Diffractive and Forward Physics with CMS.

RDMS participation.

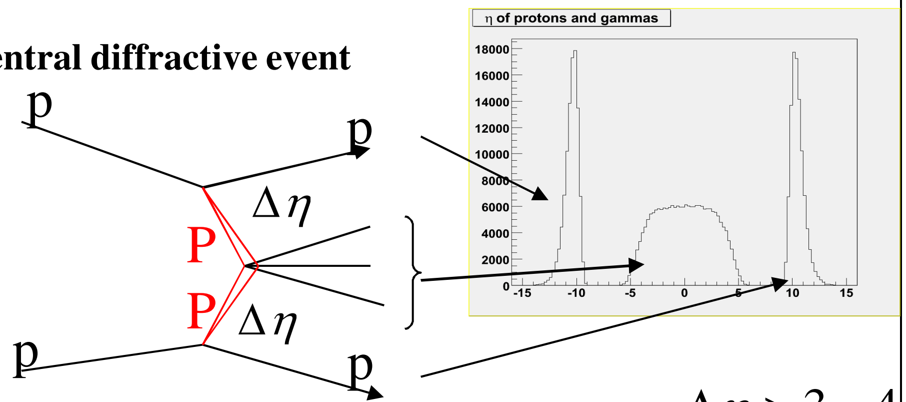
New results of RDMS in fwd physics from CMS-IHEP group.

2 stages of the fwd and diffractive physics in CMS

Present

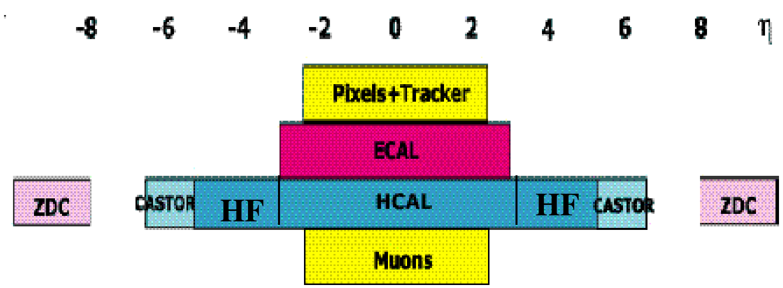
First runs at LHC
Low lumi => no pile-up or small pile-up (<2)
Absent of the forward tracker
Rapidity gaps technique
Physics with high cross section

Central diffractive event



Exchange of color singlets, Pomerons, gives $\Delta\eta > 3-4$

ZDC, CASTOR and HF provide good rapgap covering

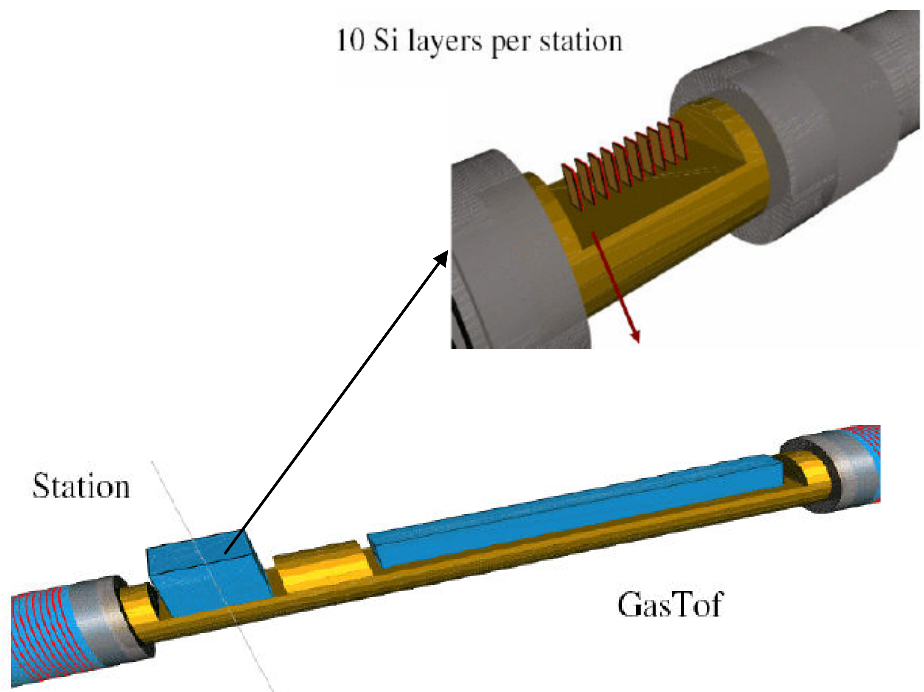


Future

~ after 2010
High lumi => pile-up
Forward tracker detector at 240 and/or 420m
TOF detectors: QUARTIC / GAZTOF
Missing mass method

$$M_X^2 = s\xi_1\xi_2$$

Physics with high and low cross sections
like pp -> p H p

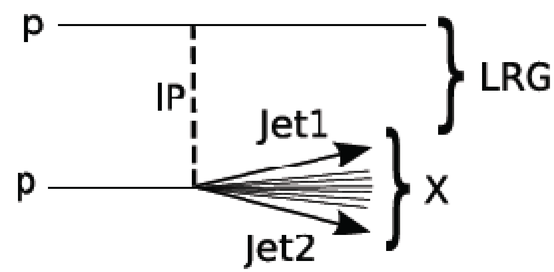


What we are ready to measure and analyse at first 200 pb^-1?

Observation of single-diffractive production of di-jets at the LHC

Subject:

$$pp \to pjjX$$



Physics motivations:

Observation of single diffractive di-jet production is an important ingredient in establishing hard diffraction at the LHC. This reaction is sensitive to the diffractive structure function of the proton, notably its gluon component. It is also sensitive to the rapidity gap survival probability. This process has been studied at the Tevatron, where the ratio of the yields for SD and inclusive di-jet production has been measured to be approximately 1%. Theoretical expectations for LHC are at the level of a fraction of a percent.

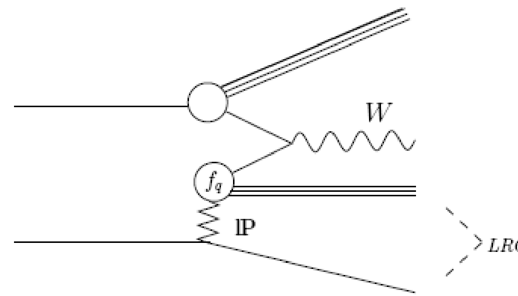
Expected results:

Assuming a rapidity gap survival probability of 0.05, N~6000 reconstructed signal events are expected with a signal-to-background ratio of up to 30 if the CASTOR calorimeter is available. If CASTOR is not available, the HF information alone may be sufficient.

Study of single-diffractive production of W bosons at the LHC

Subject:

$$pp \to pWX \ (W \to \mu\nu)$$



Physics motivations:

This reaction is sensitive to the diffractive structure function of the proton, notably its quark component, since W bosons originate from quark fusion. It is also sensitive to the rapidity gap survival probability.
This process has been studied at the Tevatron, where the ratio of the SD W and the inclusive W yields has been measured to be approximately1%. Theoretical expectations for LHC vary from a fraction of a percent to as much as 30% .

Expected results:

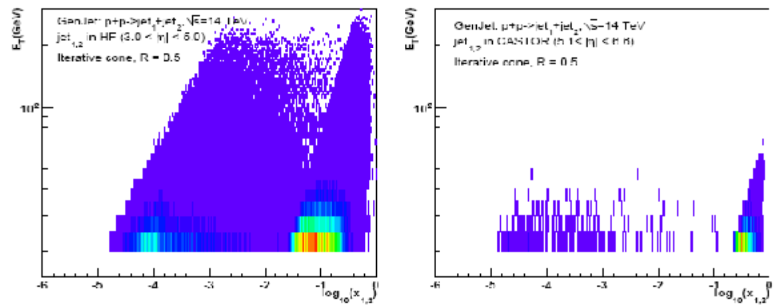
Assuming a rapidity gap survival probability of 0.05, approximately 200-400 reconstructed signal events are expected and a signal-to-background ratio of up to 20 if the CASTOR calorimeter is available. If only T2 is used, the signal increases by about a factor two, with a signal-to-background ratio as high as 5. Even if neither CASTOR nor T2 are available, the HF information alone may be suficient.

Low-x QCD studies with jets in the CMS Hadron Forward calorimeter in proton-proton collisions at $\sqrt{s}$ = 14 TeV

Subject:

p-p $\rightarrow$ jet+X

pp $\rightarrow$ jet$_1$ + jet$_2$



Physics motivations:

Perturbative QCD calculations allow one to compute the amplitudes for the hard scattering of partons at high energies and, convoluted with the corresponding parton distribution functions (PDFs) in the proton, determine the cross sections for inclusive jet production. Conversely, measuring with good accuracy the jet cross-sections can help to better constrain the PDFs.

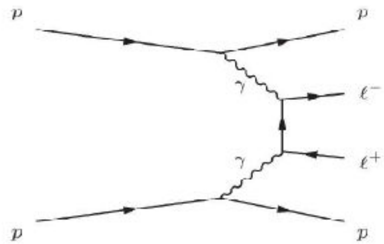
Inclusive dijet production (Mueller-Navelet) at large pseudorapidity intervals in high energy hadron-hadron collisions has been considered an excellent testing ground for BFKL and also for saturation QCD evolutions.

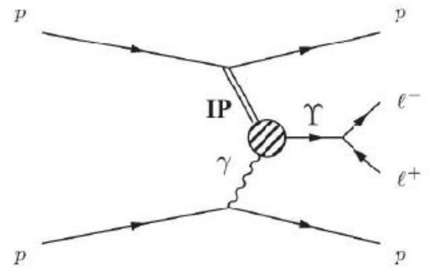
Expected results:

In summary, the HF calorimeter is a well adapted detector to carry out forward jet reconstruction studies in CMS above pT > 35 GeV/c. The single inclusive forward jet pT spectrum may help to constrain the low-x proton PDFs, if the jet energy-scale uncertainty is controlled below the 5% level. The enhanced azimuthal decorrelation of (Mueller-Navelet) jets with increasing rapidity separation expected by BFKL-evolution models will be clearly measurable.

Exclusive $\ell^+\ell^-$ production

Subject: **exclusive** $\gamma\gamma \rightarrow \ell^+\ell^-$ **and** $\gamma p \rightarrow \Upsilon \rightarrow \ell^+\ell^-$

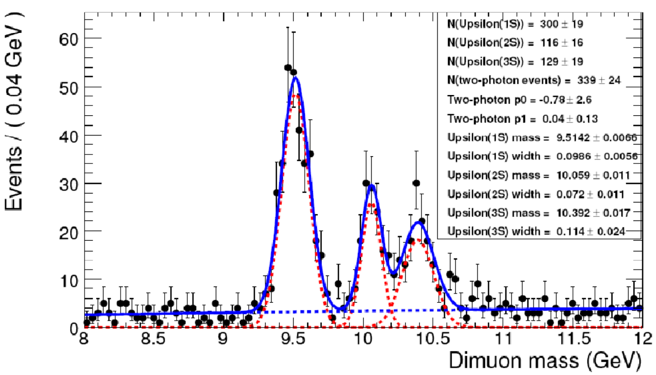




Physics motivations:

Due to the high luminosity of the LHC, a large number of these dilepton events will be produced and reconstructed each year, even in the initial low luminosity phase of running. Such events can be used to monitor the integrated luminosity collected by CMS, and for studies of lepton reconstruction and identication. At higher luminosities, these events will serve as a control sample for studies of supersymmetric leptons and other non-Standard Model physics produced in interactions. Furthermore, if the energy of the dilepton state is well measured in CMS, simple kinematics give the true forward proton energy. This process can therefore be used to calibrate forward tracking detectors.

Expected results:



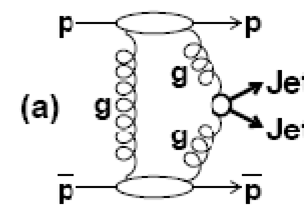
Requiring exclusivity conditions in central detectors and no activity above noise level in CASTOR and ZDC, O(700) μμ events and O(70) ee events can be obtained in 100 pb of data.
We expect a signicant signal for exclusive dimuon production, over a small background from non-exclusive processes, to be visible with early CMS data. With 200pb of integrated luminosity, it should be possible to separate the γγ ->ll and γp->Y->ll contributions by performing a fit to the invariant mass spectrum. A signal for exclusive dielectron production should also be visible with 200 pb, although with much lower statistics and no sensitivity to the resonance region.

Under investigations

Exclusive 2 jets production in DPE

$$pp \rightarrow p + jet + jet + p$$

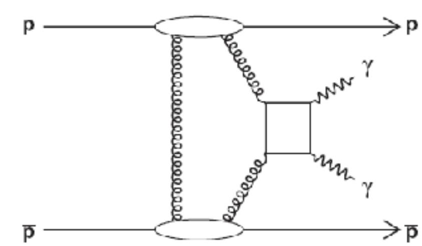
This process has been observed at the Tevatron. It can be studied in more detail and, in particular, at larger ET at the LHC.



Exclusive gamma-gamma production in DPE

$$pp \rightarrow p + \gamma\gamma + p$$

This process can be used as a 'standard candle' to check and to monitor the exclusive ggPP luminosity that has been used for the prediction of the Higgs cross section.



Exclusive cc and bb production in DPE

$$pp \rightarrow p + \chi_{c0} + p$$

$$pp \rightarrow p + \chi_{b0} + p$$

Jet-gap-jet production and others

RDMS participation in the FWD and Diffractive physics in CMS

Moscow SU: Sarycheva, Proskuryakov, Merkin
- Trigger calculations
- MC simulations for the first runs physics
- Electronics for CASTOR

PNPI: Kim, Oreshkin
- Theory: BFKL models
- MC Generators: GoZo for DPE including BFKL evolution

Yerevan SU: Bunyatyan, Sirunyan et al.
- Theory: cosmic ray models, DPE
- $\mu\mu$ and γjet production

ITEP: Rostovcev, Zhokin, Popov
- G4 model of FP420 tracker detectors
- Reconstruction of the forward protons
- LED/Laser calibration system for CASTOR

IHEP: Petrov, Ryutin, Sobol, Samoylenko, Kuznetsov, Baishev, Azhgirey
- Theory: Regge-eikonal models, leading neutrons in pp collisions
- MC Generators: EDDE
- MC simulations for the first runs physics
- G4 model of QUARTIC (TOF detector for FP420)
- Calculation and optimization of the rad. background in the fwd region

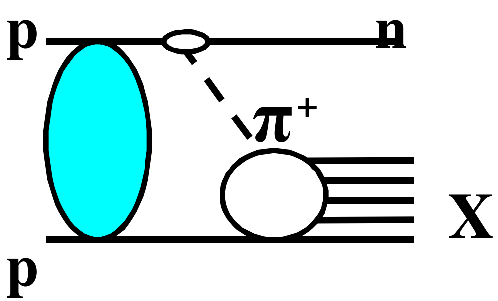
New results of RDMS in fwd physics from CMS-IHEP group.

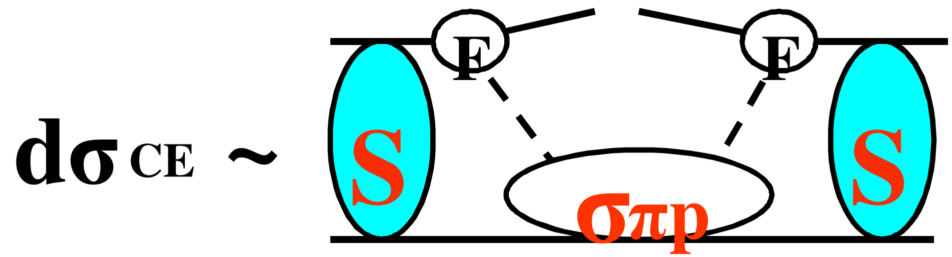
Leading neutrons measurement with CMS.

We propose an experiment at the LHC with leading neutron production. The latter can be used to extract from it the total $\pi^+ p$ cross-sections. With two leading neutrons we can get access to the total $\pi^+\pi^+$ cross-sections.

Charge Exchange (CE)

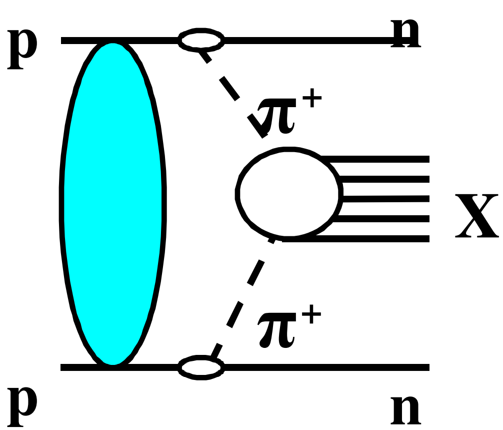
$$p + p \rightarrow n + X$$

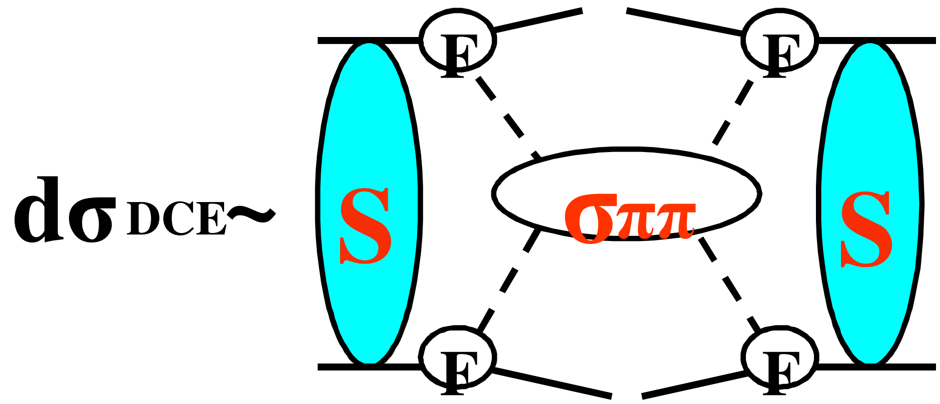




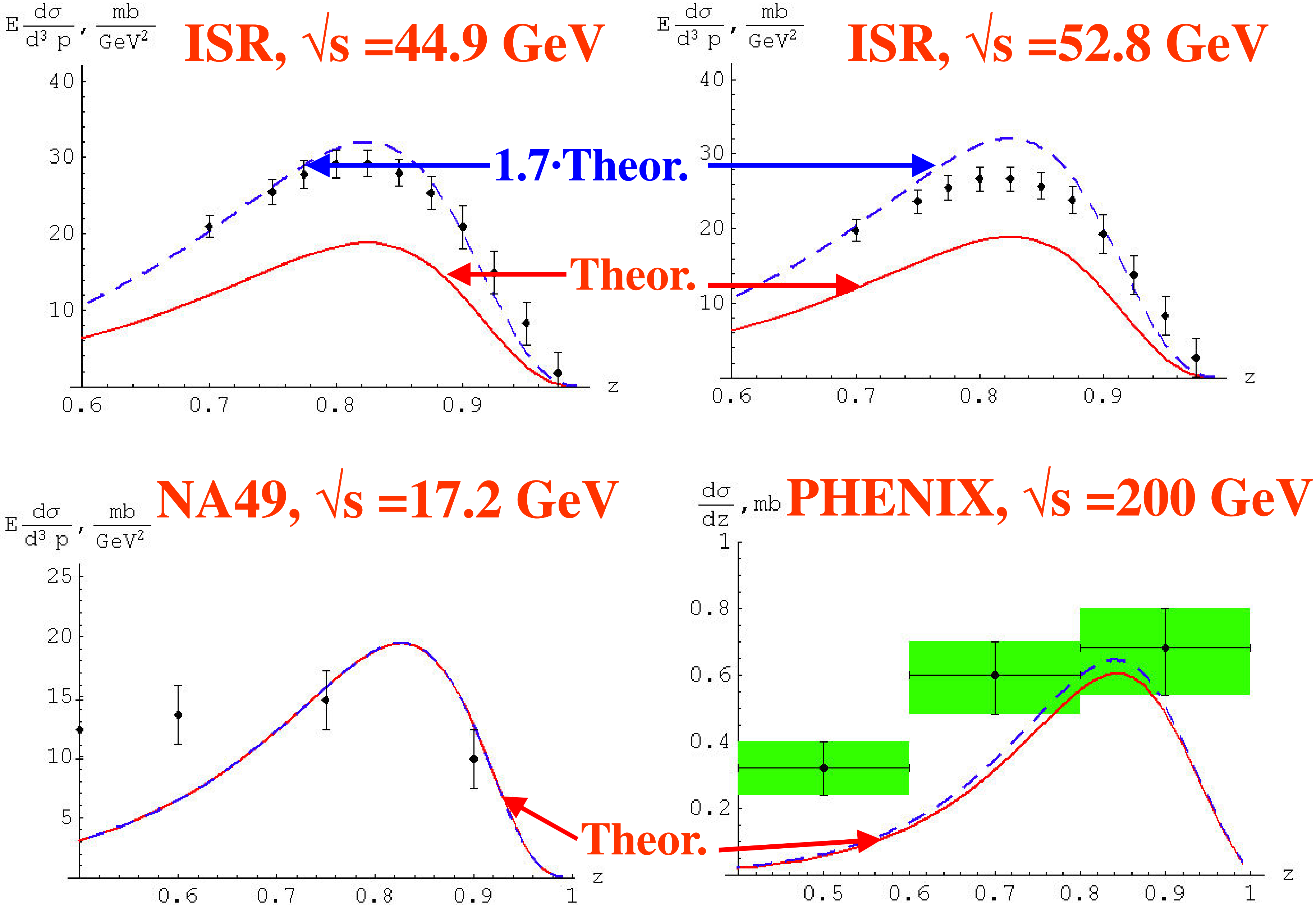
Double Charge Exchange (DCE)

$$p + p \rightarrow n + X + n$$



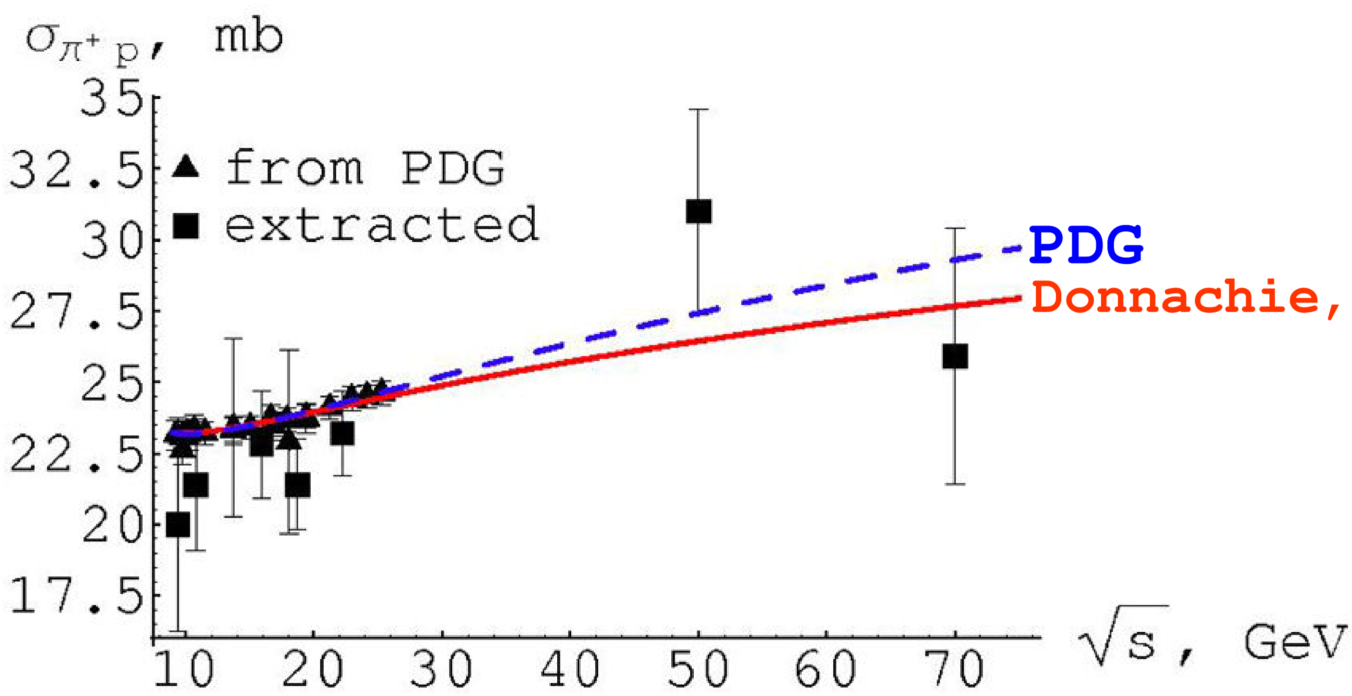


$$\sigma_{\pi^+\mathbf{p}}(\xi s) = \frac{\frac{d\sigma_{CE}}{d\xi dt}}{F_0(\xi,t)\cdot S(s/s_0,\xi,t)} \rightarrow \left.\frac{\frac{d\sigma_{CE}}{d\xi dt}}{F_0(\xi,t)}\right|_{t\rightarrow 0}$$


ISR, √s =44.9 GeV
ISR, √s =52.8 GeV
1.7·Theor.
Theor.
NA49, √s =17.2 GeV
PHENIX, √s =200 GeV
Theor.
$E\frac{d\sigma}{d^3p}$, $\frac{mb}{GeV^2}$
$\frac{d\sigma}{dz}$, mb
z

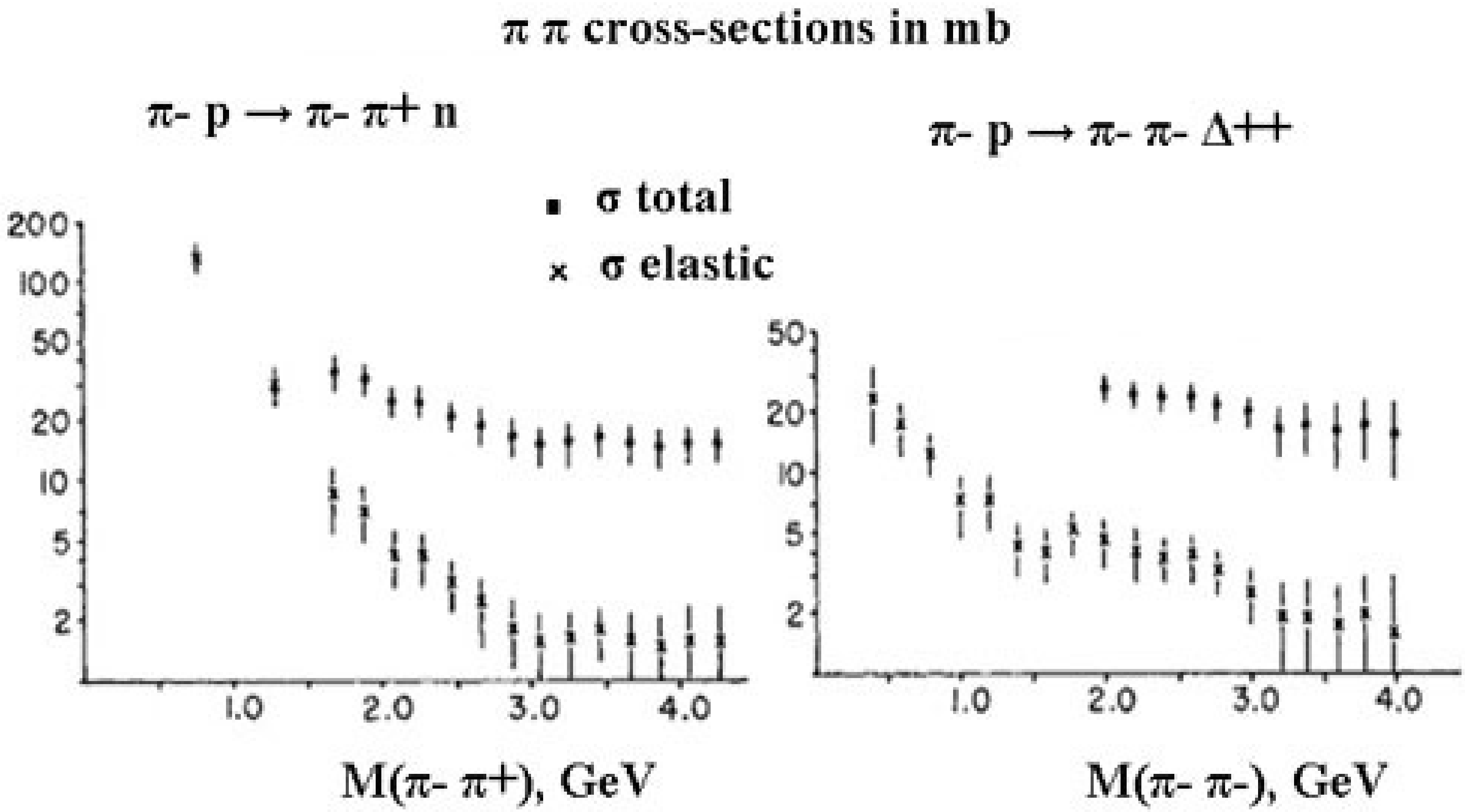
Extracted σ(πp) versus parametrization for real data from Particle Data Group

	NA49	ISR				HERA	PHENIX
$\sqrt{s}$	9.4	10.8	15.9	18.7	22.2	50	70
σ(ext.)	20±3.8	21.4±2.3	22.8±1.9	21.4±1.6	23.2±1.5	31±3.6	25.9±4.5
σ(PDG)	23.2	23.19	23.55	23.85	24.27	27.43	29.3



Extracted σ(π π) at low energies

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



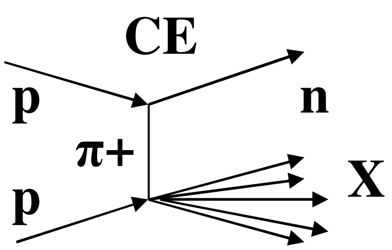
CE and DCE cross sections at 10 TeV for two different parametrizations

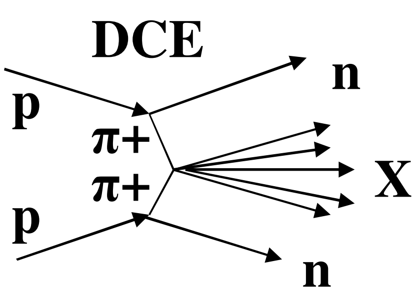
$|qt|<1$ GeV, $0 < \xi < \max(\xi)$

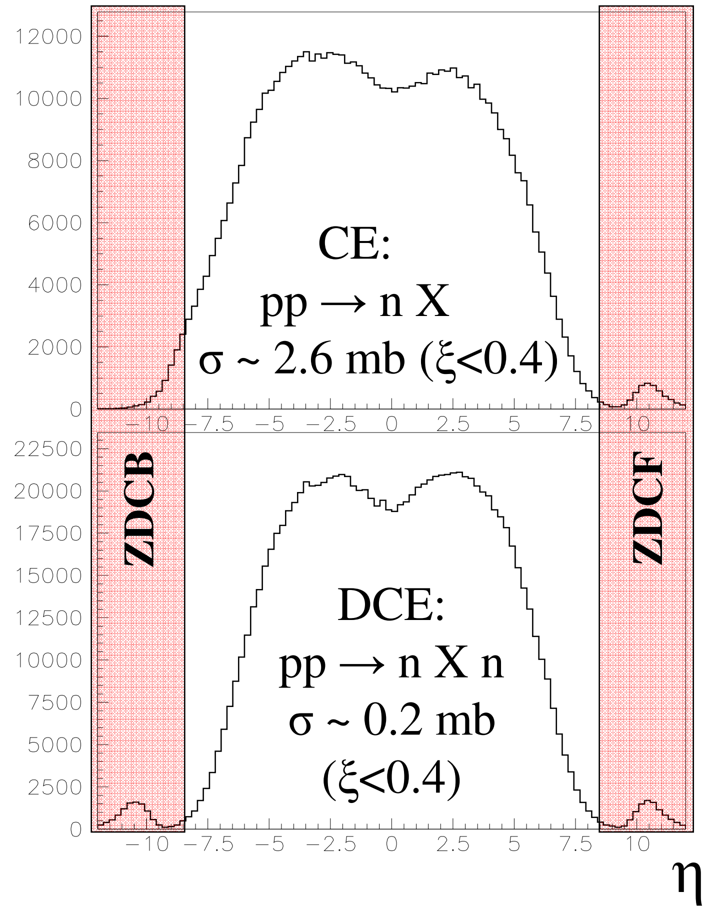
max(ξ)	0.05	0.1	0.2	0.3
σ(CE), μb	42 (57)	175 (244)	576 (820)	921 (1320)
σ(DCE), μb	0.08 (0.1)	1.7 (2.2)	25 (33)	76 (104)

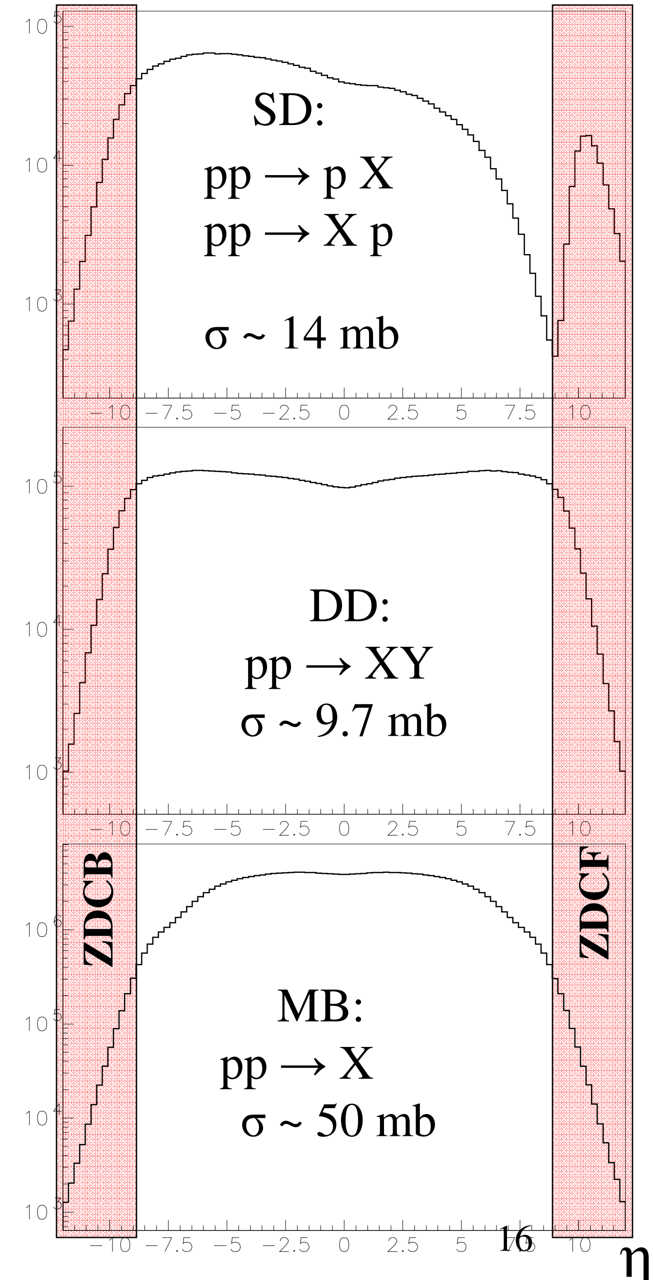
Charge Exchange (CE) and Double Charge Exchange (DCE) at LHC

We propose to perform measurements of CE and DCE processes at 10 TeV.
For the leading neutron detection Zero Degree Calorimeter could be used.









All processes have leading neutrons at |η|>8.5. So
- **SD, DD and MB can imitate CE and DCE;**
- **CE can imitate DCE**

L1 selection: N and ξ of leading neutrons in ZDC

$$\mathrm{TCE}: \left[\begin{array}{lll} N_n^f = 1 \ \text{.and.} & N_n^b = 0 \ \text{.and.} & \xi_n^f < 0.4 \\ N_n^b = 1 \ \text{.and.} & N_n^f = 0 \ \text{.and.} & \xi_n^b < 0.4 \end{array} \right.$$

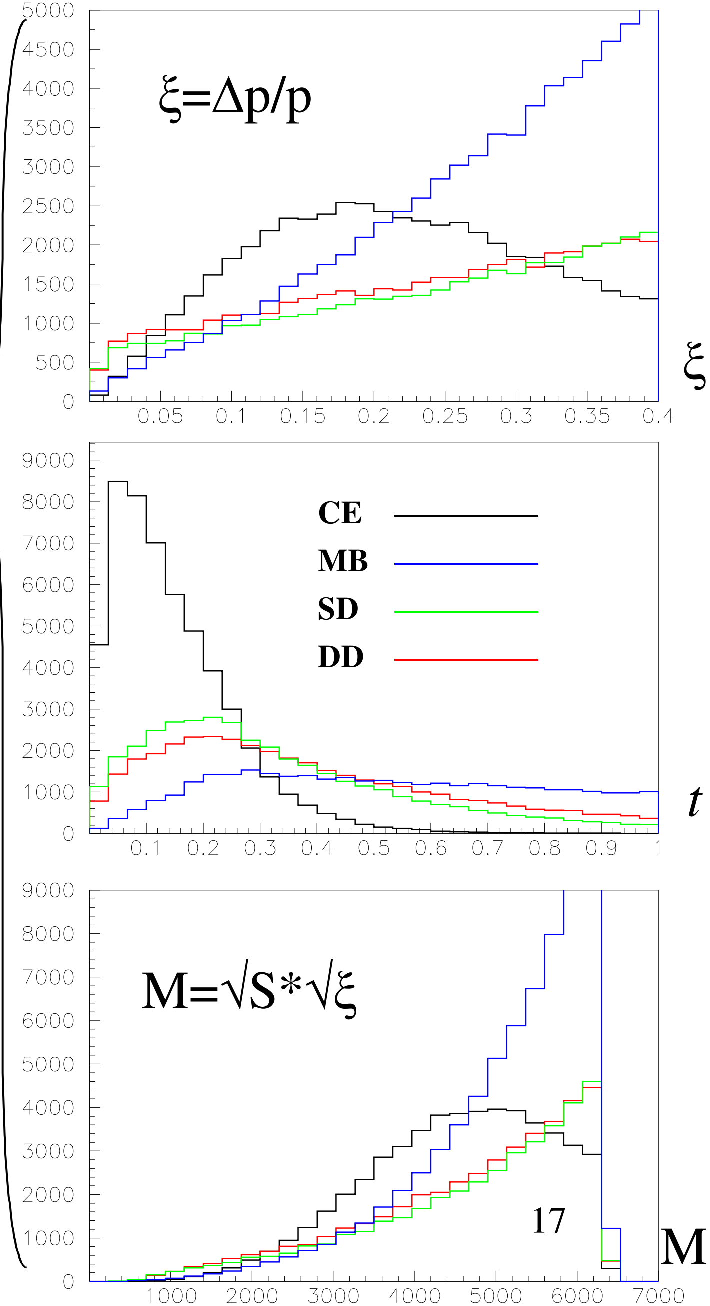
	CE	:	DCE	:	SD	:	DD	:	MB	S	:	B
NOT. TCE	1	:	0.08	:	5.4	:	3.8	:	19.2	1	:	28.4
TCE	1	:	0	:	0.8	:	0.8	:	1.2	1	:	2.7

$$\mathrm{TDCE}: \left\{ \begin{array}{ll} N_n^f = 1 \ \text{.and.} & N_n^b = 1 \\ \xi_n^f < 0.4 \ \text{.and.} & \xi_n^b < 0.4 \end{array} \right.$$

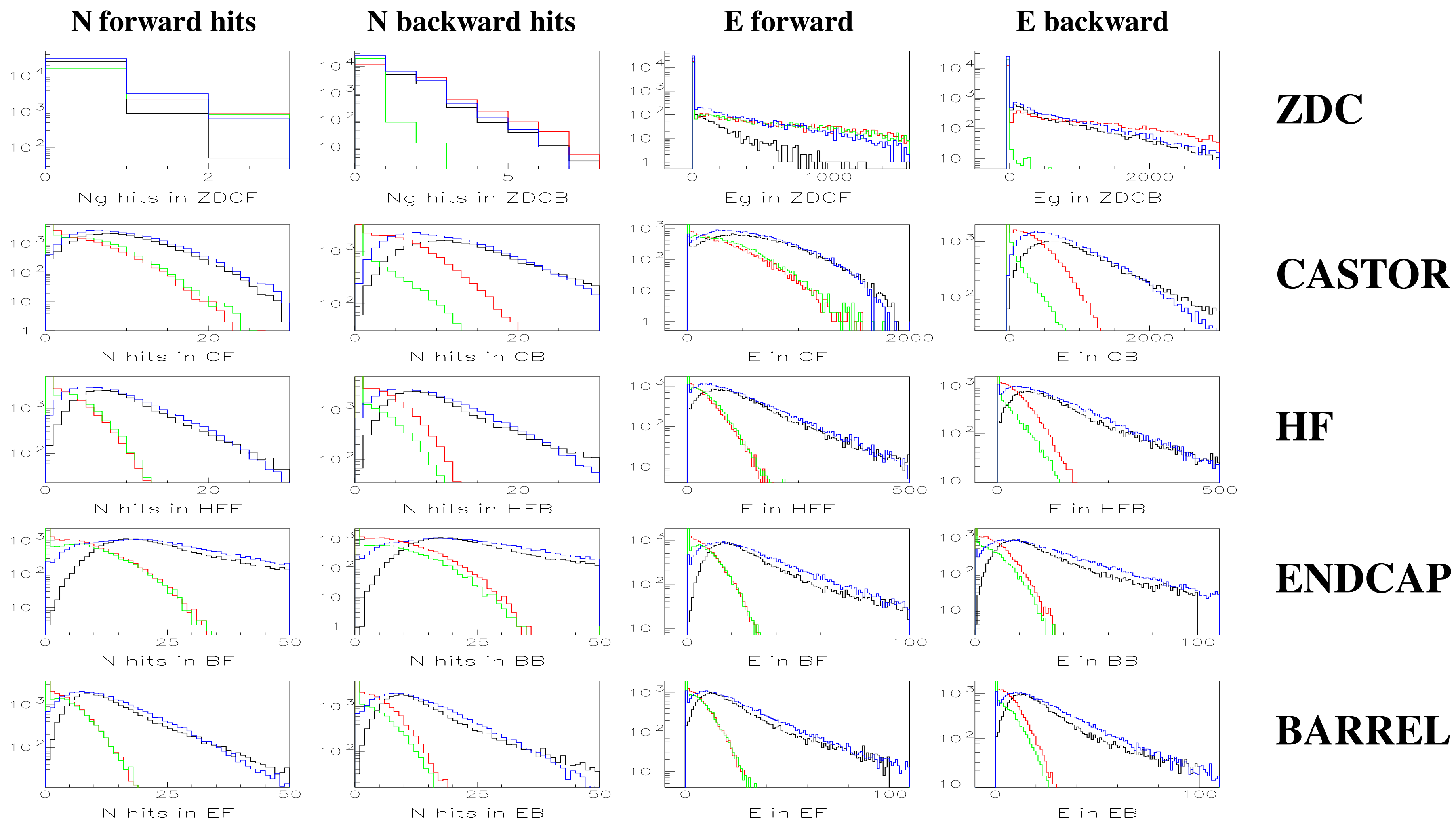
	DCE	:	CE	:	SD	:	DD	:	MB	S	:	B
NOT. TDCE	1	:	13	:	70	:	49	:	250	1	:	382
TDCE	1	:	0.5	:	0	:	0.8	:	0.3	1	:	1.6

Some conclusions for CE separation :

- **best region for S/B separation : M < 5000 GeV**
- **excellent separation by *t* : *t* < *0.25*,**
  but ZDC cannot measure *t* ☹



We selected events with 1 neutron detected in ZDCForward and look on Calo in forward and backward region



Some conclusions for CE separation :

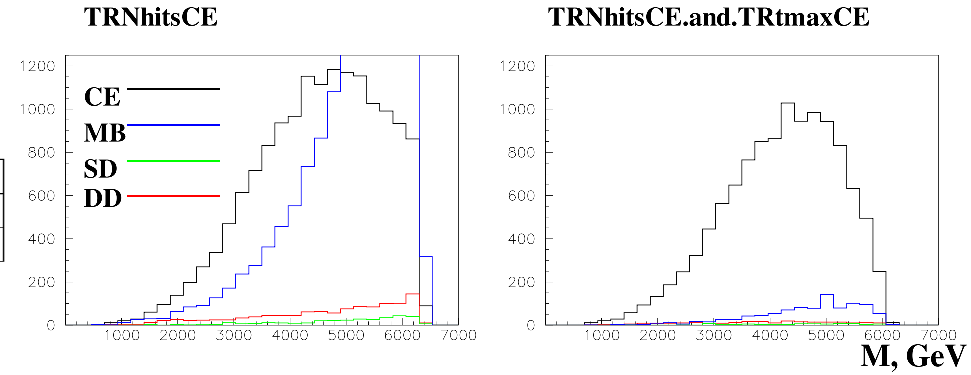
- **easy to suppress SD and DD by N hits in Calo, for example, we could use HF: NHB > 7**
- **no way to suppress MB**

S/B ratios

$$\text{THFhitsCE}: \left[\begin{array}{llllllll} N_n^f = 1 & .\text{and}. & N_n^b = 0 & .\text{and}. & \xi_n^f < 0.4 & .\text{and}. & N_{\text{hits}}^{\text{HFB}} > 7 \\ N_n^b = 1 & .\text{and}. & N_n^f = 0 & .\text{and}. & \xi_n^b < 0.4 & .\text{and}. & N_{\text{hits}}^{\text{HFF}} > 7 \end{array}\right.$$

$$\text{TtmaxCE}: \quad t_n < 0.2 \quad \text{GeV}^{-2}$$

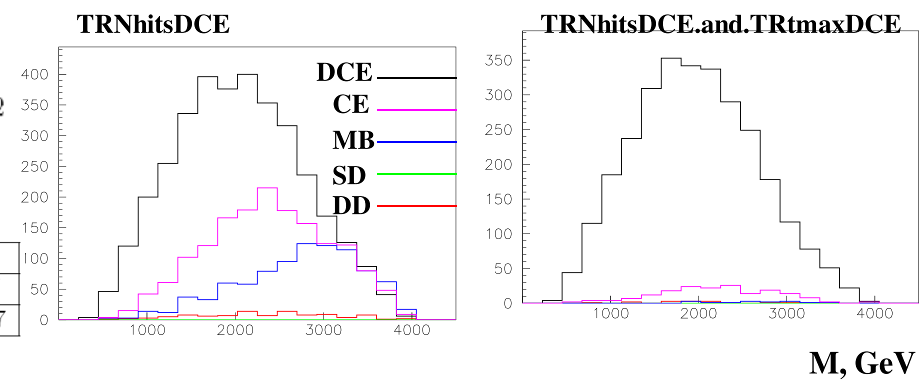
	CE	:	SD	:	DD	:	MB	S	:	B
TNhitsCE	1	:	0.013	:	0.06	:	0.48	1	:	0.56
TNhitsCE.and.TRtmaxCE	1	:	0.005	:	0.02	:	0.055	1	:	0.08



$$\text{THFhitsDCE}: \quad N_{\text{hits}}^{\text{HFF}} > 4 \quad .\text{and}. \quad N_{\text{hits}}^{\text{HFB}} > 4$$

$$\text{TtmaxDCE}: \quad t_n^f < 0.3\text{GeV}^{-2} \quad .\text{and}. \quad t_n^b < 0.3\text{GeV}^{-2}$$

	DCE	:	CE	:	SD	:	DD	:	MB	S	:	B
TNhitsDCE	1	:	0.47	:	0.0	:	0.03	:	0.2	1	:	0.7
TNhitsDCE.and.TRtmaxDCE	1	:	0.06	:	0.0	:	0.005	:	0.004	1	:	0.07



- **for effective signal/background separation we should measure *t* of leading neutron,**
- **combination of 2 simple cuts, Nhits in HF and *t* of leading neutron, could suppress background by a factor of ~760 for CE (~9500 for DCE), saving 35 % of CE events (60 % of DCE)**

for CE: S/B ~ 1/28 before selection and S/B ~ 100/8 after selections
for DCE: S/B ~ 1/380 before selection and S/B ~ 100/7 after selections

Some conclusions (generator level)

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

- **cross-sections for CE and DCE processes are estimated at 10 TeV:**

  CE: σ_{ce} ~ 2.6 mb at ξ<0.4

  DCE: σ_{Dce} ~ 200 μb at ξ<0.4

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

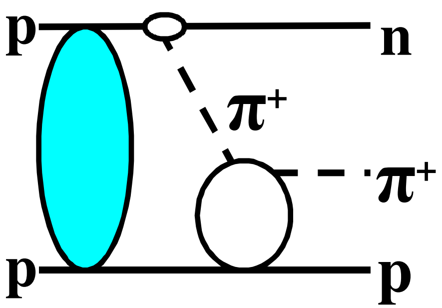
- **on the generator level we have studied possible background for CE and DCE**

- **N hits in HF and t of the leading neutron could be used for effective background suppression**

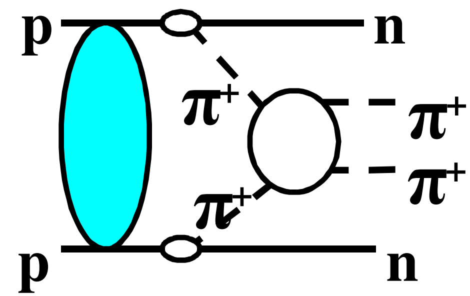
- **for t measurement ZDC should be redesigned.**

- **we could make CE and DCE measurement at first 10 TeV runs with present design of the ZDC. Using information from CMS Calo we could suppress SD and DD to zero and observe mixing of CE with MB. Cut N hits in Barrel > 50 could suppress MB events but restricts acceptance to M>2000 GeV**

- Elastic $\pi^+ p$ ($pp \to n\, \pi^+ p$) and $\pi^+\pi^+$ ($pp \to n\, \pi^+\pi^+$) scattering measurements

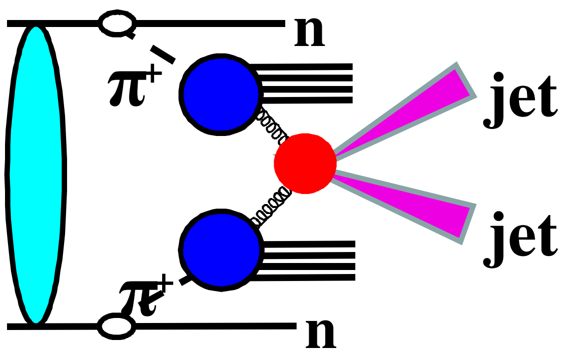


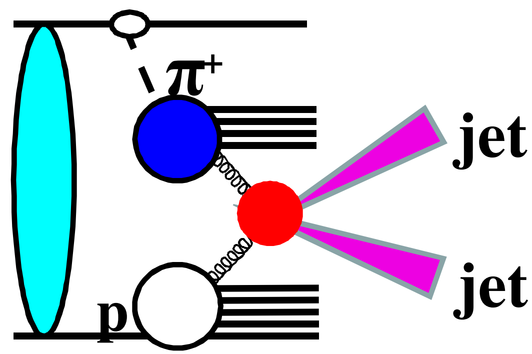
$\sigma \sim 100\ \mu b$



$\sigma \sim 1\ \mu b$

- Hard $\pi^+ p$ ($pp \to n$ jet jet X) and $\pi^+\pi^+$ ($pp \to n$ jet jet X n) interaction





$\sigma \sim 20$ nb

$\sigma \sim 0.5$ nb
pt(jet)>40 GeV
$\xi<0.2$

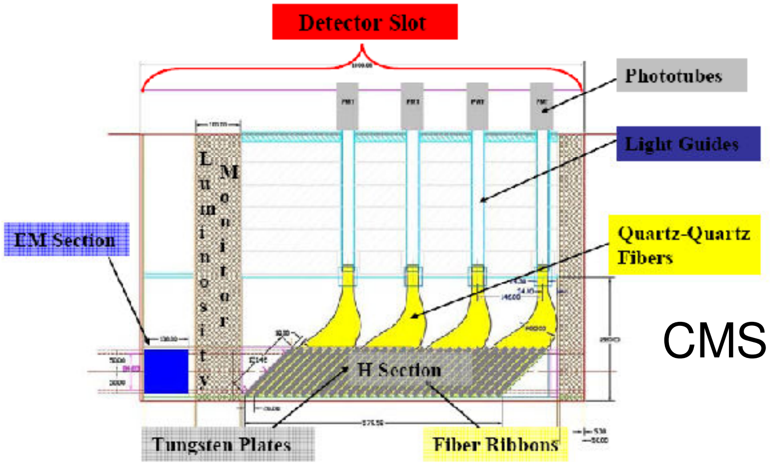
gives access to a

- 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

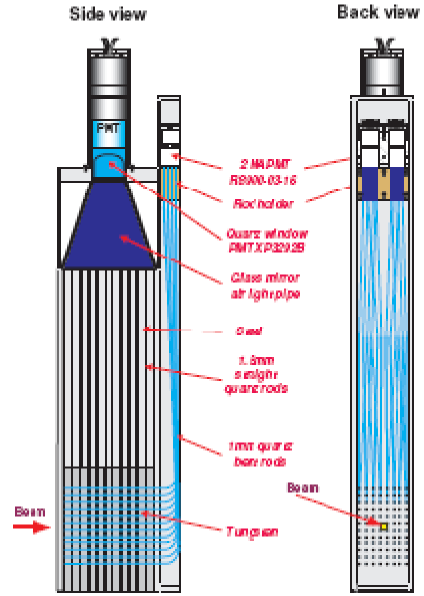
Measurement of t neutron with ZDC

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

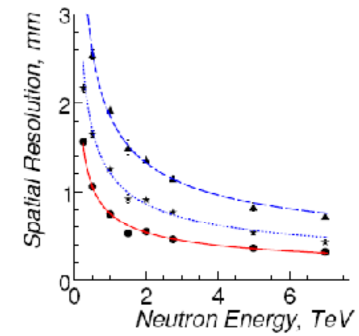
Central cell (2x10 cm) of EM ZDC: t<1.2 GeV-2



CMS ZDC



ATLAS ZDC



We suggest to change fiber layers by THGEM plates

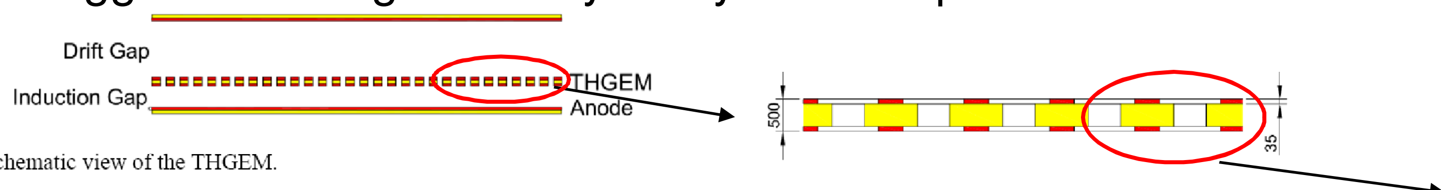
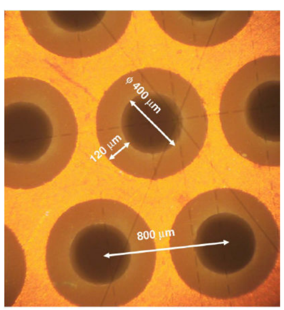


Fig. 1. Schematic view of the THGEM.



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**

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Thank you.