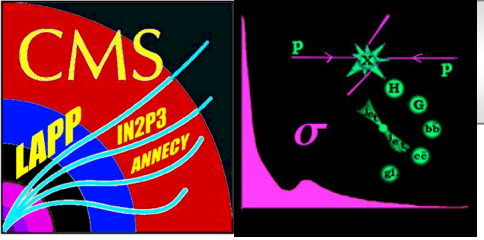


Elastic π+p and π+π+ scattering at LHC

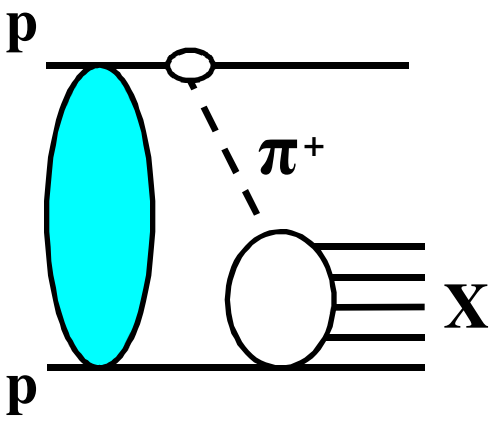
R.Ryutin, A.Sobol, V.Petrov, IHEP

Plan

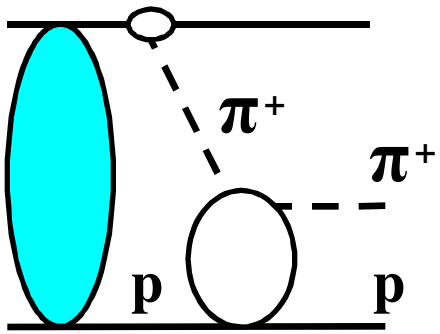
1. Motivations. Elastic $\pi^+ p$ and $\pi^+ \pi^+$ cross-sections. Extraction procedure. Absorption.
2. History.
3. Signal and Backgrounds. Cross-sections.
4. Estimations on the generator level.
5. Conclusion

Motivations

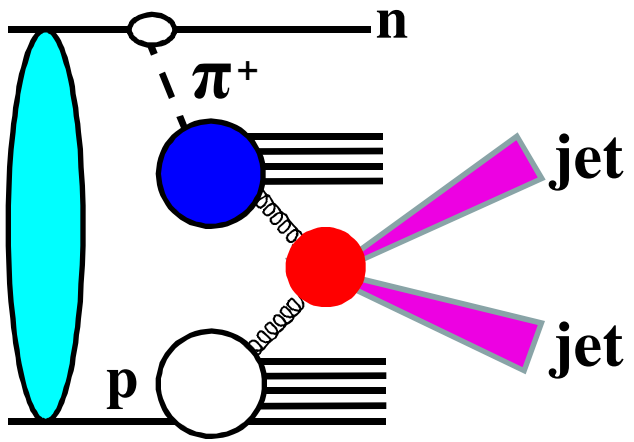
CE: total



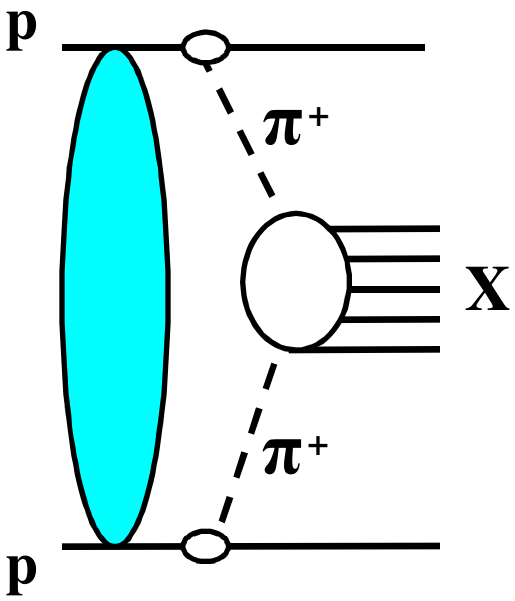
elastic



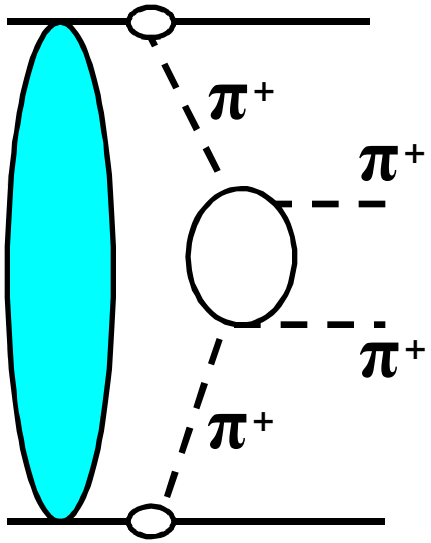
inclusive 2-jet π+p



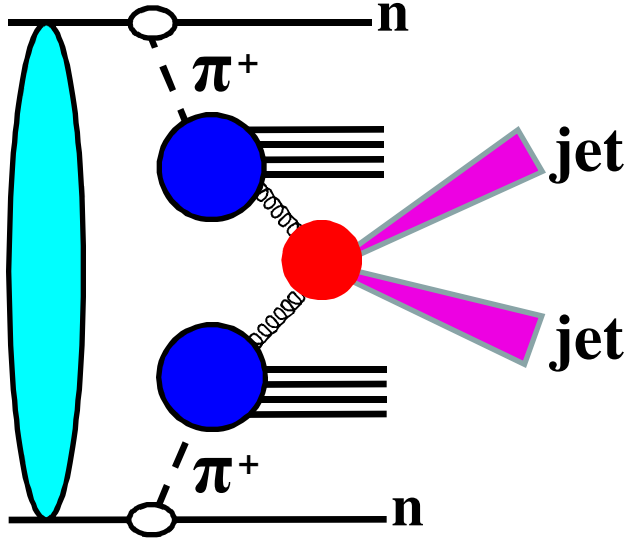
DCE: total



elastic

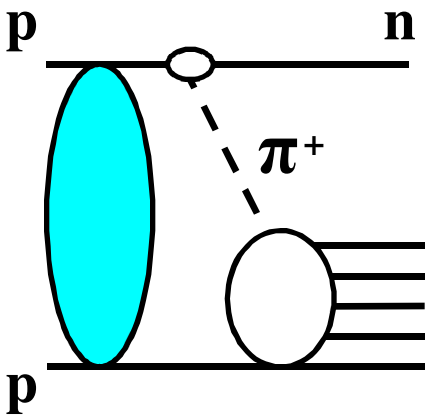


inclusive 2-jet π+ π+

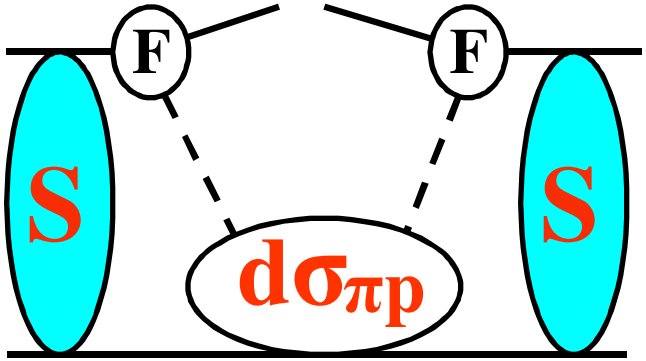


Motivations

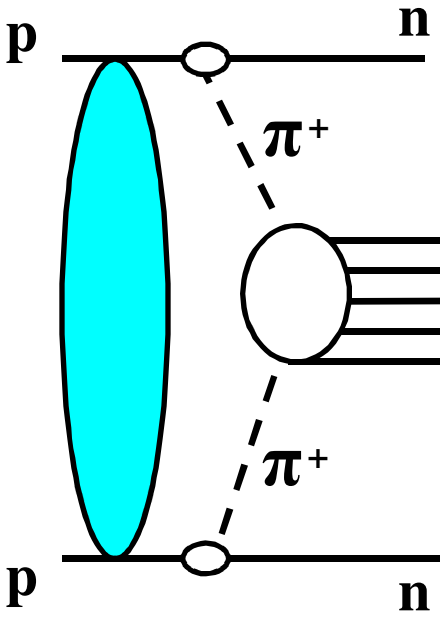
Single pion (charge) exchange (CE)



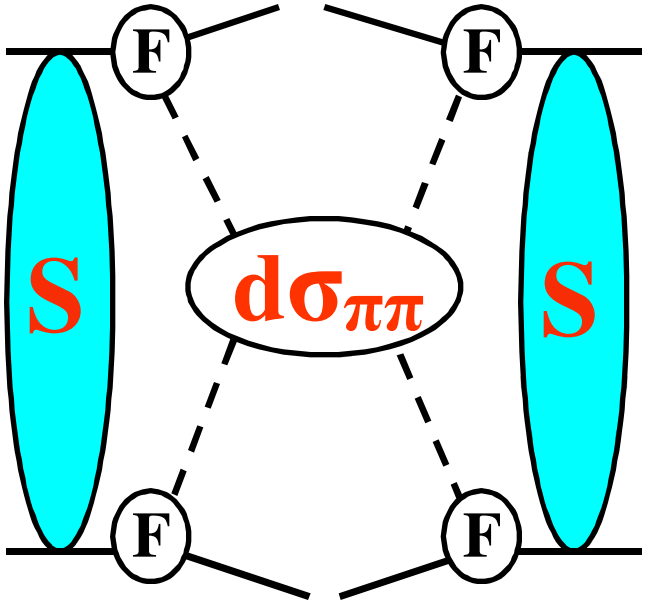
$$d\sigma_{CE} \sim$$



Double pion (charge) exchange (DCE)



$$d\sigma_{DCE} \sim$$



Motivations (extraction of cross-sections)

$$F_0(\xi,t) = \frac{G^2_{\pi^+pn}}{16\pi^2}\frac{-t}{(t-m_\pi^2)^2}\mathrm{e}^{2bt}\xi^{1-2\alpha_\pi(t)}$$

$$-t \simeq \frac{\vec{q}^{\,2}+m_p^2\xi^2}{1-\xi},\ G^2_{\pi^+pn}/(8\pi) = 13.75$$

$$\alpha_\pi(t) \simeq 0.9(t-m_\pi^2),\ b \sim 0.3\ \mathrm{GeV}^{-2}$$

ξ=0.1
M(CE)~3 TeV
M(DCE)~1 TeV

Model dependent → independent extraction

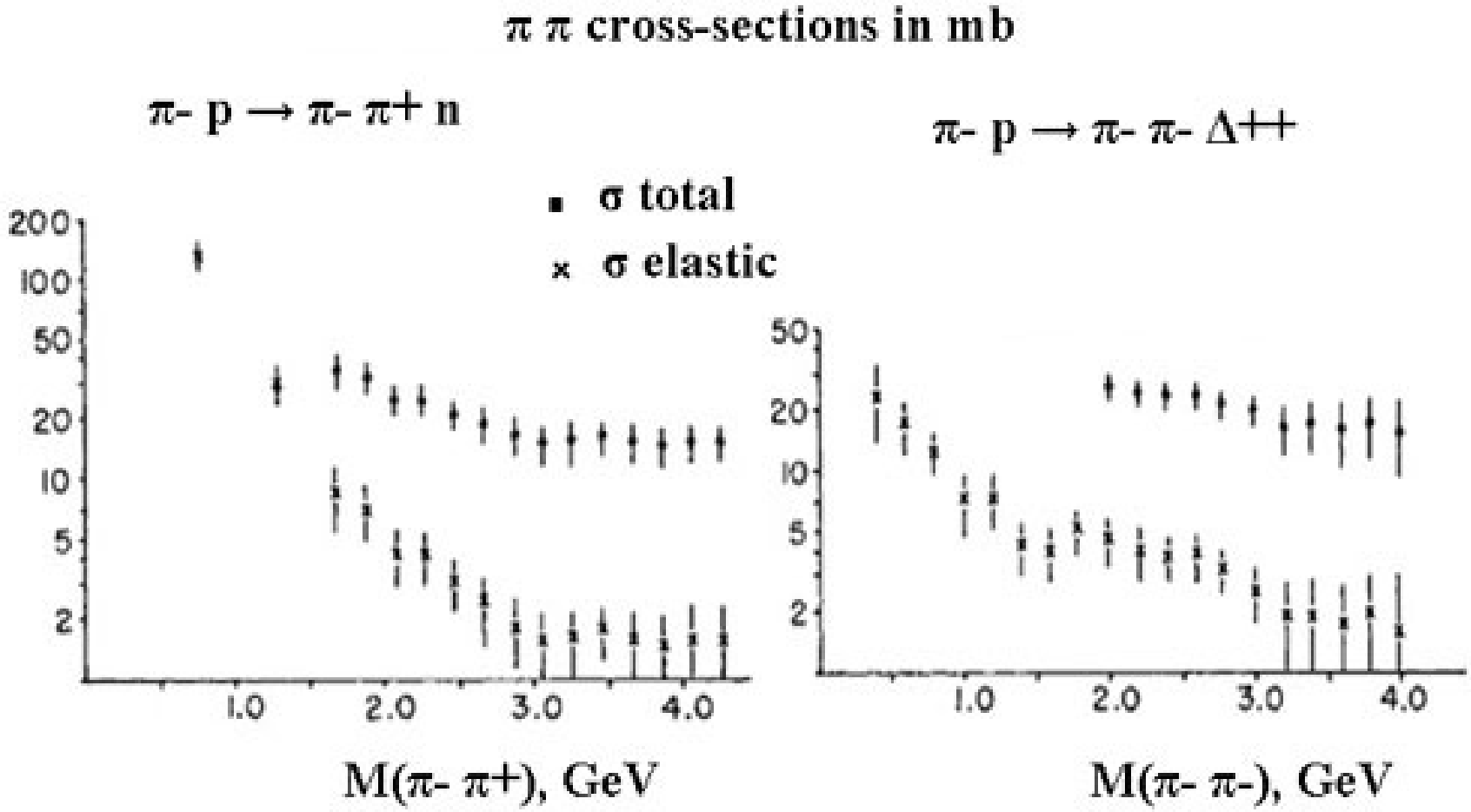
$$\frac{d\sigma_{\pi^+\mathbf{p}}(\xi s)}{d\Phi_{\pi p}} = \frac{\frac{d\sigma_{CE}}{d\xi dt d\Phi_{\pi p}}}{F_0(\xi,t)\cdot S(s/s_0,\xi,t)} \to \left.\frac{\frac{d\sigma_{CE}}{d\xi dt d\Phi_{\pi p}}}{F_0(\xi,t)}\right|_{t\to m_\pi^2}$$

$$\frac{d\sigma_{\pi^+\pi^+}(\xi_1\xi_2 s)}{d\Phi_{\pi\pi}} = \frac{\frac{d\sigma_{DCE}}{d\xi_1 d\xi_2 dt_1 dt_2 d\Phi_{\pi\pi}}}{F_0(\xi_1,t_1)F_0(\xi_2,t_2)\cdot S_2(s/s_0,\xi_{1,2},t_{1,2})} \to \left.\frac{\frac{d\sigma_{DCE}}{d\xi_1 d\xi_2 dt_1 dt_2 d\Phi_{\pi\pi}}}{F_0(\xi_1,t_1)F_0(\xi_2,t_2)}\right|_{t\to m_\pi^2}$$

History

Extracted $\sigma(\pi\pi)$ at low energies

[W.J. Robertson, W.D. Walker, J.L. Davis, Phys. Rev. D7 (1973) 2554]



Cross-sections

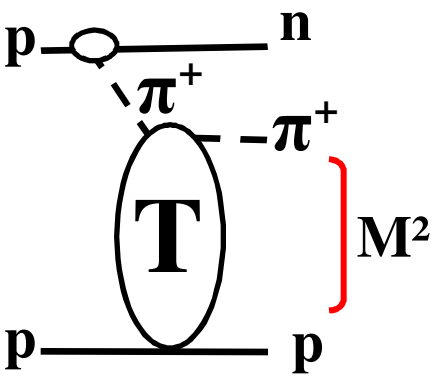
CE and DCE cross sections, corresponding to elastic π+p and π+π+ scattering at 10 TeV for the BSW parametrization

[C. Bourrely, J. Soffer, T.T. Wu, Eur. Phys. J. C 28 (2003) 97]

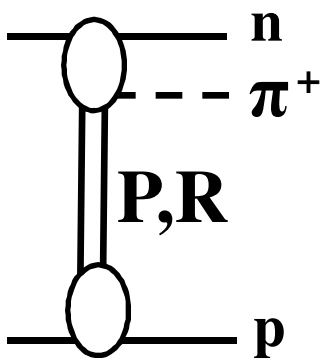
in the region: |qt|<0.5 GeV, 0 < ξ < max(ξ)

max(ξ)	0.05	0.1	0.2	0.3
σ(SCE), μb	8.6	38	130	213
σ(DCE), μb	0.01	0.3	4.8	15.5

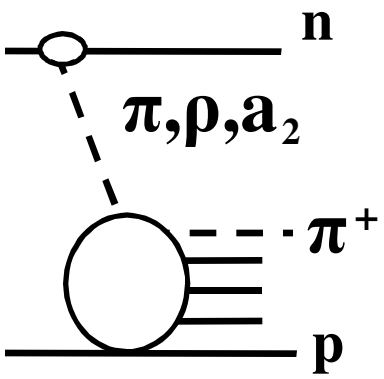
Signal and Backgrounds for CE



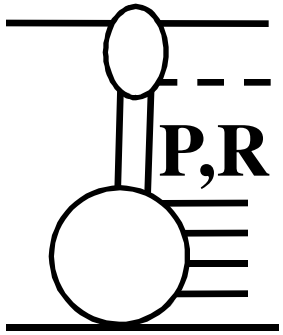
a) signal



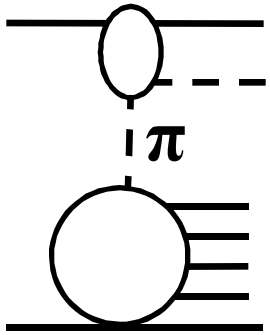
b) low mass SD



c) inclusive CE

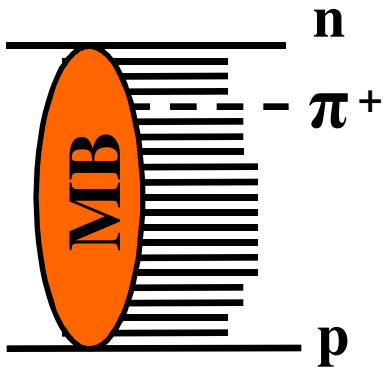


d)



e)

Double Dissociation



f) minimum bias,
a)-e) excluded

At $\sqrt{s} = 10$ TeV total pp cross section is equal to $\sigma_{pp}^{tot} = 96.1$ mb (PYTHIA 6.420)

Elastic Scattering (ES) : $pp \to pp$ $\sigma_{pp}^{ES} = 19.6$ mb

Minimum Bias (MB) : $pp \to X$ $\sigma_{pp}^{MB} = 50$ mb

Single Diffraction (SD) : $pp \to pX$ $\sigma_{pp}^{SD} = 14$ mb

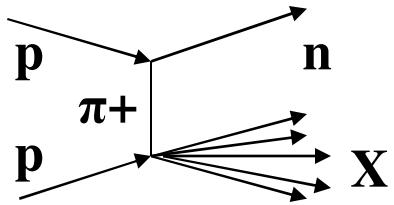
Double Diffraction (DD) : $pp \to XY$ $\sigma_{pp}^{DD} = 9.7$ mb

---

Single Charge Exchange (SCE or SπE) :

$$pp \to nX$$

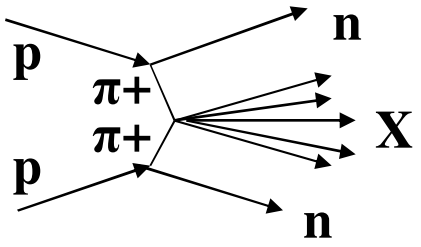
$\sigma_{pp}^{SCE} = 2.6$ mb at $\xi_n < 0.4$



Double Charge Exchange (DCE or DπE) :

$$pp \to nXn$$

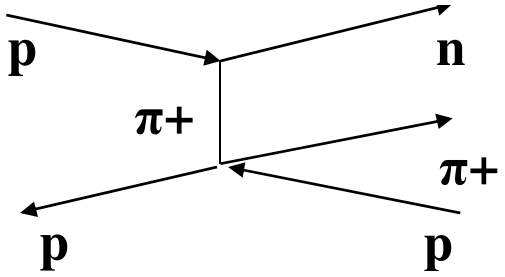
$\sigma_{pp}^{DCE} = 0.2$ mb at $\xi_n < 0.4$



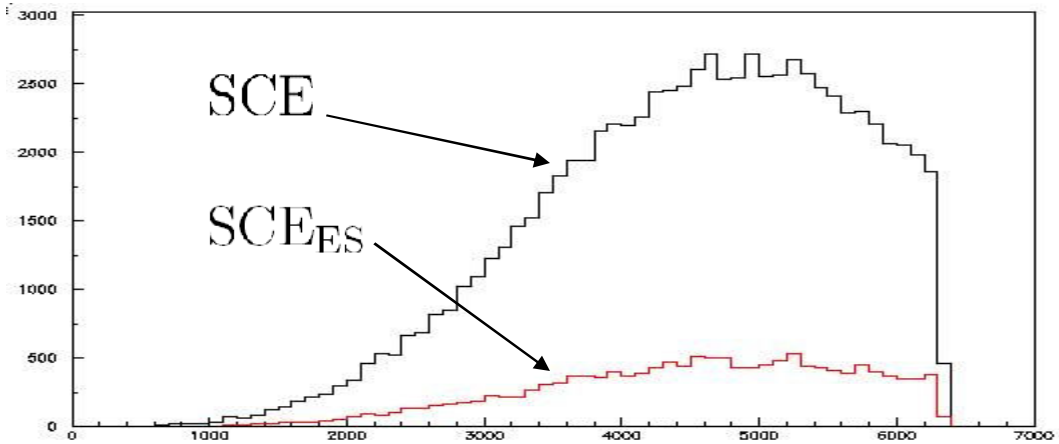
V.A. Petrov, R.A. Ryutin, A.E. Sobol, **LHC as πp and $\pi\pi$ Collider**, Jun 2009 arXiv:0906.5309 [hep-ph], to be published in EPJ.

At $\sqrt{s} = 10$ TeV SCE cross section is equal $\sigma^{tot}_{SCE} \sim 2.6$ mb at $\xi_n < 0.4$ (Petrov, Ryutin)

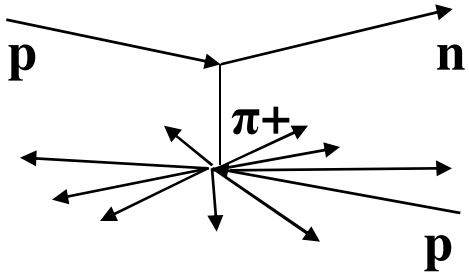
$\mathrm{SCE_{ES}}$: $pp \to n\pi^+ p$



$\sigma^{ES}_{SCE} \sim 0.36$ mb

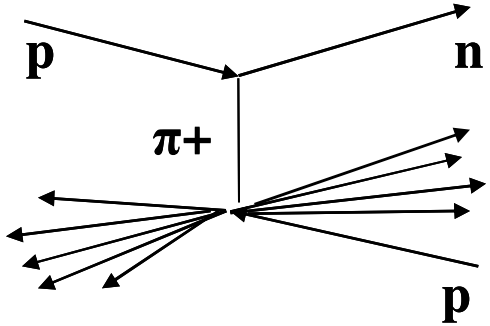


$\mathrm{SCE_{MB}}$: $pp \to nX$



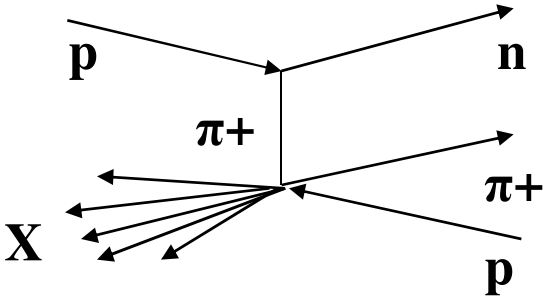
$\sigma^{MB}_{SCE} \sim 1.54$ mb

$\mathrm{SCE_{DD}}$: $pp \to nXY$



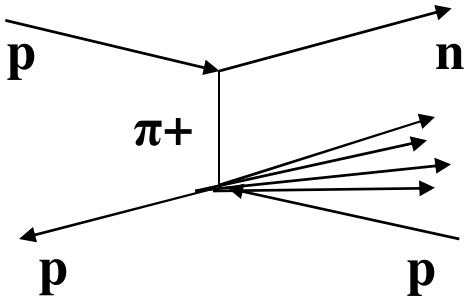
$\sigma^{DD}_{SCE} \sim 0.27$ mb

$\mathrm{SCE_{SD1}}$: $pp \to n\pi^+ X$



$\sigma^{SD1}_{SCE} \sim 0.23$ mb

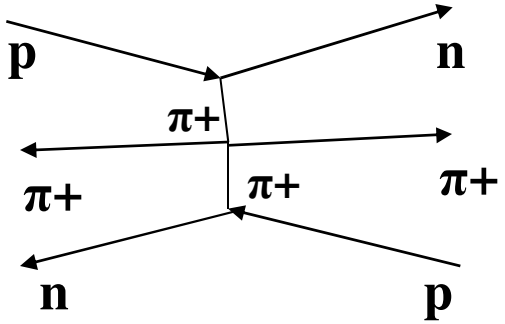
$\mathrm{SCE_{SD2}}$: $pp \to npX$



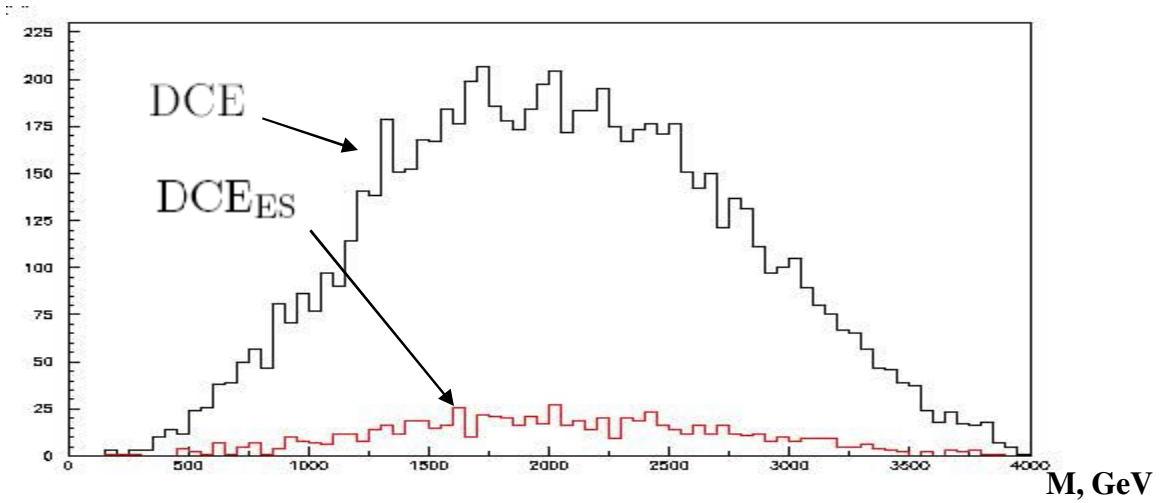
$\sigma^{SD2}_{SCE} \sim 0.20$ mb

At $\sqrt{s} = 10$ TeV DCE cross section is equal $\sigma^{tot}_{DCE} \sim 200\ \mu$b at $\xi_n < 0.4$ (Petrov, Ryutin)

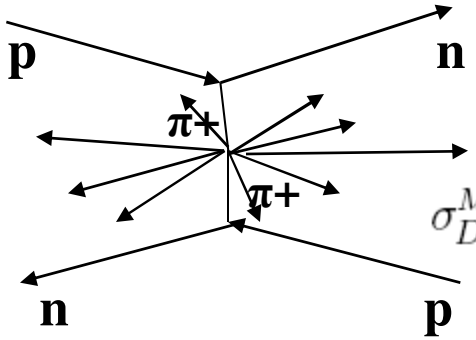
$\mathrm{DCE_{ES}}: \quad pp \to n\ \pi^+\pi^+\ n$



$\sigma^{ES}_{DCE} \sim 24\ \mu$b



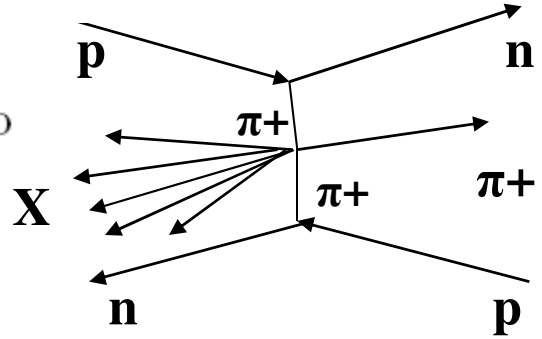
$\mathrm{DCE_{MB}}: \quad pp \to nXn$



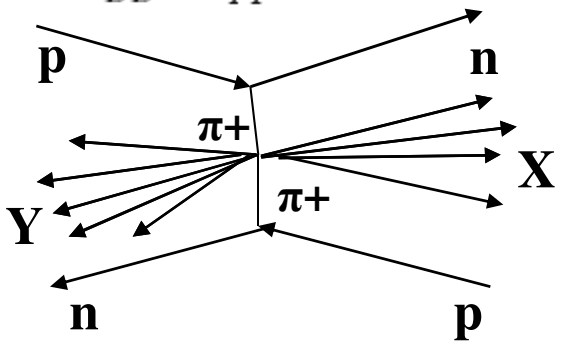
$\sigma^{MB}_{DCE} \sim 124\ \mu$b

$\mathrm{DCE_{SD}}: \quad pp \to n\ \pi^+X\ n$

$\sigma^{SD}_{DCE} \sim 30\ \mu$b

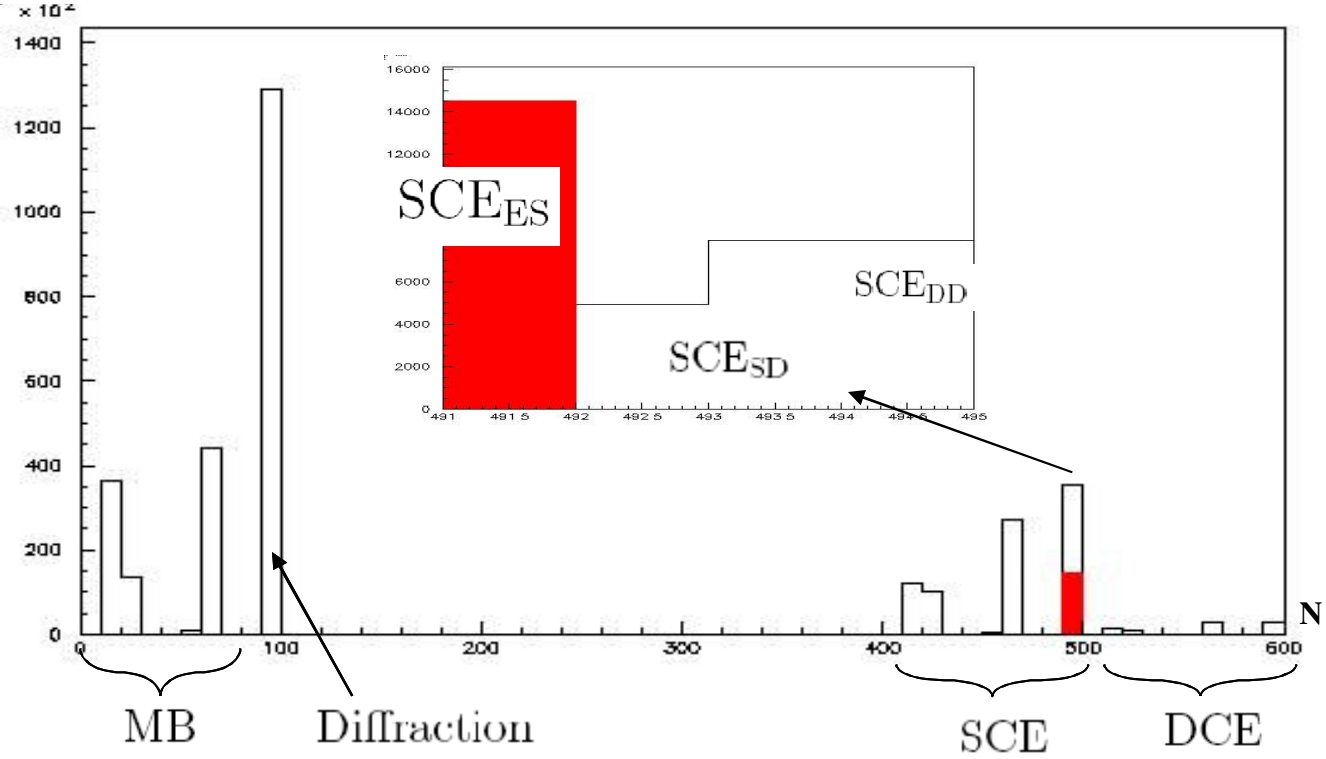


$\mathrm{DCE_{DD}}: \quad pp \to nXYn$



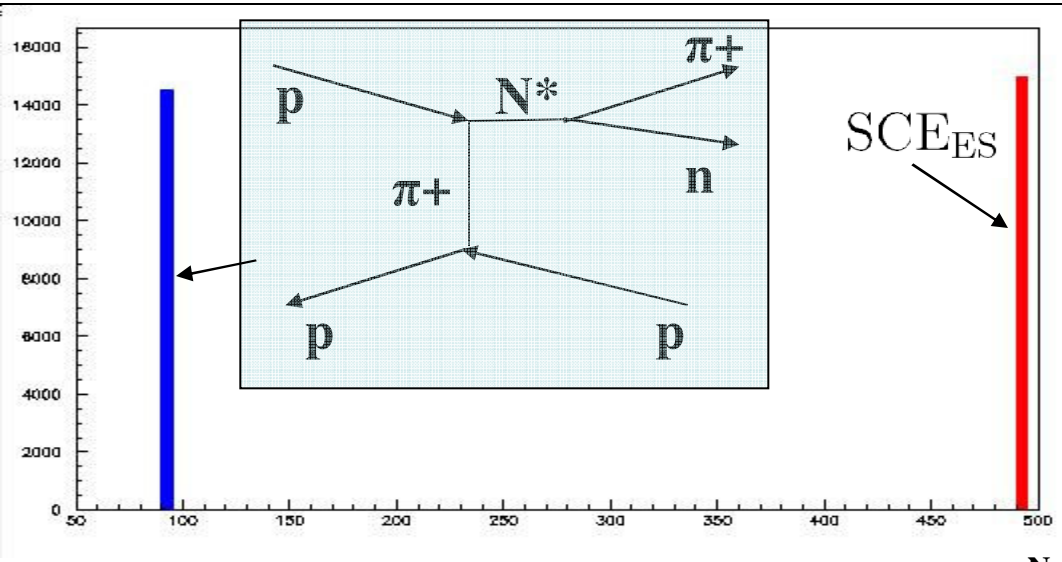
$\sigma^{DD}_{DCE} \sim 22\ \mu$b

$\pi^+ p$ elastic scattering selection



$$\begin{bmatrix} N_n^f > 0 & .and. & N_n^b = 0 \\ N_n^f = 0 & .and. & N_n^b > 0 \end{bmatrix}$$

$$\frac{S}{B} = 0.05$$

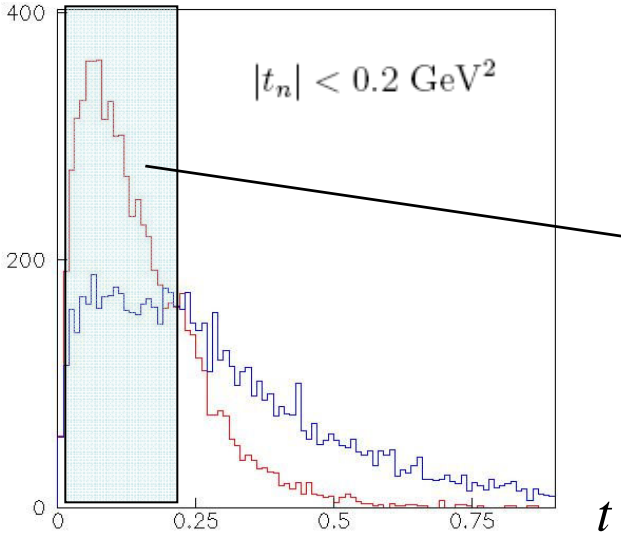


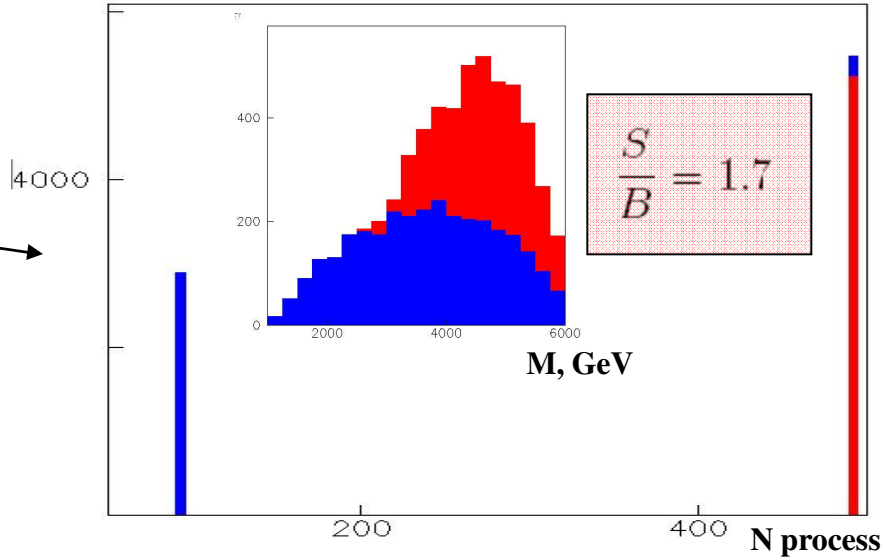
$$\begin{bmatrix} N_n^f > 0 & .and. & N_n^b = 0 \\ N_n^f = 0 & .and. & N_n^b > 0 \end{bmatrix}$$

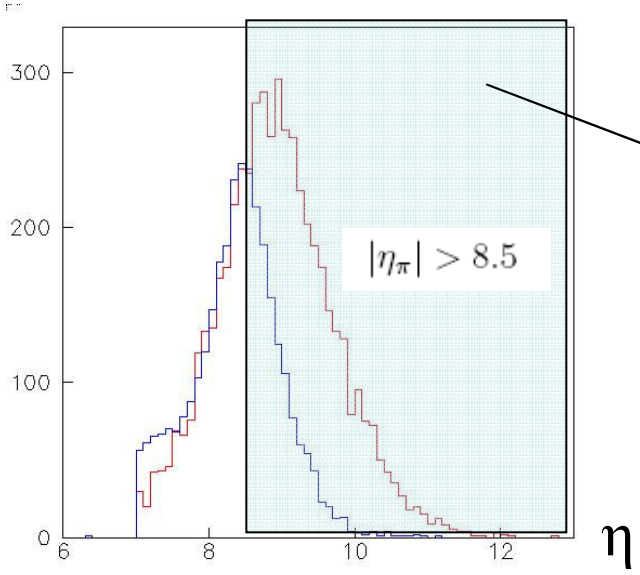
$$\begin{cases} N_{Barrel} = 0 \\ N_{Endcap} = 0 \\ N_{HF} = 0 \\ N_{CASTOR} = 0 \\ N_{EZDC} = 0 \end{cases}$$

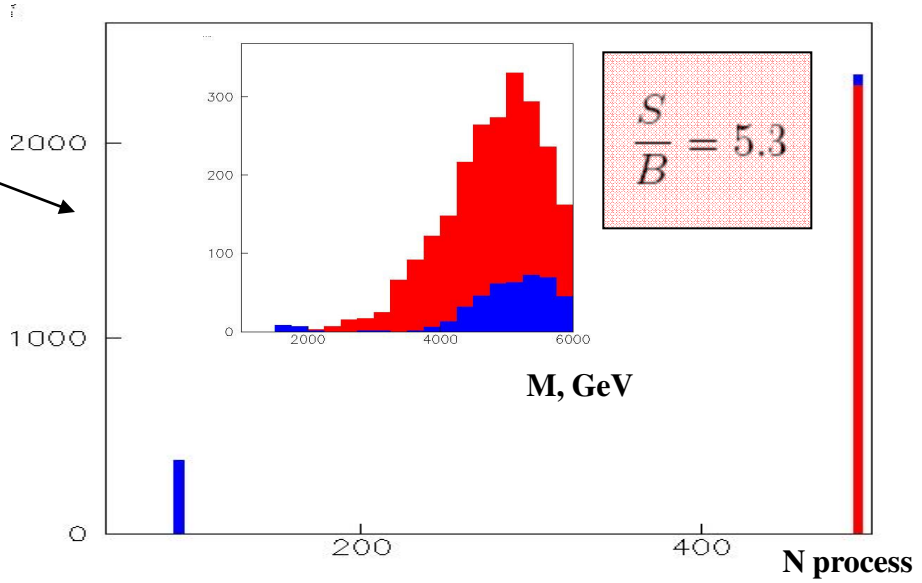
$$\frac{S}{B} = 0.9$$

$\pi^+ p$ elastic scattering selection

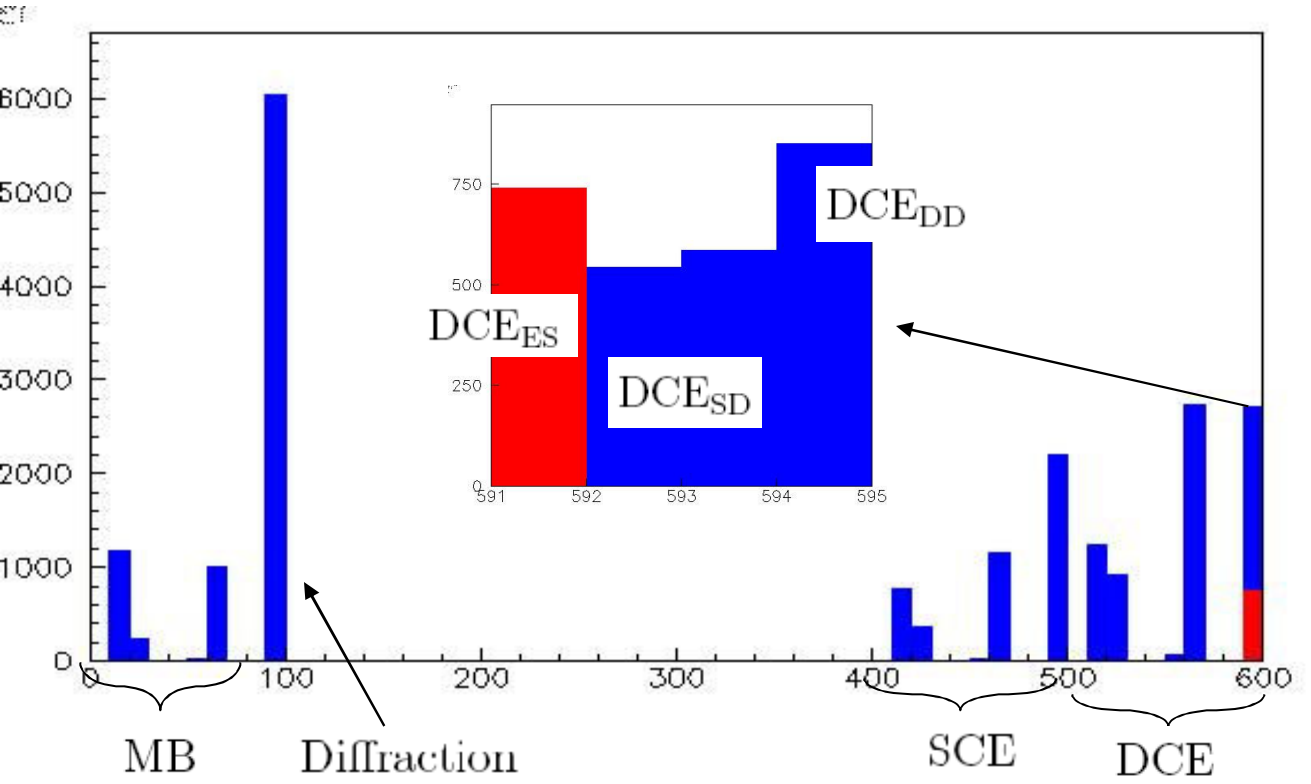






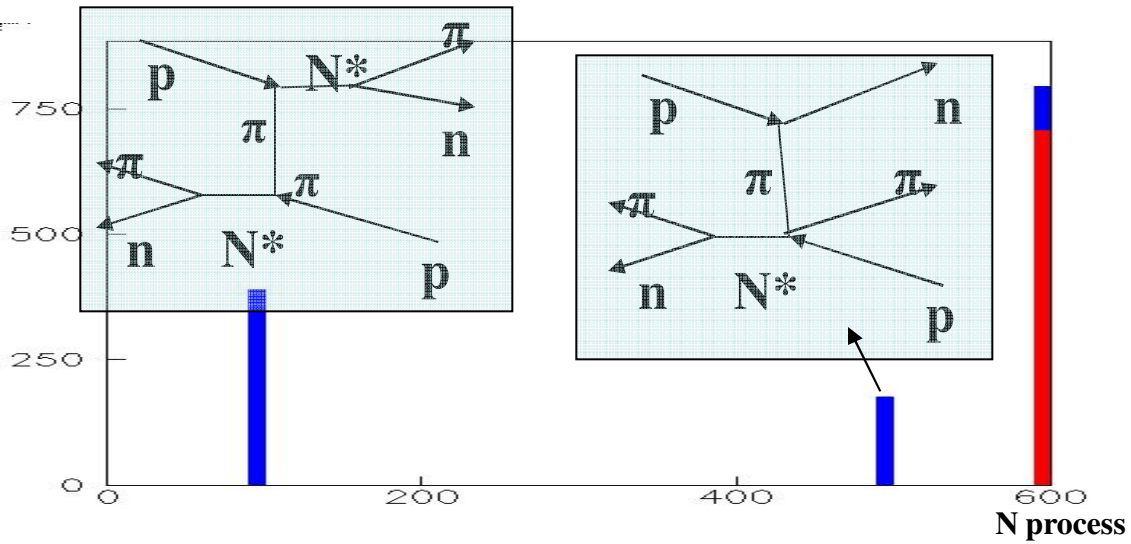


$\pi^+\pi^+$ elastic scattering selection



$N_n^f > 0 \quad .and. \quad N_n^b > 0$

$$\frac{S}{B} = 0.04$$

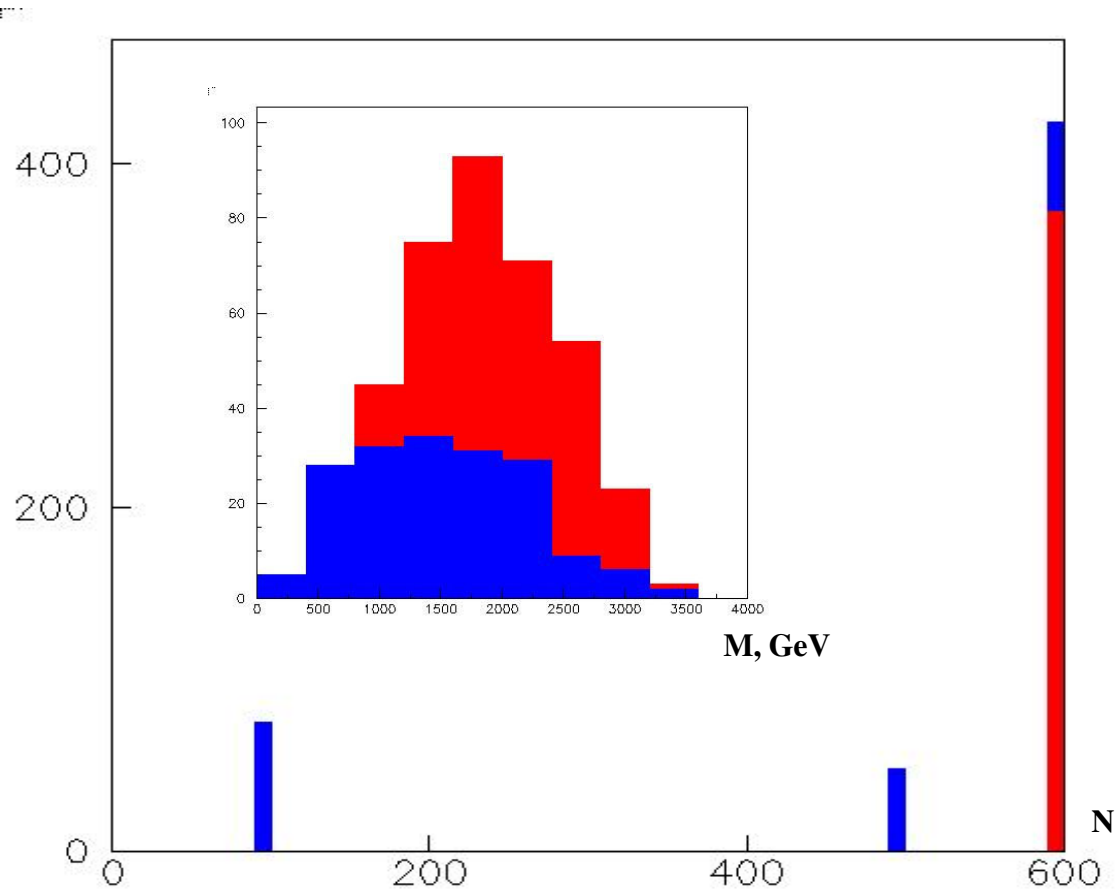


$N_n^f > 0 \quad .and. \quad N_n^b > 0$

$$\begin{cases} N_{Barrel} = 0 \\ N_{Endcap} = 0 \\ N_{HF} = 0 \\ N_{CASTOR} = 0 \\ N_{EZDC} = 0 \end{cases}$$

$$\frac{S}{B} = 1.1$$

$\pi^+\pi^+$ elastic scattering selection



$$N_n^f > 0 \quad .\text{and.} \quad N_n^b > 0$$

$$\begin{cases} N_{\text{Barrel}} = 0 \\ N_{\text{Endcap}} = 0 \\ N_{\text{HF}} = 0 \\ N_{\text{CASTOR}} = 0 \\ N_{\text{EZDC}} = 0 \end{cases}$$

$$\begin{cases} |t_n^f| < 0.2 \text{ GeV}^2 \\ |t_n^b| < 0.2 \text{ GeV}^2 \end{cases}$$

$$\frac{S}{B} = 2.1$$

Some conclusions

- **SCE (pp-> nX) and DCE (pp -> nXn) processes measured at LHC could provide us with unique information of π+p and π+π+ elastic cross sections at very high c.m. energy (up to several TeV)**

- **cross-sections for SCE and DCE with π+p and π+π+ scattered elastically are estimated at 10 TeV:**

$$\sigma \text{ (pp -> n } \pi\text{+p) ~ 360 } \mu\text{b at } \xi<0.4$$

$$\sigma \text{ (pp -> n } \pi\text{+}\pi\text{+ n) ~ 24 } \mu\text{b at } \xi<0.4$$

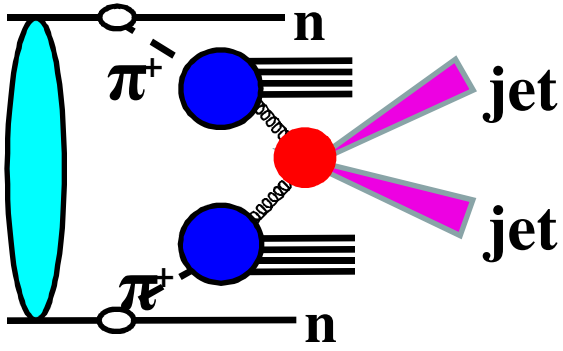
- **generator for such event simulation is developed and included to EDDE v.3**

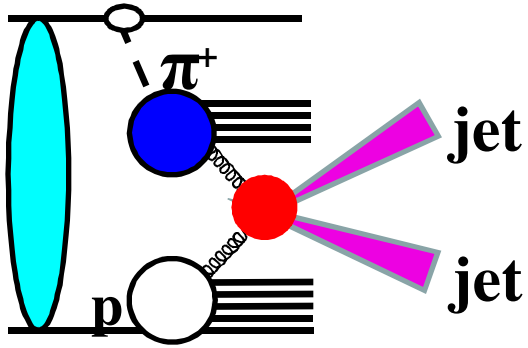
- **on the generator level we have studied possible background for CE and DCE**

- **Information from all CMS Calorimeters and t of the leading neutron, measured by ZDC, could be used for effective background suppression**

- **Extraction of π+ p and π+ π+ elastic cross-sections is possible with t of neutrons measurement by ZDC. Uncertainties: absorption can benormalized to pp, tends to 1 at t~0.**

Hard π+p (pp → n jet jet X) and π+π+ (pp → n jet jet X n) interaction





σ ~ 20 nb

σ ~ 0.5 nb

pt(jet)>40 GeV

ξ<0.2

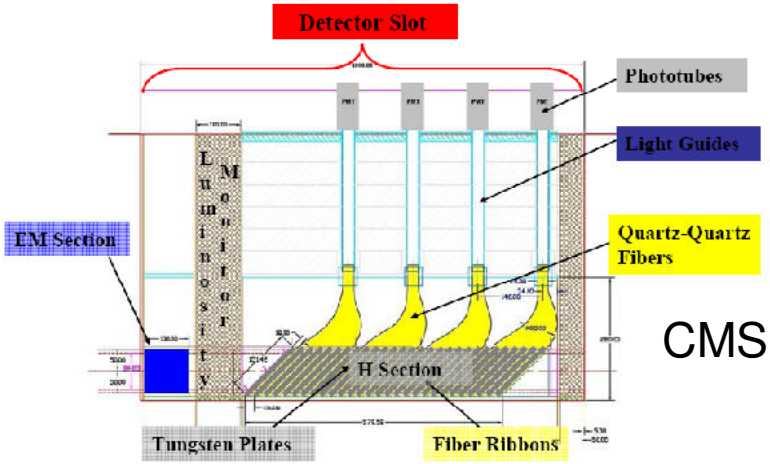
gives access to a

- **parton distributions in a pion in a still unexplored domain of Q^2 and x**
- **possible extraction of effective strangeness, charm, and beauty content of the pion**
- **study of the d-u asymmetry in the pion**

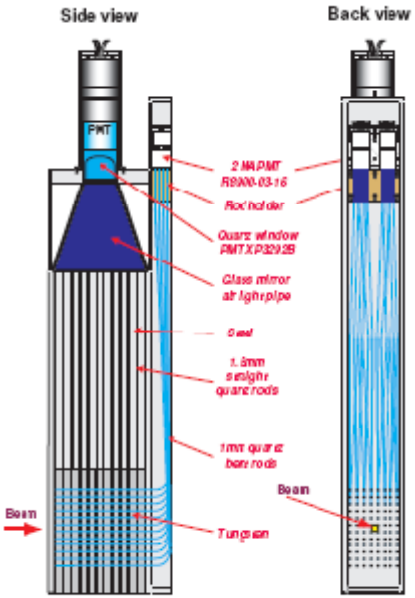
Measurement of t neutron with ZDC

At 140 m for 5 TeV neutron t ~ 0.128 R^2: t < 0.3 =>R<1.5 cm

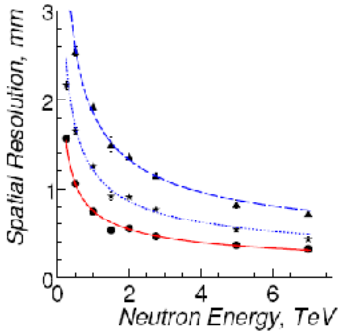
Central cell (2x10 cm) of EM ZDC: t<1.2 GeV-2



CMS ZDC

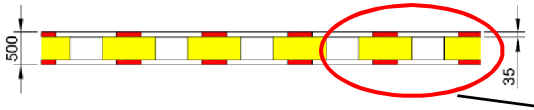


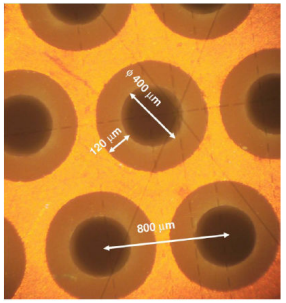
ATLAS ZDC



We suggest to change fiber layers by THGEM plates

Fig. 1. Schematic view of the THGEM.





Microscope photograph of the THGEM electrode.

1. A Concise review on THGEM **detectors.**
Nucl.Instrum.Meth.A598:107-111,2009.
e-Print: **arXiv:0807.2026** [physics.ins-det]

2. Development of detector active element based on thgem.
e-Print: **arXiv:0906.4441** [physics.ins-det]

- **cheap**
- **fast**
- **high rad. resistance**
- **coordinate and energy measurement**
- **upgrade HE CMS**