70$

However, not enough statistics (for the J/ψ in particular) to go beyond $N_{tracklets} > 60$

Corresponds to $\frac{dN_{ch}}{d\eta} \approx 0.56 * 60 \approx 33$

Five times the average $dN_{ch}/d\eta$.

Pile up rate estimation in the last tracklet multiplicity bin : $45 < N_{tracklets} < 60$



	SPD method	MC method
Pile up becomes dominant	$N_{tracklets}$ > ~90	$N_{tracklets}$ > ~70
% Pile Up in $45 < N_{tracklets} < 60$	~15 %	<25 %

Outline

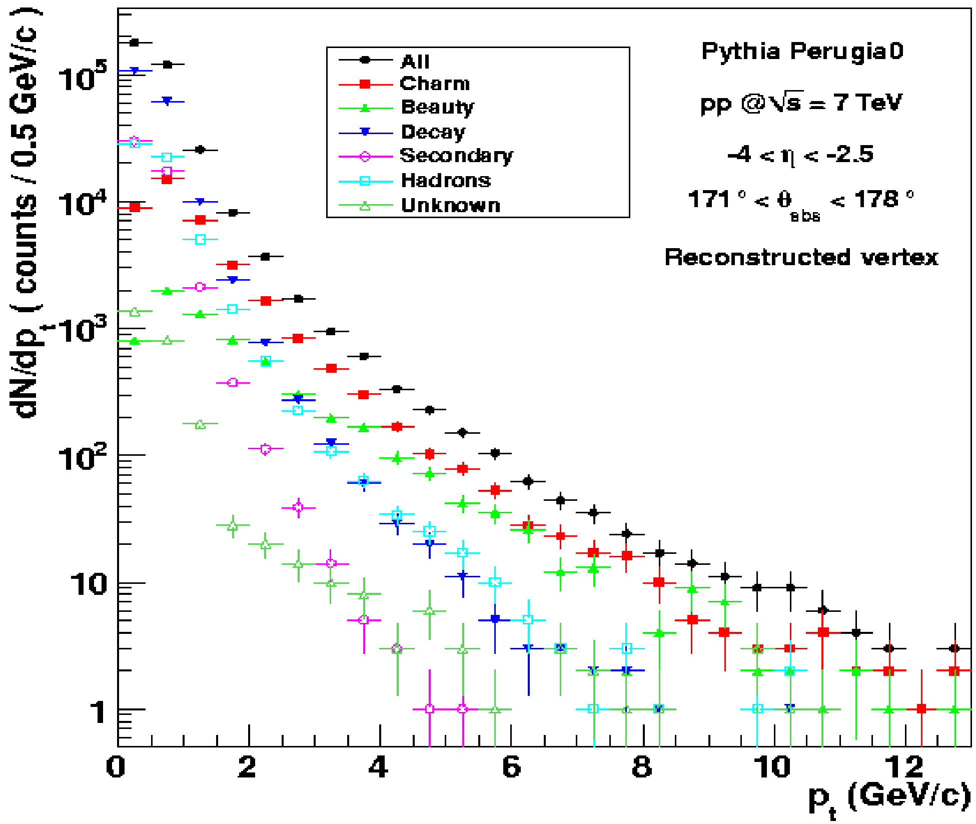
Single Muons as a function of the tracklet multiplicity

- Introduction
- Single Muon yields.
- Ratio of High p_T over Low p_T Muon yields.
- Single Muon $\langle p_T \rangle$

Single Muon : Introduction

Two muon sources :

- Low p_T Muons ($1.0 < p_T < 4.0$ GeV/c) : coming from π and K decays (~50%), or Charm and Beauty (~50%) decays.
- High p_T Muons ($4.0 < p_T < 8.0$ GeV/c) : coming from Beauty (~50%) and Charm (~50%) decays.



Cuts on the events :

- $|z| < 10.0$ cm
- Events triggered by the muon trigger system.

Cut on the tracklets :

- $|\eta| < 1.6$

Cuts on the muons :

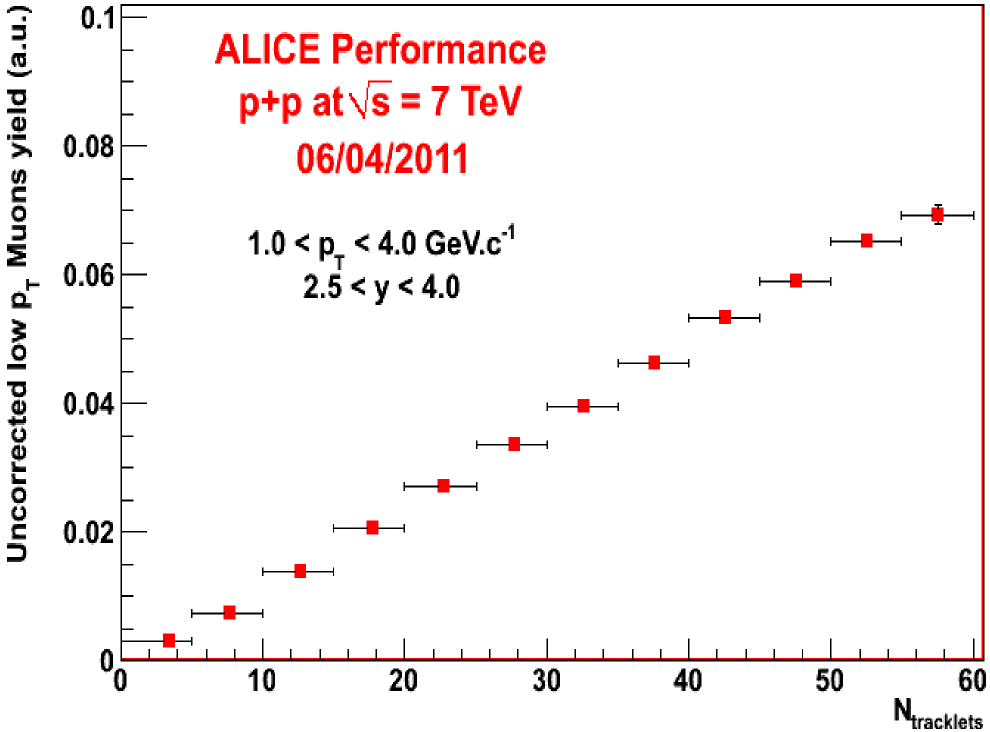
- The muon (tracking) track match the muon (trigger) track
- Acceptance : $-4.0 < \eta < -2.5$ and $2.0^{\circ} < \theta_{abs} < 9.0^{\circ}$
- p*DCA cut at 4σ

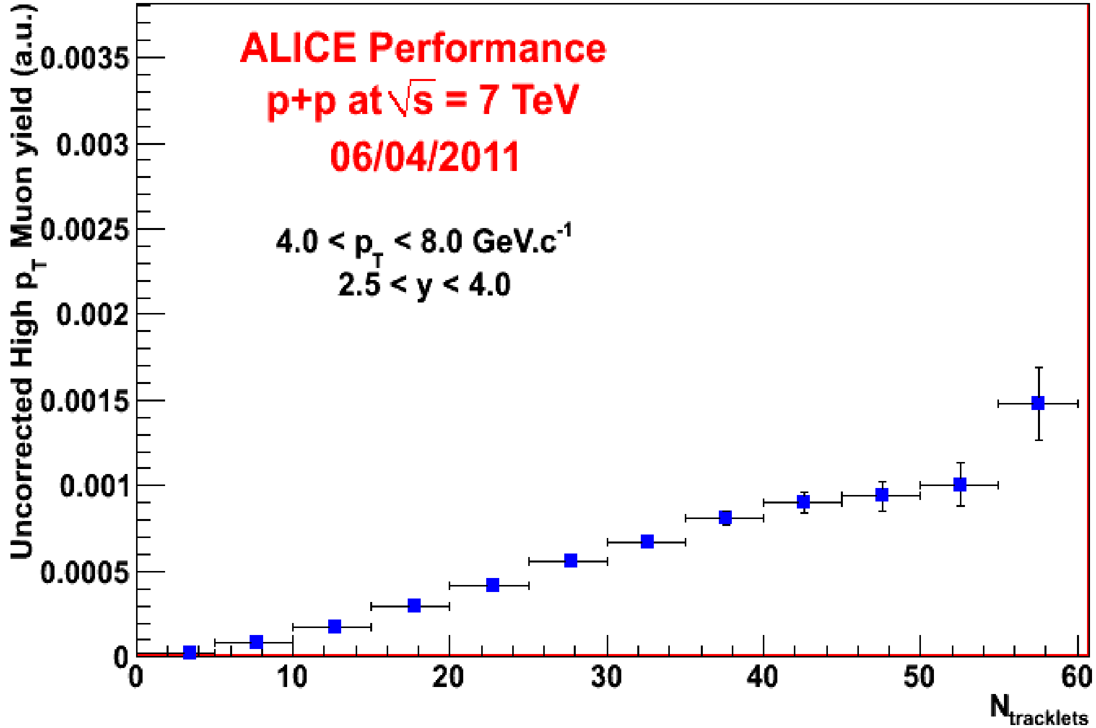
Tracklet Multiplicity Range :

- 0 - 5
- 5 - 10
- 10 - 15
- 15 - 20
- 20 - 25
- 25 - 30
- 30 - 35
- 35 - 40
- 40 - 45
- 45 - 50
- 50 - 55
- 55 - 60

Single Muon Yields

Observable of interest, the yield : $Y_{muons}(N_{tracklets}) = \frac{N_{rec\,muons}(N_{tracklets})}{N_{events}(N_{tracklets})}$





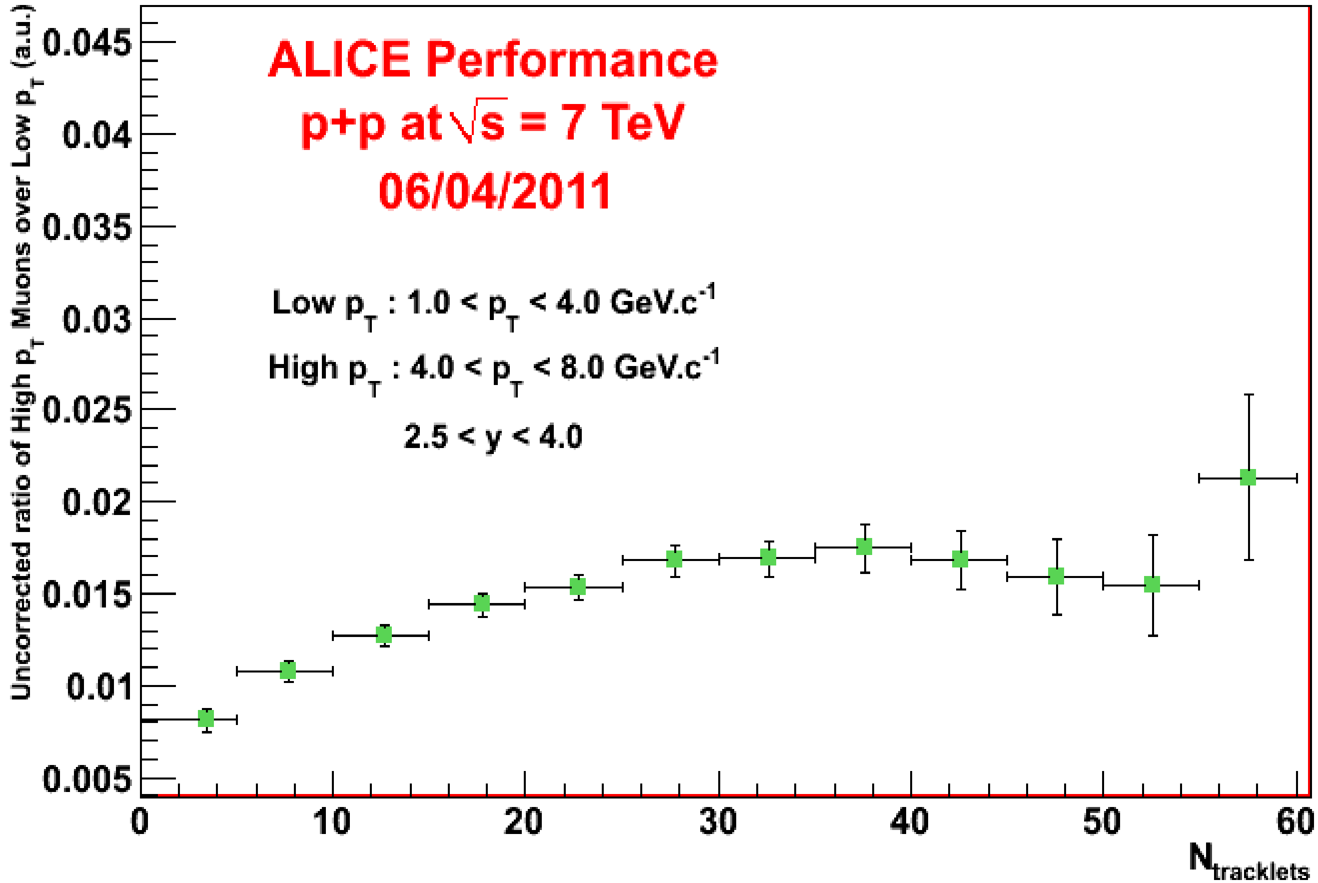
Single Muon yield (in $2.5 < \eta < 4.0$) seems to increase linearly with the tracklet multiplicity (in $|\eta| < 1.6$).

~3 units of rapidity between the two measurements.

Somewhat expected : more particles produced at mid rapidities could mean more parton-parton collisions, and then more muons produced.

Ratio of the High p_T Muons over Low p_T Muons can give their relative evolution.

Ratio of High p_T Muons over Low p_T

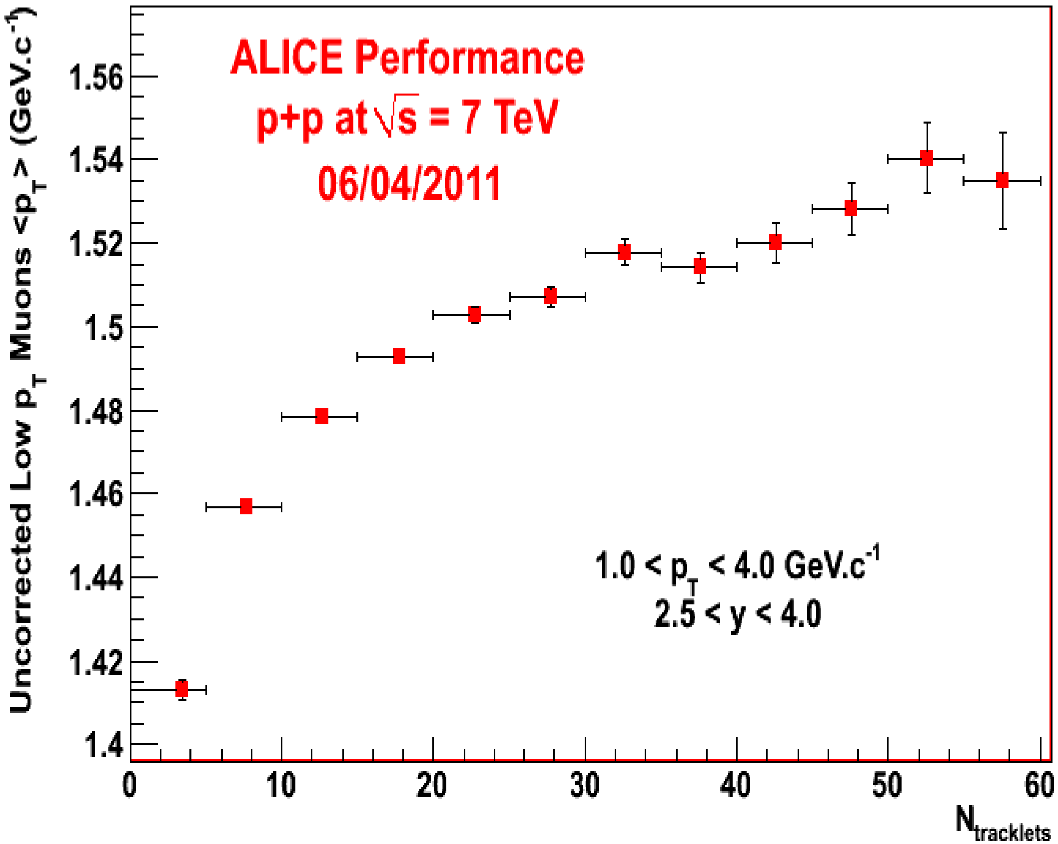


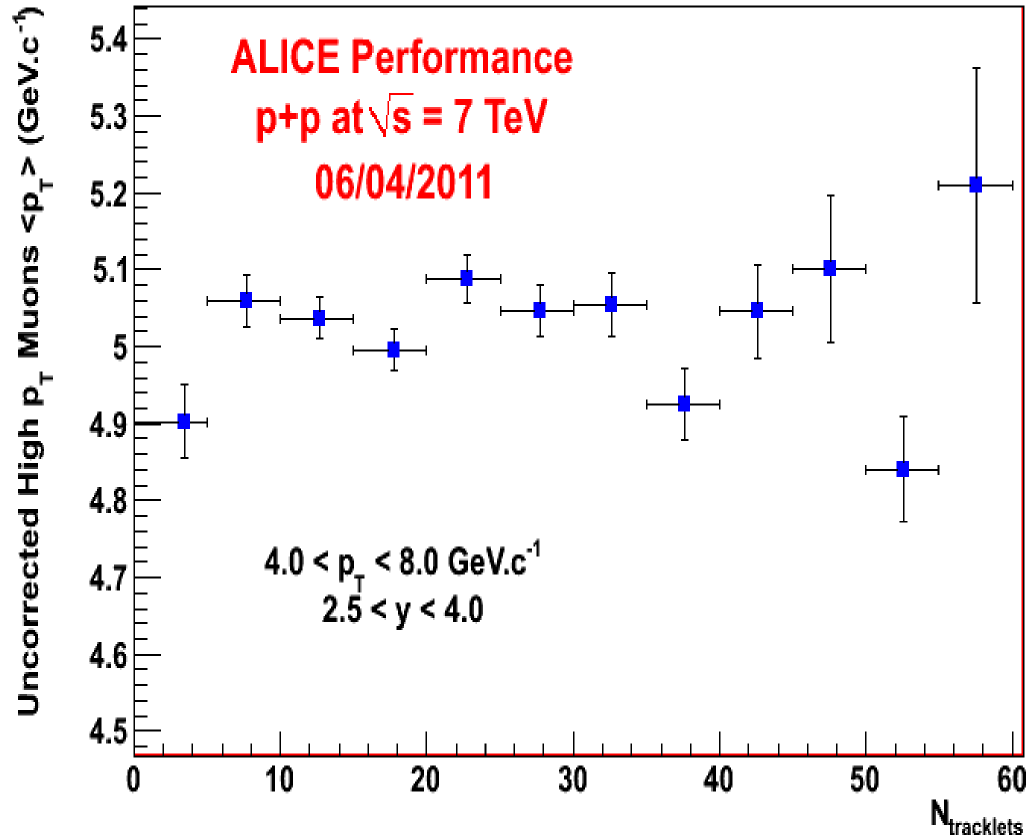
The High p_T Muon yield increases faster with the multiplicity than the Low p_T Muon yield.

It is still difficult to conclude, since the decay has not been substracted in the Low p_T region.

A possible explanation could be an increase of the $\langle p_T \rangle$ versus $N_{tracklets}$ in High p_T Muon sample.

Single Muon $<p_T>$





The $<p_T>$ for Low p_T Muons increases with the tracklet multiplicity.

They come from 50% from the decay of π and K.

This increase has already been observed for hadrons by CDF and ALICE (at 900 GeV).

The $<p_T>$ for High p_T Muons seems constant with the tracklet multiplicity.

The faster increase of the High p_T Muon yield compared to the Low p_T Muon yield can not be attributed to an increase in $<p_T>$.

Outline

J/ψ as a function of the tracklet multiplicity

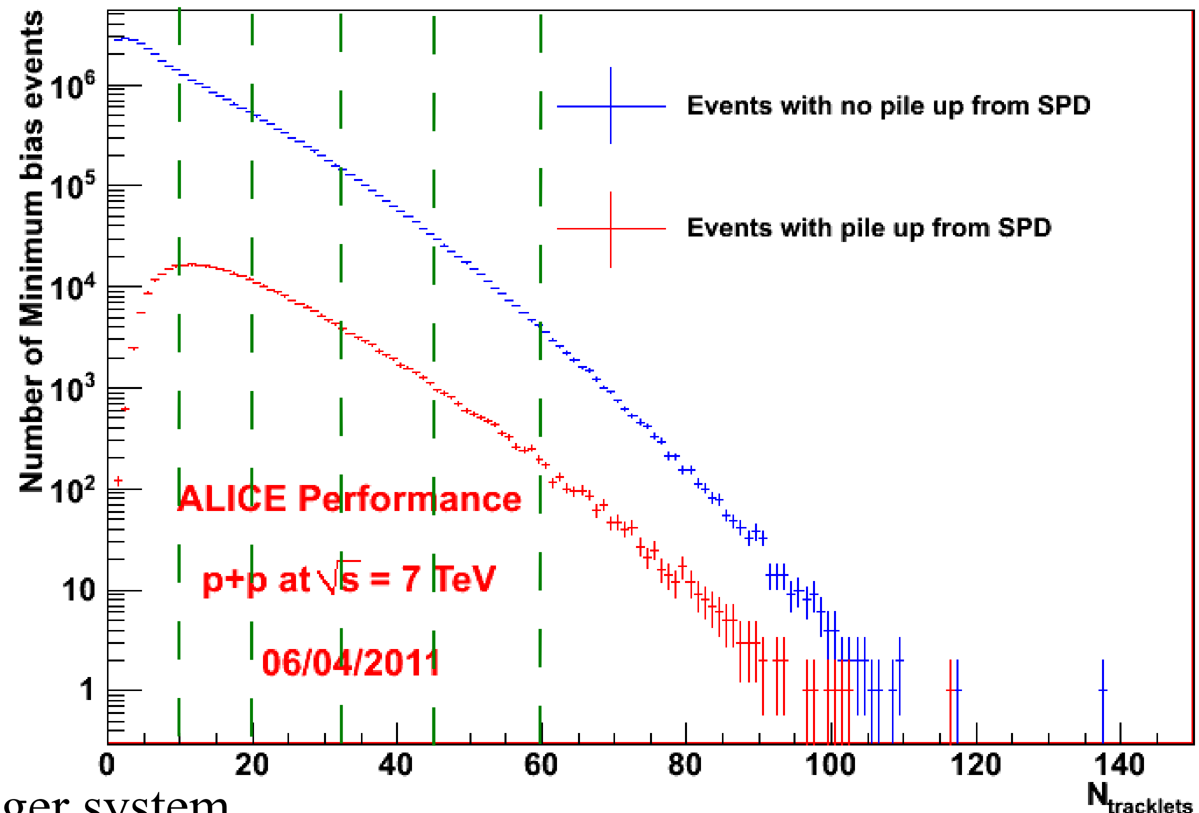
- Introduction.
- J/ψ signal extraction.
- J/ψ signal extraction as a function of the tracklet multiplicity.
- J/ψ yield as a function of the tracklet multiplicity.

J/ψ : Introduction

The statistics for the J/ψ is lower than the one for the Single Muons.

Larger ranges in tracklet multiplicity :

- 0 – 10
- 10 – 20
- 20 – 32
- 32 – 45
- 45 - 60



Cuts on the events :

- |z| < 10.0 cm
- Events triggered by the muon trigger system.

Cuts on the tracklets :

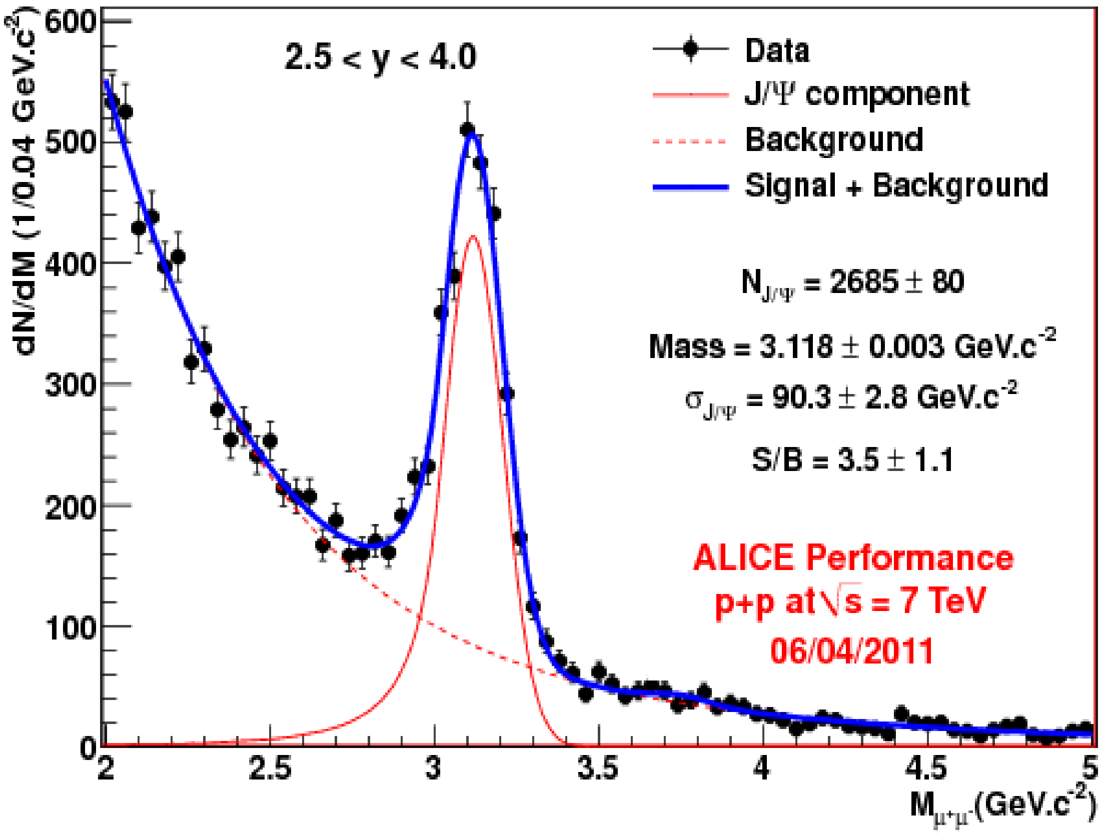
- $|\eta| < 1.6$

Cuts on the dimuon pairs :

- Opposite charge.
- At least one of the reconstructed muon track matches the corresponding muon trigger track.
- Both tracks in the spectrometer acceptance : $-4.0 < \eta < -2.5$ and $2.0^o < \theta_{abs} < 9.0^o$

J/ψ extraction

The number of J/ψ detected is extracted from a fit to the invariant mass distribution.



The fit function is the following :

Crystal Ball function (J/ψ) + Gaussian (ψ') + 2 exponentials (background)

Crystal Ball function :

$$\exp\left(\frac{-(x-\bar{x})^2}{2\sigma^2}\right) \quad \text{for} \quad \frac{x-\bar{x}}{\sigma} > -\alpha$$

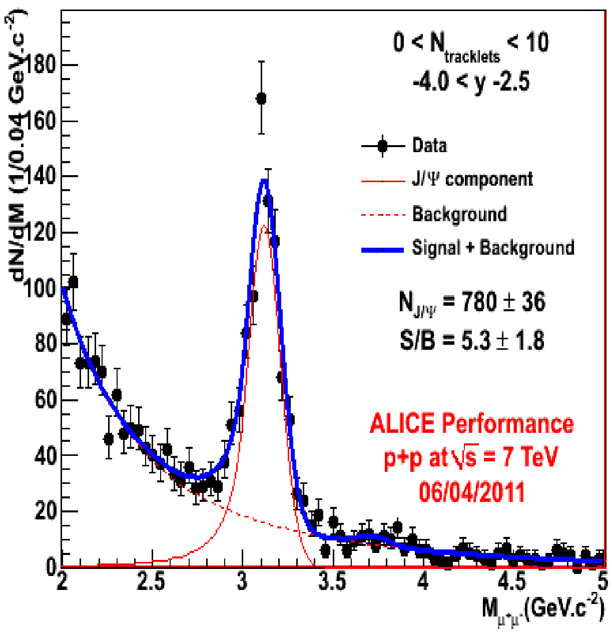
$$\left(\frac{n}{|\alpha|}\right)^n \exp\left(\frac{-\alpha^2}{2}\right)\left(\frac{n}{|\alpha|} - |\alpha| - \frac{x-\bar{x}}{\sigma}\right)^{-n} \quad \text{otherwise}$$

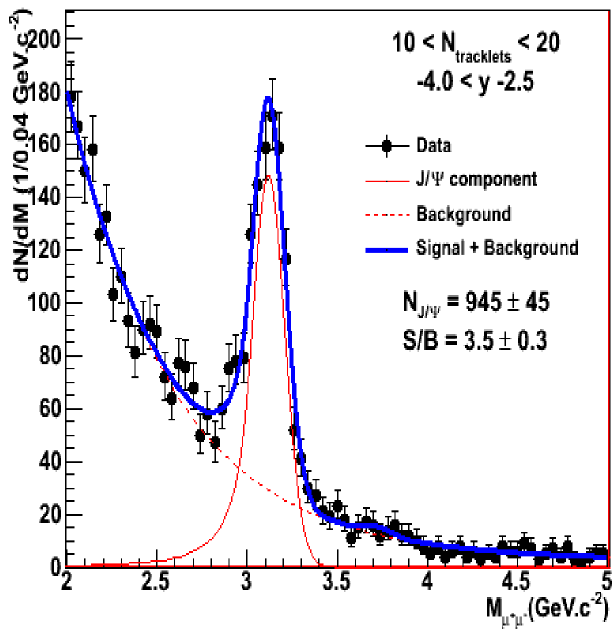
- $M_{J/\psi} = 3.117 \pm 0.003$ GeV/c^2
- $\sigma_{J/\psi} = 90 \pm 3$ MeV/c^2
- n = 2.75 (fixed to MC)
- α = 1.21 (fixed to MC)

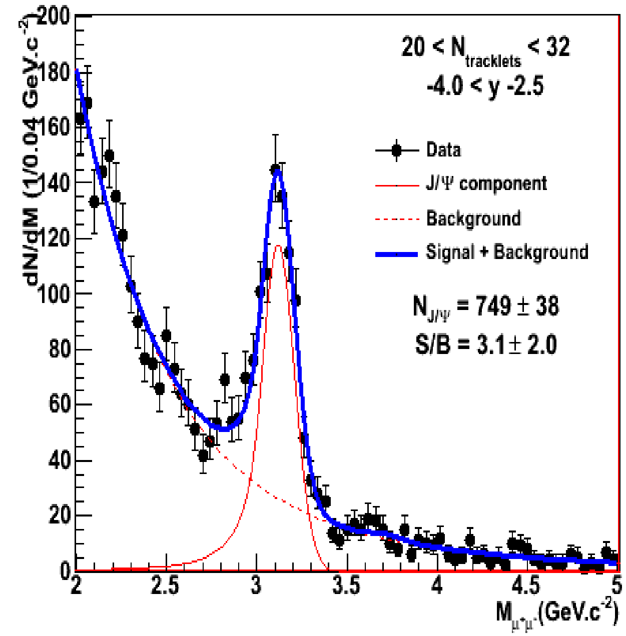
- $M_{\psi'} = 3.7 \pm 0.1$ GeV/c^2
- $\sigma_{\psi'} = 86$ MeV/c^2(fixed to MC)

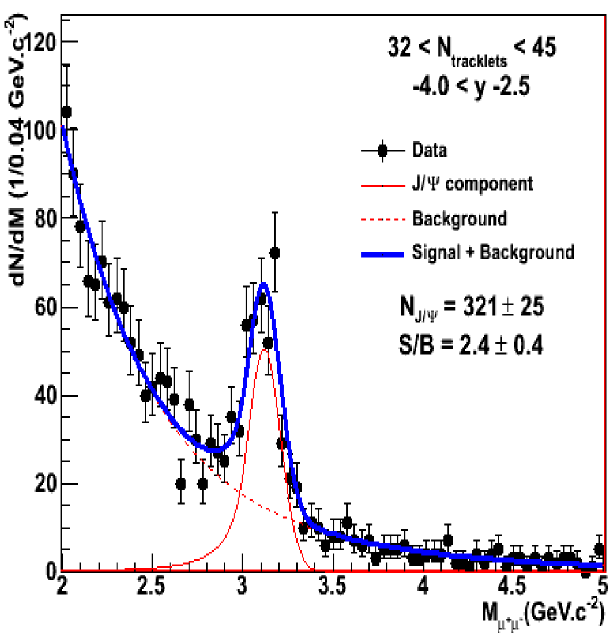
The values of these parameters obtained in the fit will be fixed in the fits shown in the following slide.

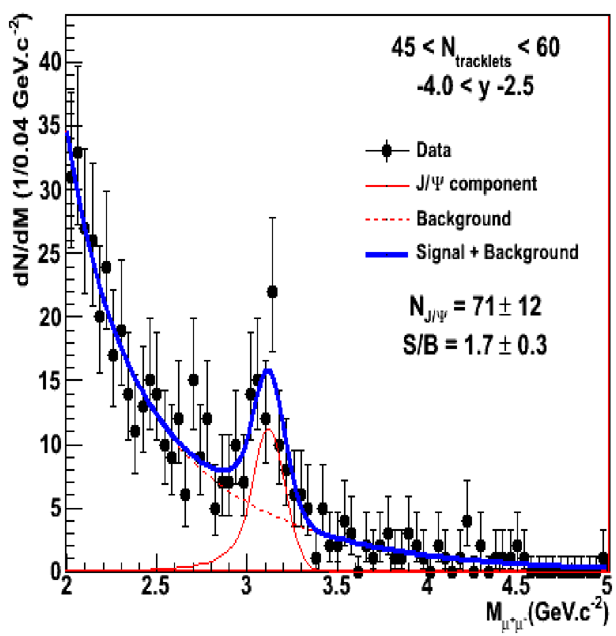
J/ψ extraction as a function of tracklet multiplicity











The S/B decreases with the tracklet multiplicity.

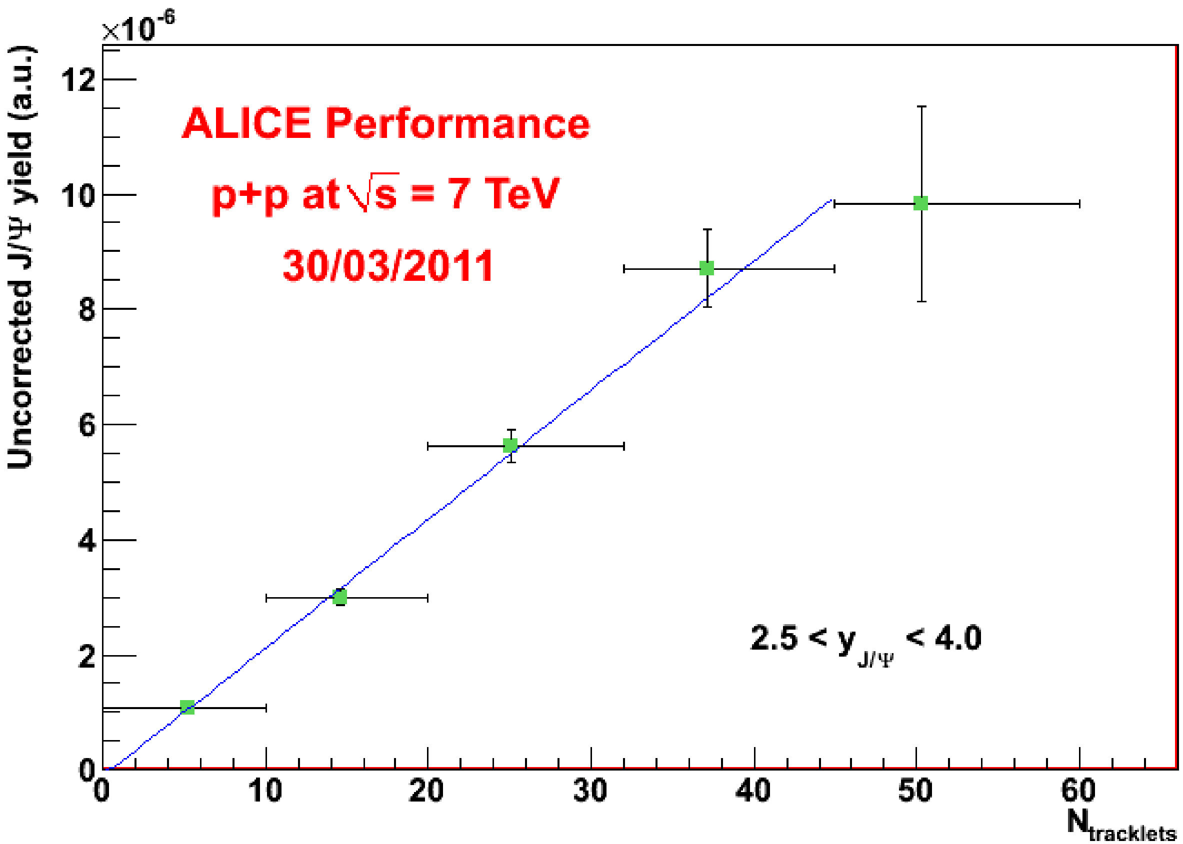
May simply be due to an increase of the combinatorial background.

J/ψ yield as a function of tracklet multiplicity

Uncorrelated errors		Correlated errors	
Statistic	from fit	Signal extraction	7.5 %
Background (pile up)	in progress	Acceptance input	2%
		Trigger efficiency	4%
		Reconstruction efficiency	3%
		Luminosity	7%

Several sources of systematic errors are correlated.

We should only consider uncorrelated errors.



Observable of interest, the uncorrected yield :

$$Y_{J/\psi}\left(N_{tracklets}\right) = \frac{N_{rec\ J/\psi}\left(N_{tracklets}\right)}{N_{events}\left(N_{tracklets}\right)}$$

Seems to increase linearly with the tracklet multiplicity.

Conclusions and Outlook

- The evolution of the Single Muon and J/ψ yields at forward rapidities as a function of the tracklet multiplicity at mid-rapidity in p-p collisions at 7 TeV has been studied.

- It is possible to study up to $dN_{ch}/d\eta = \sim 0.56 * 60 = \sim 33$, five times the average density.

- The evolution of the Single Muon yield as a function of the multiplicity is linear in first approximation.
- The yield increases faster for High p_T Muons ($4 < p_T < 8$ GeV/c) than for Low p_T ($1 < p_T < 4$ GeV/c).
- For Low p_T Muons (~50% from π and K decays and ~50% from Charm and Beauty decays), the $\langle p_T \rangle$ increases with the tracklet multiplicity. This is in accordance to what has been observed for hadrons measured by CDF and ALICE at 900 GeV.
- The $\langle p_T \rangle$ of the High p_T Muons (~50% Charm and ~50% Beauty) is almost constant with the multiplicity. This precludes that the larger increase of the High p_T yield is due to an increase of the $\langle p_T \rangle$.

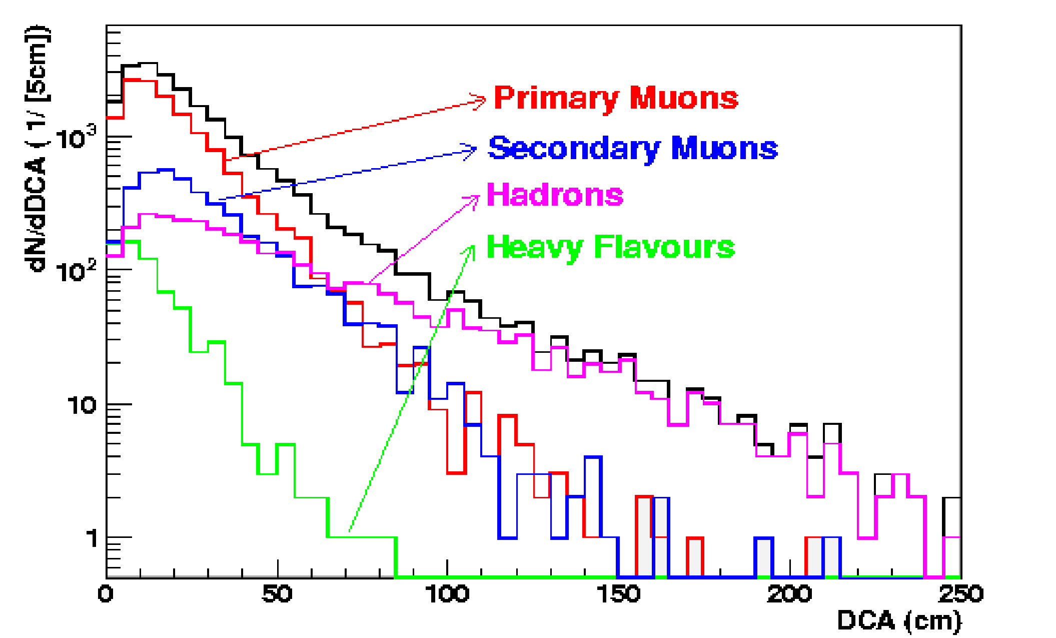
- Similarly to Single Muons, the J/ψ yield seems to increase linearly with the tracklet multiplicity.

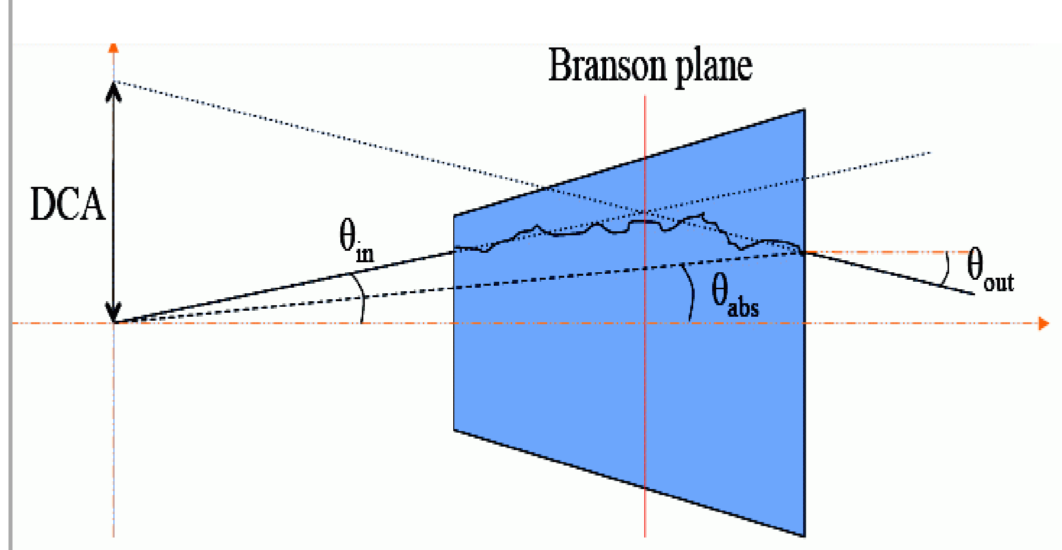
Outlook

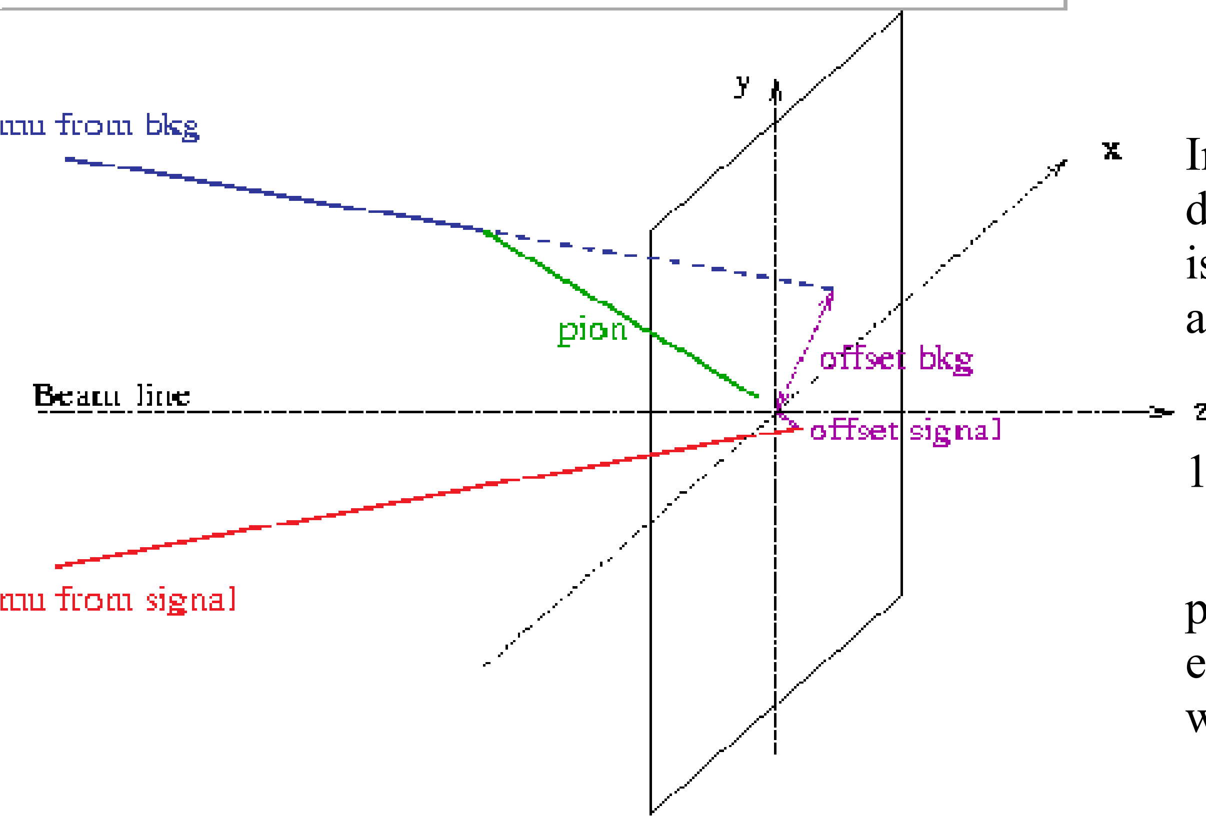
- Evaluation of the systematic from the pile up.
- Evaluation of the systematic from the background.
- Preliminary results soon, in particular corrected ratio of J/ψ to High p_T Single Muon yields.

Backup

p*DCA







In the DCA range where primary muons are dominant the principal cause of the distribution is the multiple Coulomb scattering in the absorber.

1/p dependance of the DCA distribution.

p*DCA distribution of the reconstructed muons expected to be gaussian for the primary muons, with tails from secondary muons and hadrons.