# Efforts for $\frac{1}{N_{event}}\frac{dN_{ch}}{d\eta}$ in pp collisions


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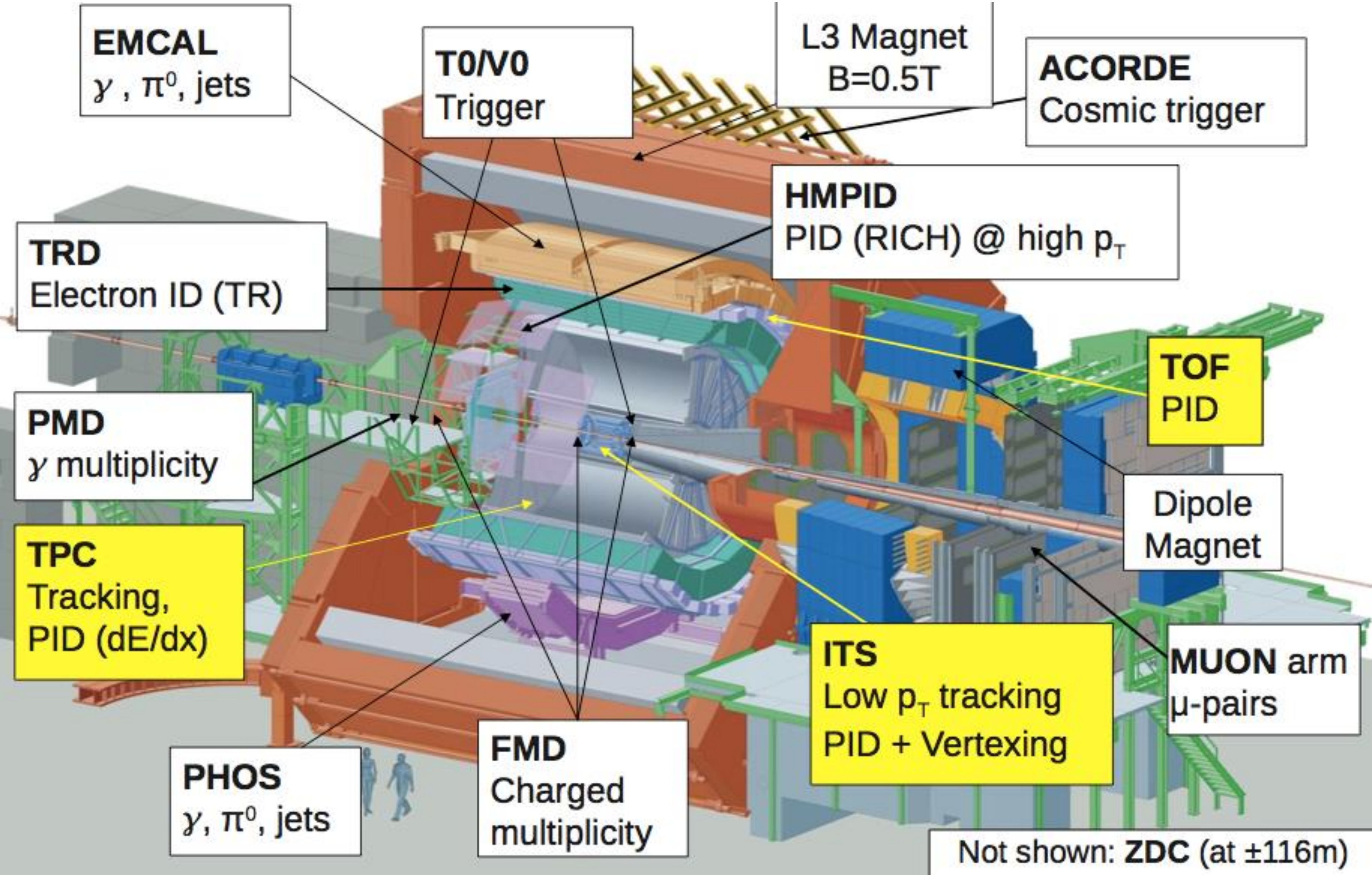
# A Large Ion Collider Experiment



# p+p studies in ALICE experiment

- ALICE is the only dedicated heavy ion experiment at LHC
- ALICE also studies p+p
  - Several signals in heavy ion collisions are measured relative to p+p
  - ALICE has a rich p+p program
- ALICE special features for p+p physics
  - Low momentum sensitivity
  - Low material budget and low magnetic filed
  - Excellent particle identification(PID) capability

| | **Magnetic Field (T)** | **$P_T$ cut-off (GeV/c)** | **Material Thickness $X/X_0$(%)** |
|---|---|---|---|
| ALICE | 0.2-0.5 | 0.1-0.25 | 7 |
| ATLAS | 2.0 | 0.5 | 30 |
| CMS | 4.0 | 0.5 | 20 |

# p+p studies in ALICE experiment

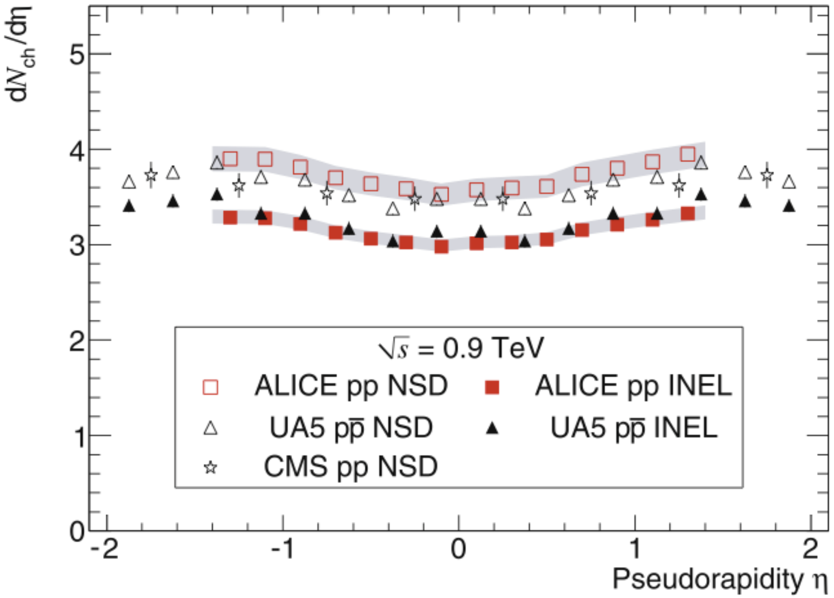
## Published papers by ALICE for p+p collisions

| | |
|---|---|
| ✓ Pseudo rapidity & multiplicity | |
| – $\sqrt{s}$ = 900 GeV | EJC: Vol. 65 (2010) 111 |
| – $\sqrt{s}$ = 2.36 TeV | EPJC: Vol. 68 (2010) 89 |
| – $\sqrt{s}$ = 7 TeV | EPJC: Vol. 68 (2010) 345 |
| ✓ $\bar{p}$/p ratio($\sqrt{s}$ = 900GeV & 7TeV) | PRL: Vol. 105 (2010) 072002 |
| ✓ Momentum distribution(900GeV) | PL B: Vol. 693 (2010) 53 |
| ✓ Bose-Einstein correlation(900GeV) | PRD: Vol. 82 (2010) 052001 |
| ✓ Strangeness(900GeV) | EPJC: Vol.71(2011) 1594 |
| ✓ Rapidity & $P_T$ distribution of J/Ps(7TeV) | PLB: Vol. 704(2011) 442 |
| ✓ Pion, kaon, proton yield(900GeV) | Epjc: Vol.71(2011) 1655 |

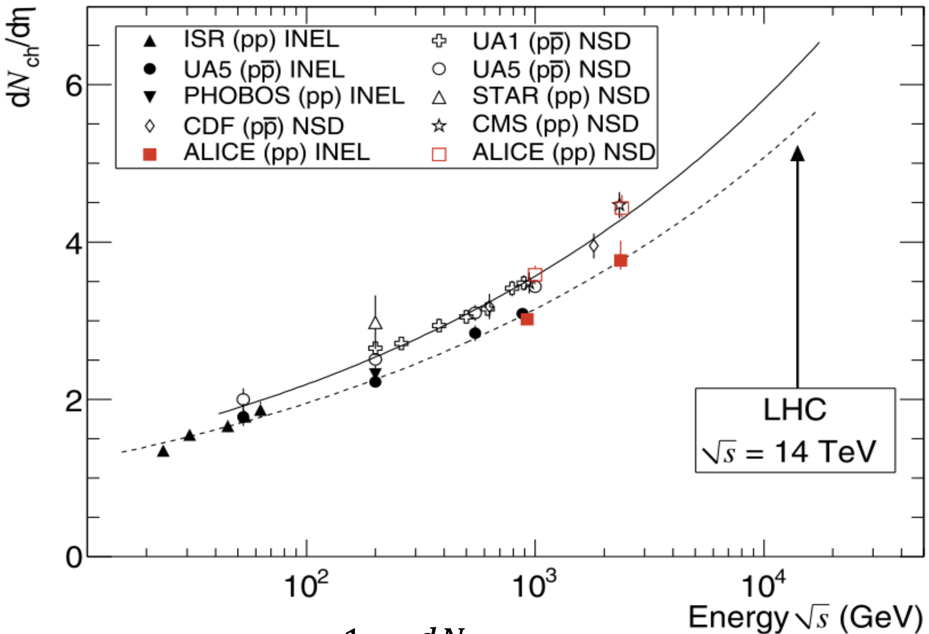
- dNdEta and multiplicity measurement
  - Basic measurements to examine the global characteristics of the collision
  - Useful to study QCD in the non-perturbative regime, and to constrain phenomenological models and event generators

# $dN_{ch}/d\eta$ measurement

$$\frac{1}{N_{event}}\frac{dN_{ch}}{d\eta} \equiv \frac{\text{All \# of primary charged particles}}{\text{All \# of events}} \text{ @ } \eta$$




Typical $\frac{1}{N_{event}}\frac{dN_{ch}}{d\eta}$ distribtuion



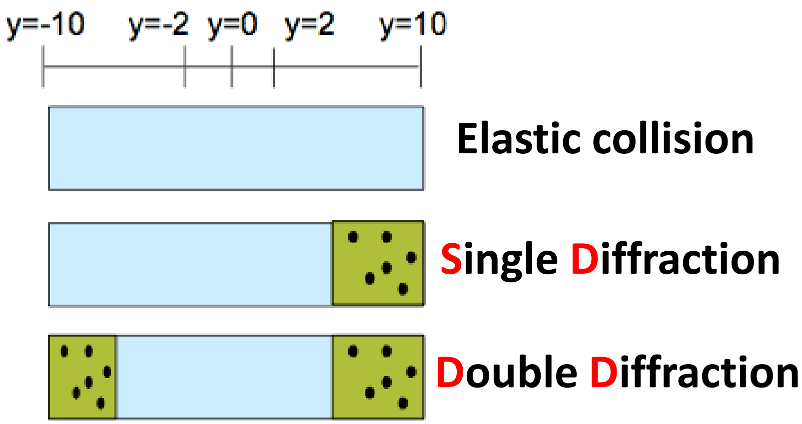

$\frac{1}{N_{event}}\frac{dN_{ch}}{d\eta}|_{\eta=0}$ vs. $\sqrt{s}$

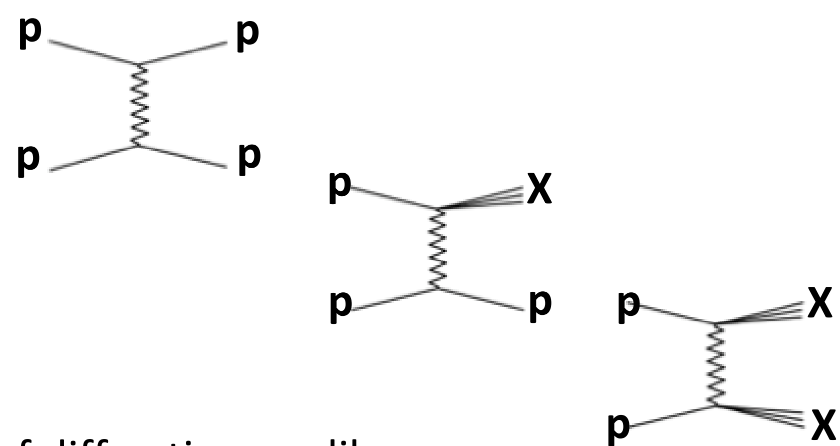
If we integrate $\frac{1}{N_{event}}\frac{dN_{ch}}{d\eta}$ in the region $|\eta|<0.5$, we can have $\frac{1}{N_{event}}\frac{dN_{ch}}{d\eta}|_{\eta=0}$

# Physics motivation - diffraction

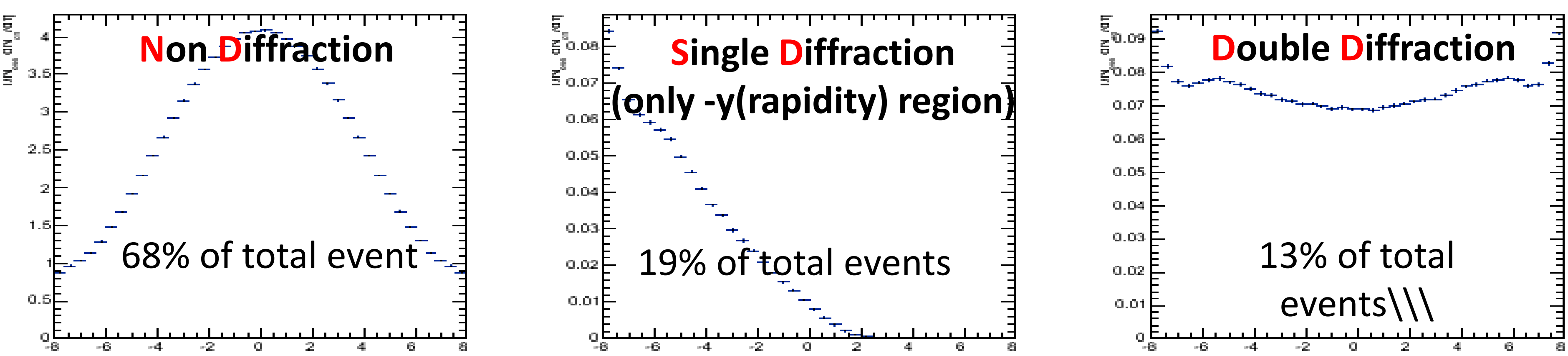
- Why is the diffraction important in pp collisions?
  - In HE p+p collisions, **about 30% of $\sigma_{inelastic}$ comes from diffractive processes** like

Single diffraction(SD) + Double diffraction(DD)



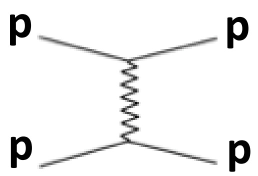

  - The default MC(pythia-perugia0) has a rate of diffractions as like,
  - NSD = ND + DD(less dependent to a diffraction rate, easy to detect)



# Physics motivation - diffraction

- Two definitions of the diffraction
  - Elastic or quasi elastic scattering by the absorption of components of the wave functions of the incoming particles (**s-channel view**)
  - Large rapidity gap which is caused by pomeron exchange (**t-channel view**)

- Regge's formalism **(can also describe hard process**) for diffraction
  - Can describe these diffractive physics
  - The t-channel dominant wave-function in the high energy(as s→∞)




$$\mathrm{T}(\mathrm{s},\mathrm{t}=0)\sim\mathrm{s}^{\alpha t+\alpha_0}$$

$\mathrm{T}(\mathrm{s},\mathrm{t}=0)\sim\mathrm{s}^{\alpha(0)}=s^{1.08}$ : This is a pomeron

# Physics motivation – parton saturation?

## Parton saturation and break down of Regge theory

- From Regge theory (no parton saturation), in asymptotic regime

$$\sigma_{tot} \propto s^{\alpha(t)-1} \rightarrow \frac{1}{N_{event}} \frac{dN_{ch}}{d\eta} \propto s^{\alpha(t)-1}$$

- On the other hand, the Froissart bound(partion saturation) limits the growth of $\sigma_{tot}$:

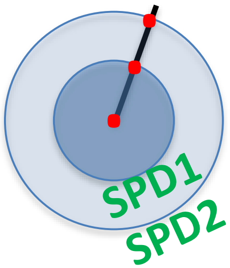
$$\sigma_{tot} \propto (\ln s)^2 \rightarrow \frac{1}{N_{event}} \frac{dN_{ch}}{d\eta} \propto (\ln s)^2$$

- There will be an energy where the power law takes over the logarithm increase. However, with present value of $\alpha_p$, at LHC top energy, both behaviours are the same:

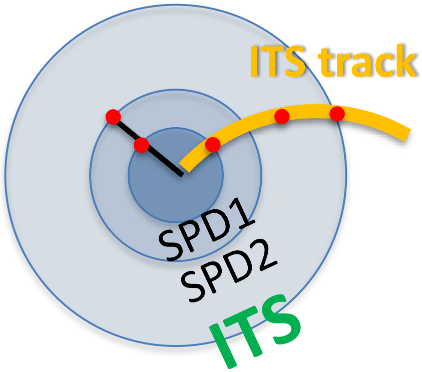
$$\sigma_{tot} \propto s^{\alpha(t)-1} \rightarrow \quad \sigma_{tot} \propto (\ln s)^2$$

$$\frac{s^{\alpha(t)-1}(14\ TeV)}{s^{\alpha(t)-1}(0.9\ TeV)} \xleftrightarrow{\mathbf{1\sim2\%difference}} \frac{(\ln s)^2(14\ TeV)}{(\ln s)^2(0.9\ TeV)}$$

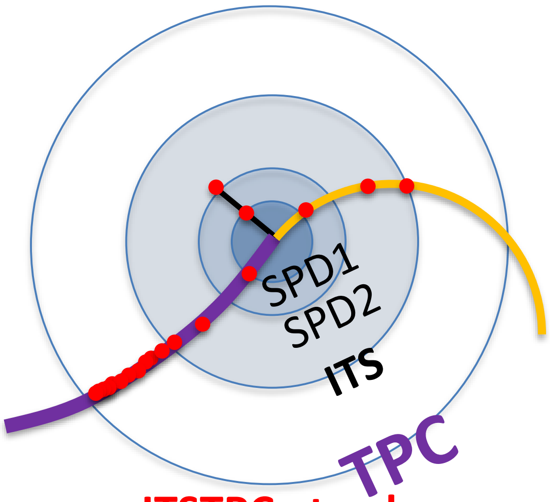
# Tracking methods in ALICE




A SPD tracklet




ITSSA+ tracks




ITSTPC+ tracks

## 3 track counting methods

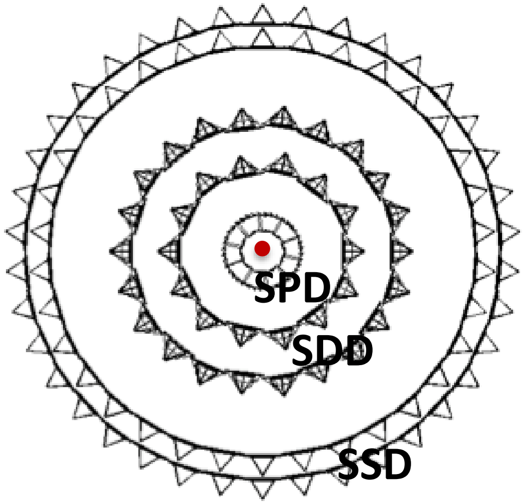
1) SPD tracklets(common method to count tracks)

2) **ITSSA+**: ITS detector's tracks + SPD tracklets

3) **ITSTPC+**: TPC tracks

+ complementary ITS detector's track

+ complementary SPD tracklets




Cross-section of ITS

# Recent efforts in pp dNdEta

- **dNdEta measurements by the use of other tracking methods**
  - **Old method : "Tracklet" for dNdEta and multiplicity**
  - **New methods: ITSSA+ tracks , ITSTPC+ tracks**
  - **Advantages of using new methods**

    More tolerance to background

    Less possibility to lose tracks

    → Good method to go over to high multiplicity events

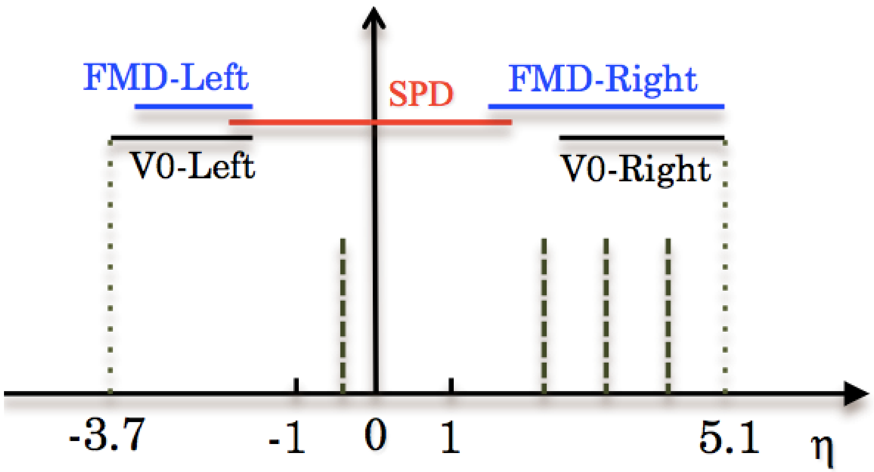
- **New dNdEta results with the modified diffraction rate**
  - **Re-calcuate dNdEta with new MC(with new measured diffraction rate)**

| 900GeV | Default MC | New MC |
|---|---|---|
| SD(%) | 22.5 | 19.45 |
| DD(%) | 12.3 | 9.46 |
| ND(%) | 100-SD-DD | 100-SD-DD |

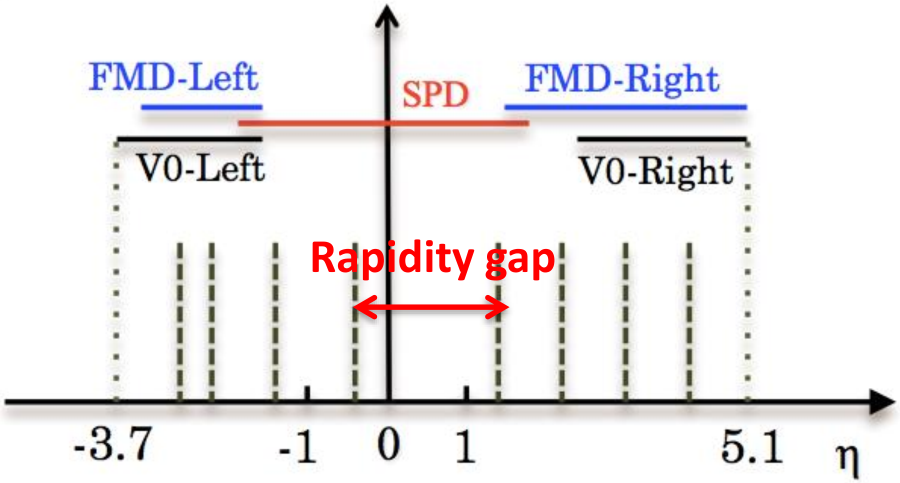
| 7TeV | Default MC | New MC |
|---|---|---|
| SD(%) | 19.2 | 17.85 |
| DD(%) | 12.9 | 8.94 |
| ND(%) | 100-SD-DD | 100-SD-DD |

# How to measure the new rate of diffraction

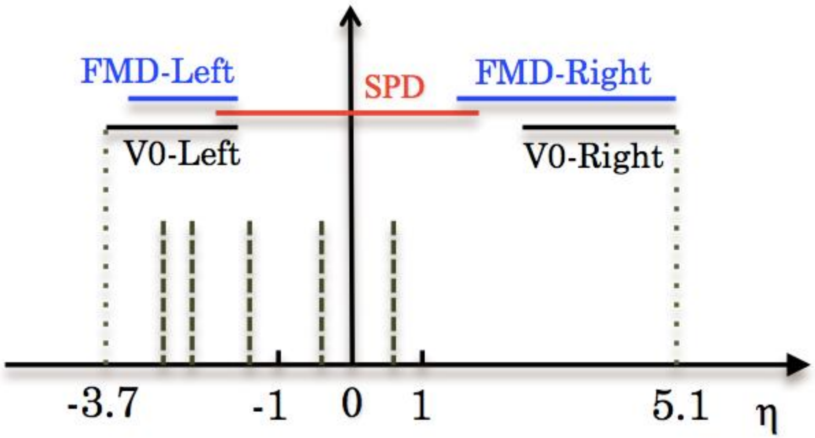
- **Corresponding trigger for SD and DD**




**Right arm trigger for right SD events**




**Two arm trigger for DD events**




**Left arm trigger for left SD events**

- Left(right) SD events are sensitive to "**Left(Right) Arm Trigger**"
- A rapidity gap in "Two Arm Trigger" is sensitive to DD events
- Trigger and MC modulation of the diffraction rate → Possible to measure "true diffraction"

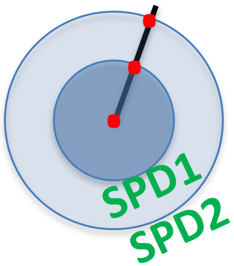
M.Phoghosyan,QM2011

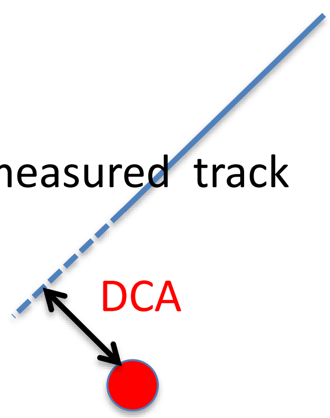
# Event and track selection

- **Event selection**
  - **Pileup rejection**: $\Delta_Z \geq 0.8$ cm and $N_{contributor} \geq 3$
  - **Vertex condition:** $-10cm < Z_{primary\ vertex} < 10$ cm
- **Track selection**
  - **SPD tracklet**

    for each pair of hits: $\Delta\phi < 80$ mrad, $\Delta\theta < 25$mrad
  - **ITS track**: $|\eta|<1.3$
  - **TPC track**: $|\eta|<0.9$
  - **Secondary particle rejection** by DCA cut

(* DCA = Distance of Closest Approach)



# dNch/dη measurement

$$\frac{1}{N_{event}} \frac{dN_{ch}}{d\eta} \equiv \frac{\text{All tracks}}{\text{All events}} \neq \frac{\text{Measured tracks}}{\text{Measured events}}$$

- **Corrections for events**

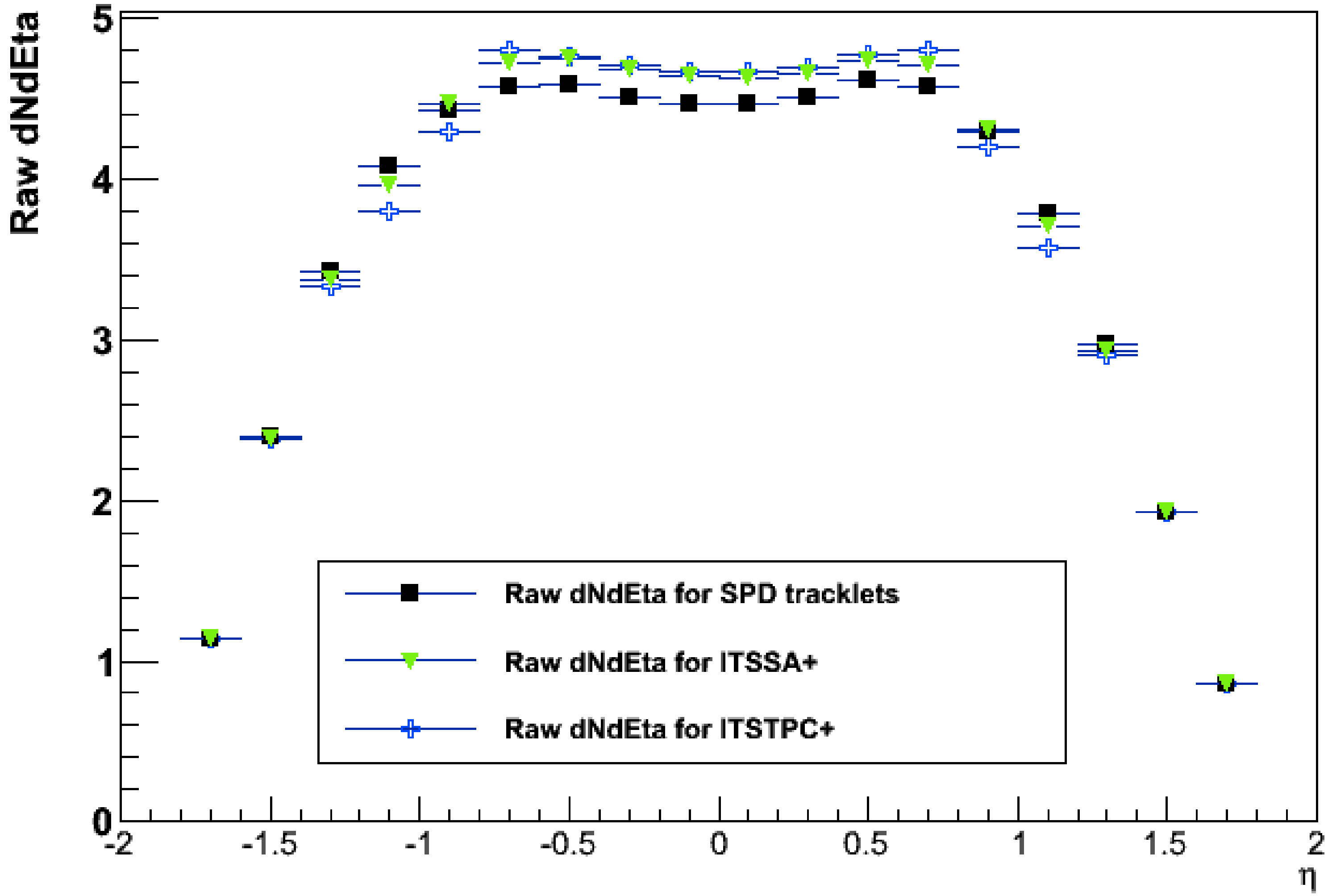
  True # of evts = Measured # of evts × Vertex finding efficiency
  × Trigger efficiency

- **Corrections for tracks**

  True # of tracks = Measured # of tracks × Detector efficiency
  × Vertex finding efficiency
  × Trigger efficiency

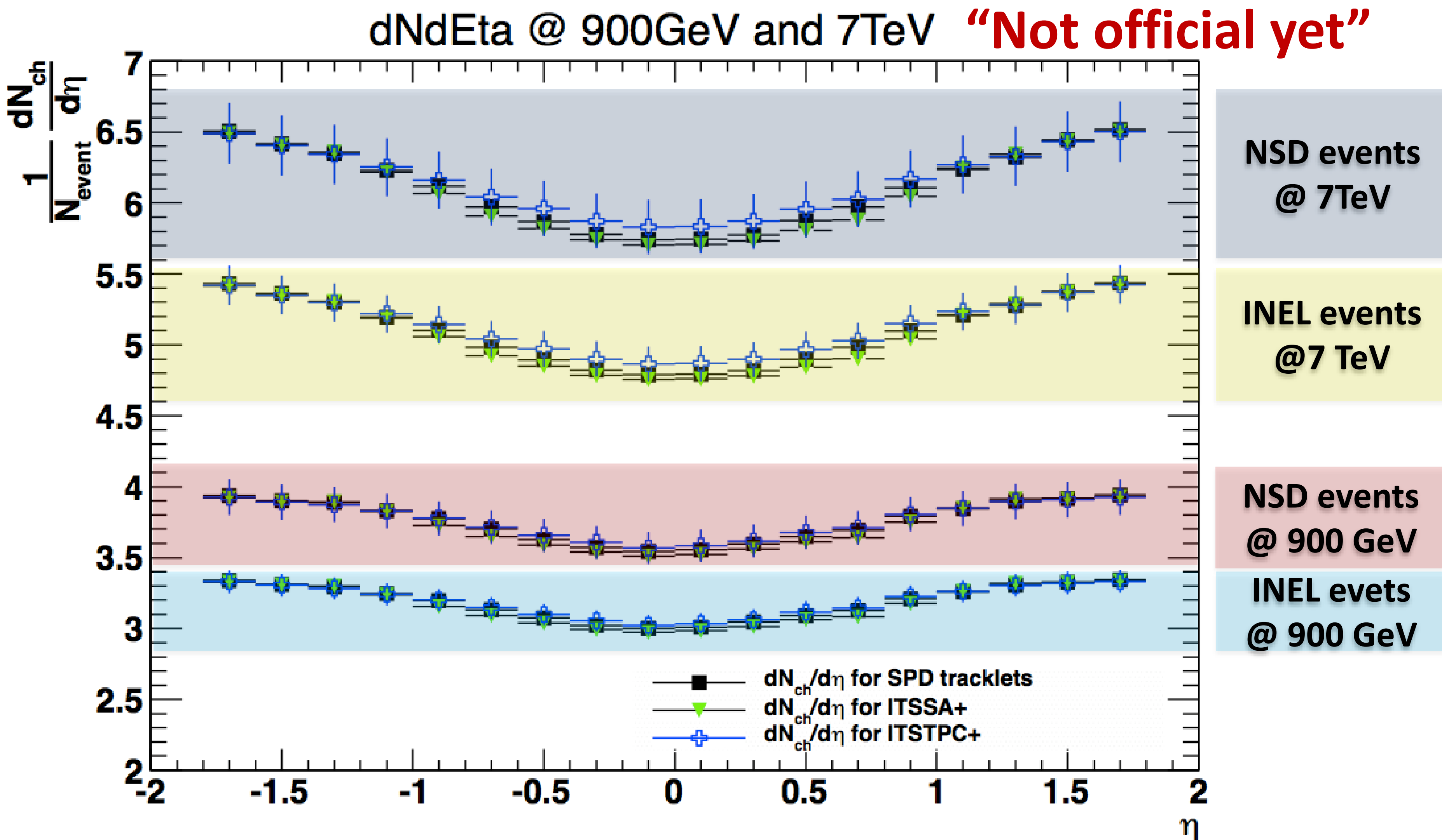
# Results – Raw dNdEta distributions

For inelastic events @ 7TeV



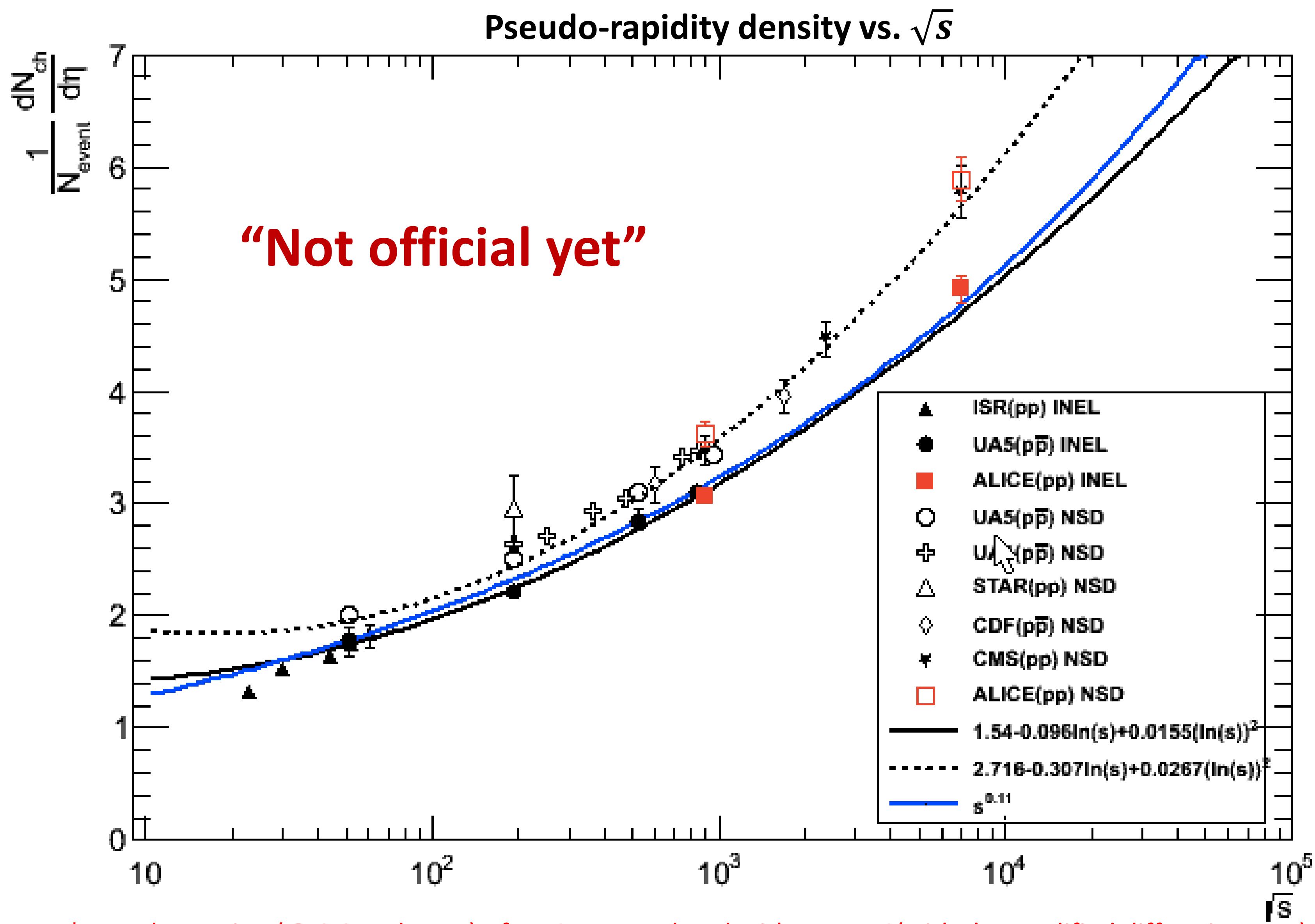

*Raw yield of ITSTPC+ tracks or ITSSA+ tracks  > SPD yields.
*As many detectors used, we can expect small background for ITSTPC+ tracks

# Results – dNdEta distribution




*Correction done with the MC, PYTHIA6 perugia0 for each energy

# Results – η density




*New data points(@ 0.9 and 7TeV) of ALICE are updated with new MC(with the modified diffraction rate)

# Summary

- **dNdEta measurements done**
  - With new tracking methods(less particle loss)
  - With newly measured diffraction rates(by Martin)
  - New data points update for η density @ 0.9 & 7TeV
- **Study more**
  - How precisely can we measure the parton saturation in pp?
- **Next plan**
  - Gradual move to high-multiplicity events in p+p