The Abdus Salam
International Centre for Theoretical Physics

United Nations
Educational, Scientific and
Cultural Organization

IAEA
International Atomic Energy Agency

SMR/1842-24

International Workshop on QCD at Cosmic Energies III

28 May - 1 June, 2007

Lecture Notes

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Forward Physics at TOTEM

V. Avati
(CERN, Case Western Reserve University)

TOTEM

- New Optics (β=90 m)
- Total cross-section measurement
- Study of elastic scattering
- Soft diffraction

CMS/TOTEM

"Prospects for Diffractive and Forward Physics at the LHC"
(CERN/LHCC 2006-039/G-124)

International Workshop on QCD at Cosmic Energies III
Trieste, May 30, 2007

Physics program

Total cross-section

Elastic pp scattering in the range $10^{-3} < t = (p\theta)^2 < 10$ GeV^2

Soft diffraction

Measurement of leading particles

Particle and energy flow in the forward direction

Soft and hard diffraction in Single and Double Pomeron Exchange production of jets, W, heavy flavours.....

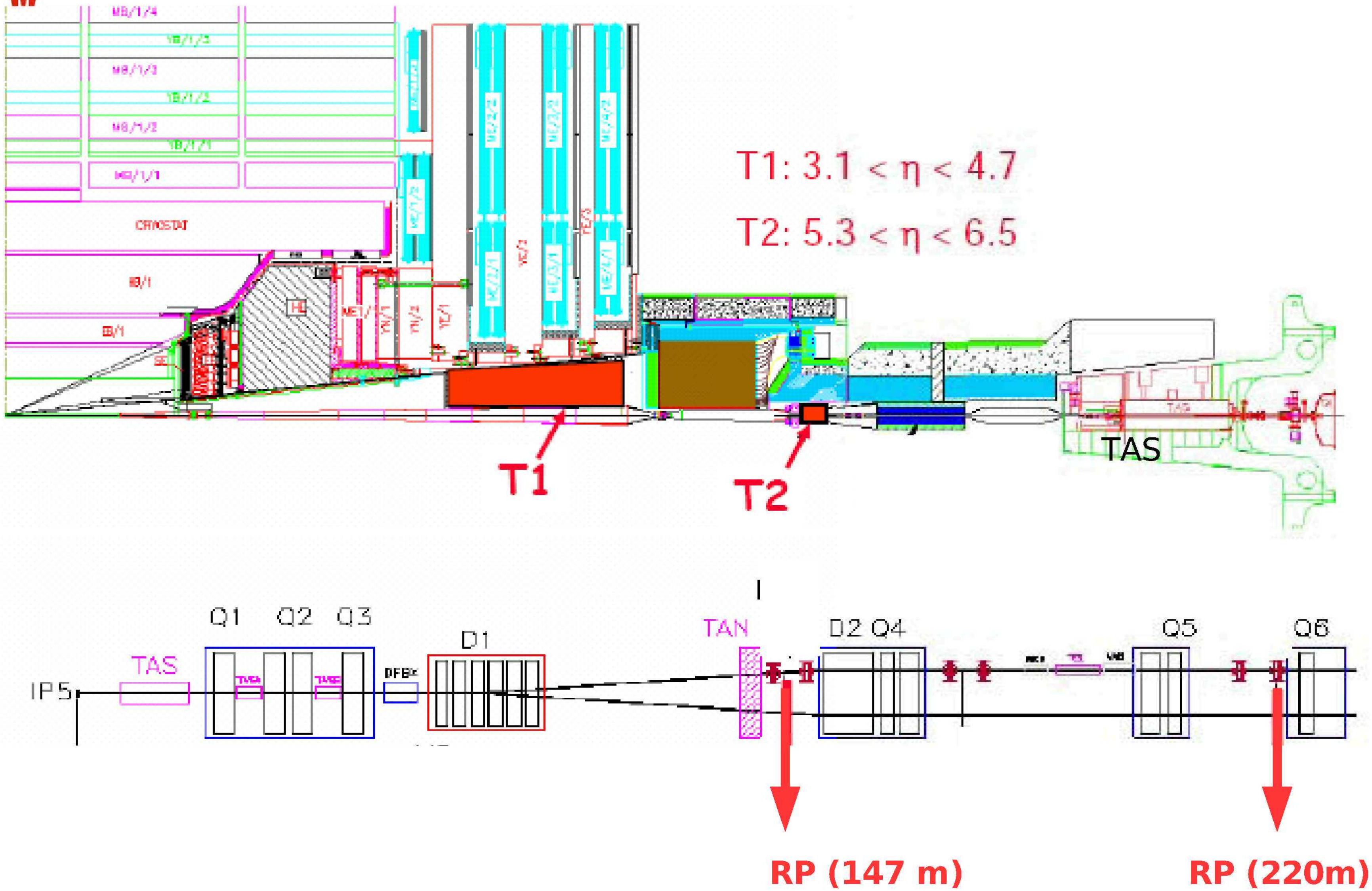
Central Exclusive Particle production

Low-x Physics

$\gamma\gamma$ and γp physics

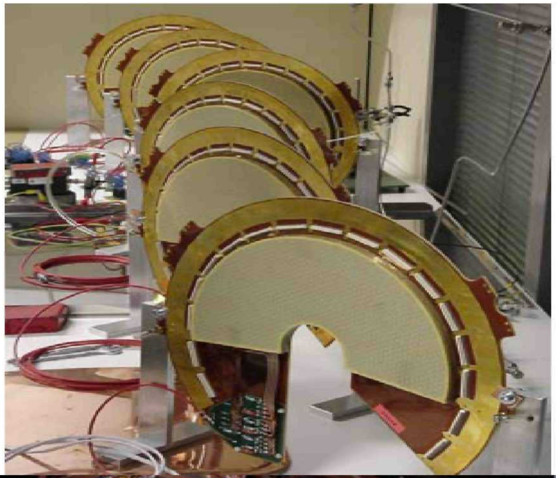
WITH CMS

TOTEM

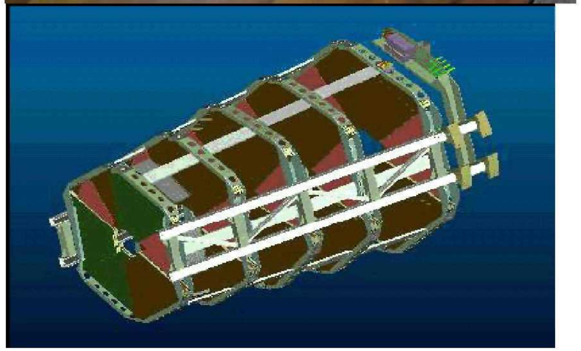


T1: 3.1 < η < 4.7
T2: 5.3 < η < 6.5
T1
T2
TAS
IP5
TAS
Q1
Q2
Q3
D1
TAN
D2 Q4
Q5
Q6
RP (147 m)
RP (220m)

Detectors: T1/T2

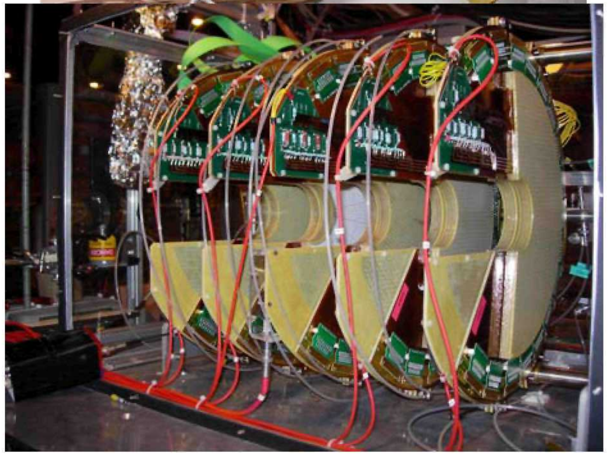


T1 Telescope
$3.1<|\eta|<4.7$
CSC: 5 planes



Fully inclusive trigger inelastic events

Primary vertex reconstruction



T2 Telescope
$5.3<|\eta|<6.5$
GEM: 10 “half-”planes

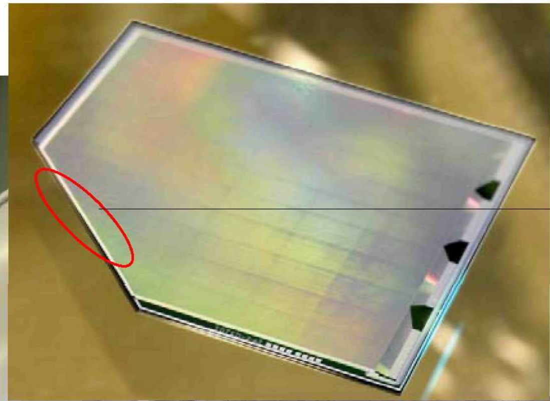
Mechanical frames and CSC detectors in production; tests in progress.

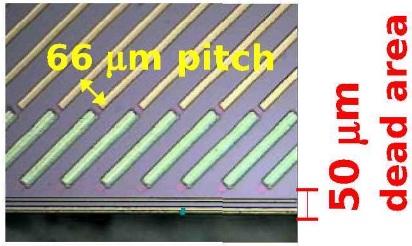
75 % of GEM chambers produced and tested up to a gain of 8×10^4.

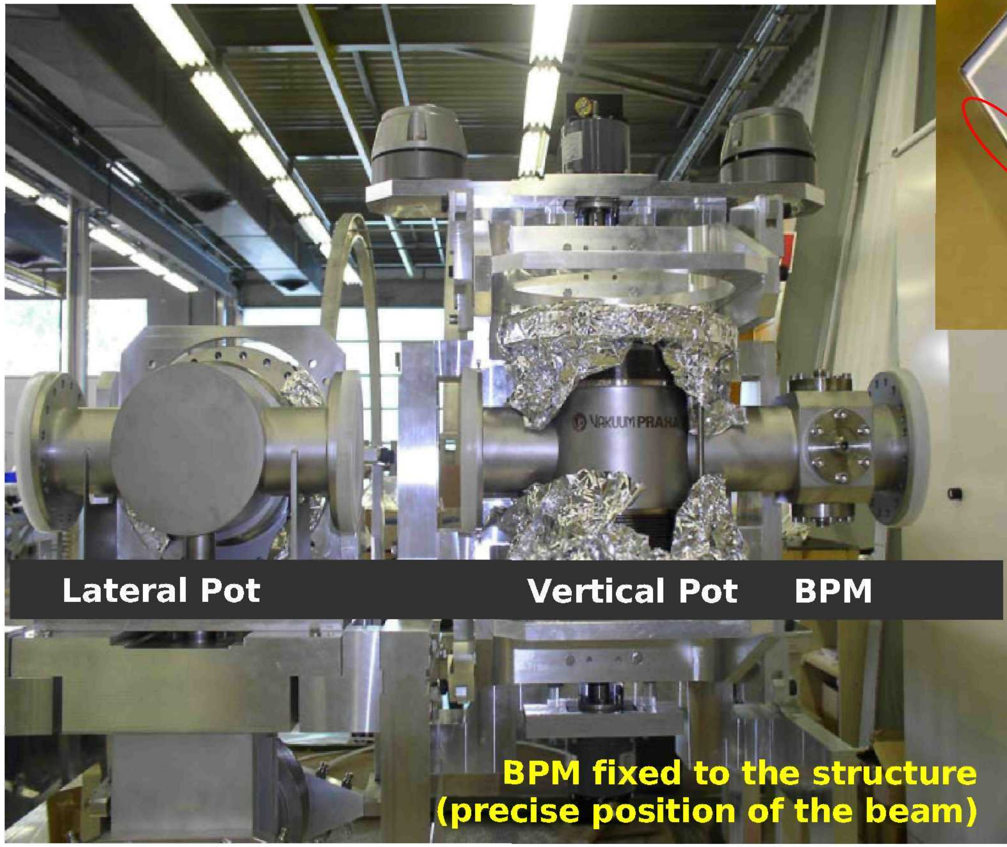
Installation schedule not yet defined (deadline April 08 ?)

Roman Pot & Leading Proton Detector

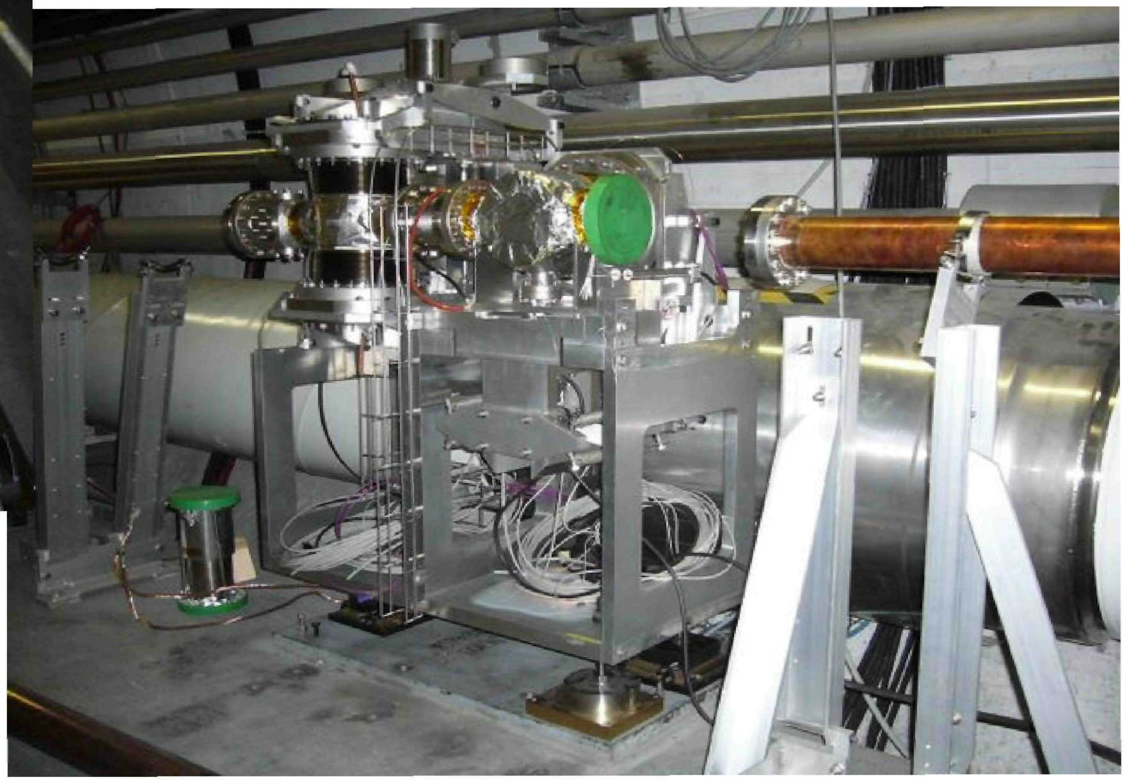
Each pot equipped with 10 planes "edgeless"
Silicon detectors (in production)







First Roman Pot station successfully installed in the LHC tunnel !!!



pp Total Cross-Section

Current models predict for

14 TeV: 90 – 130 mb

Aim of TOTEM: **~ 1%** accuracy

First year : **~5%**

Luminosity independent method:

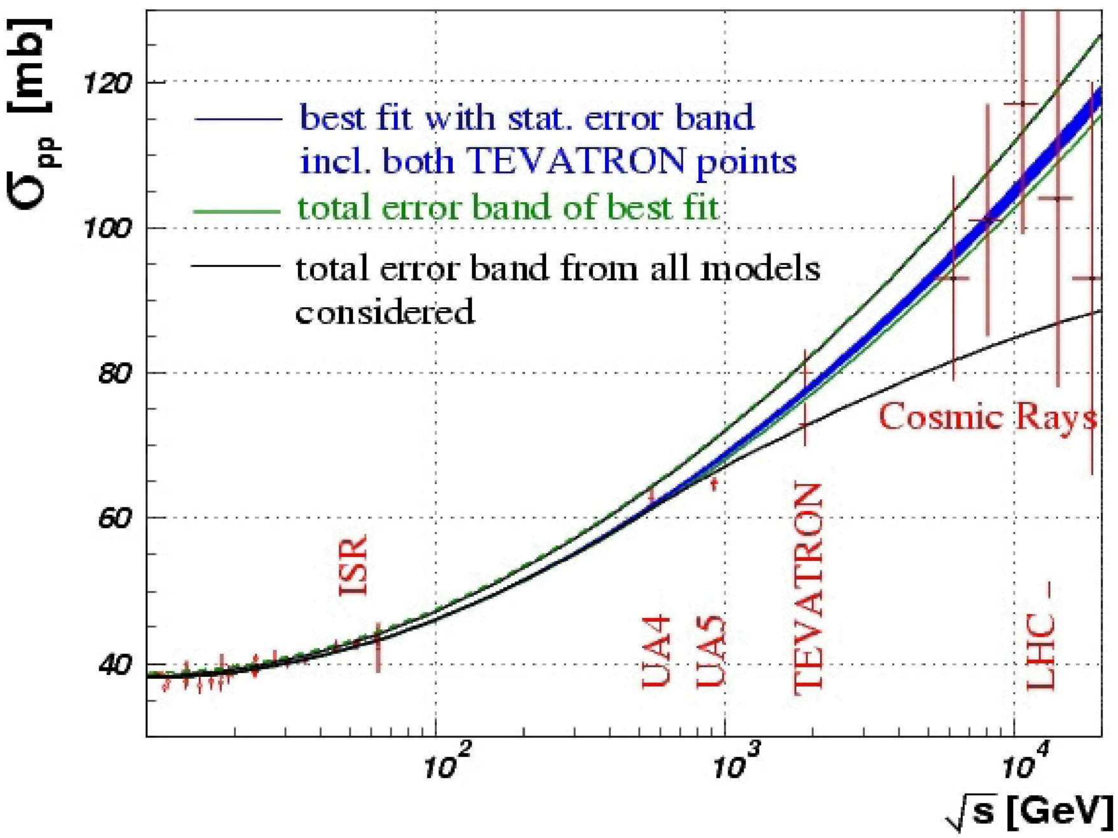
Optical Theorem $$\mathrm{L}\sigma_{tot}^2 = \frac{16\pi}{1+\rho^2} \times \left.\frac{dN}{dt}\right|_{t=0}$$

$$\mathrm{L}\sigma_{tot} = N_{elastic} + N_{inelastic}$$

⇩

$$\sigma_{tot} = \frac{16\pi}{1+\rho^2} \times \frac{(dN/dt)|_{t=0}}{N_{el} + N_{inel}}$$

COMPETE Collaboration:



Totem Optics

TOTEM needs special/independent short runs at high-β* and low ε for precise measurement of the scattering angles of a few μrad

As consequence of high β* : large beam size at IP **$\sigma_{\theta*} = \sqrt{\varepsilon/\beta^*} \sim 0.3\ \mu rad$**

$\sigma^* = \sqrt{\varepsilon\, \beta^*} \sim 0.4\ mm$

Require parallel-to-point focusing: trajectories of proton scattered at the same angle but at different vertex locations ($\Rightarrow$ $y \sim \Theta^*_y$)

Reduced number of bunches (43, 156) to avoid interactions further downstream

Baseline optics β*=1540 m: Parallel-to-point focusing in both transverse planes, allows

very low-t detection ($|t| \sim 2\ 10^{-3}$ GeV^2)

requires special injection optics

probably not available at beginning of LHC

⇓

“Early” optics β*=90 m : paralle-to-point focusing only in vertical plane

t detection down to ~ 2 10^{-2} GeV^2

achievable by un-squeezing the standard LHC injection optics

Comparison of High β Optics

Parameters	β^* **β**= 1540 m (baseline optics)	β^* **β**= 90 m (early optics)
Crossing angle	0.0	0.0
N of bunches	43	156
N of part./bunch	$3 \cdot 10^{10}$	$4 \cdot 10^{10}$
Emittance ε_n [μm · rad]	1	3.75
RMS beam size at IP [μm]	450	200
RMS beam divergence [μrad]	0.29	2.3
10 σ beam width at RP220 [mm]	0.8	6.25
Peak luminosity [cm^{-2} s^{-1}]	$1.6 \cdot 10^{28}$	$5 \cdot 10^{29}$
Injection	special	standard
MD commissioning	more difficult	less difficult

β=90 m

- fits into the 2008 run scenario;
- small integrated luminosity loss in 2008
- ideal for training the RP operation due to wide beams;
- helps beam diagnostics
  - luminosity
  - beam position
  - vertex distribution

Proposal submitted to the LHCC and well received.

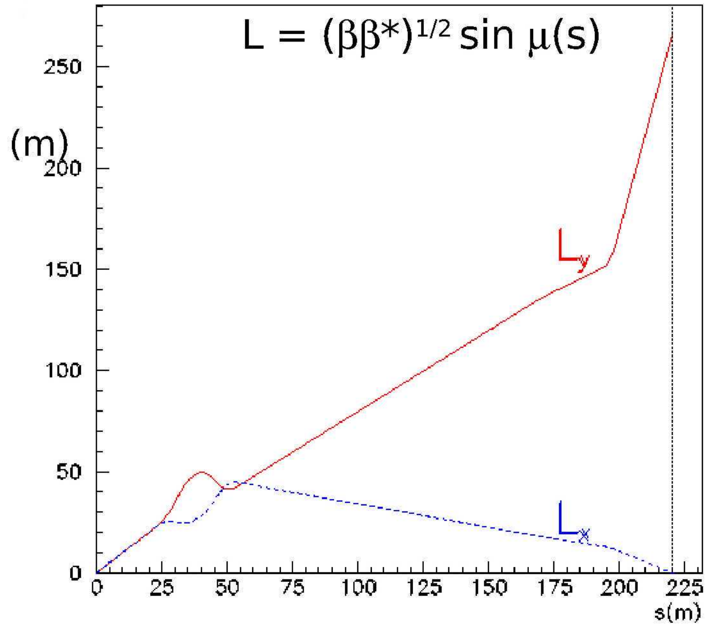
Parameter Evolution and Rates

All values for nominal emittance, 7TeV and 10m β* in points 2 and 8

Parameters			Beam levels		Rates in 1 and 5		Rates in 2 (and 8)	
k_b	N	β* 1,5 (m)	I_{beam} proton	E_{beam} (MJ)	Luminosity ($cm^{-2}s^{-1}$)	Events/ crossing	Luminosity ($cm^{-2}s^{-1}$)	Events/ crossing
43	$4\ 10^{10}$	11	$1.7\ 10^{12}$	2	$1.1\ 10^{30}$	<< 1	$1.2\ 10^{30}$	0.15
43	$4\ 10^{10}$	2	$1.7\ 10^{12}$	2	$6.1\ 10^{30}$	0.76	$1.2\ 10^{30}$	0.15
156	$4\ 10^{10}$	2	$6.2\ 10^{12}$	7	$2.2\ 10^{31}$	0.76	$4.4\ 10^{30}$	0.15
156	$9\ 10^{10}$	2	$1.4\ 10^{13}$	16	$1.1\ 10^{32}$	3.9	$2.2\ 10^{31}$	0.77
936	$4\ 10^{10}$	11	$3.7\ 10^{13}$	42	$2.4\ 10^{31}$	<< 1	$2.6\ 10^{31}$	0.15
936	$4\ 10^{10}$	2	$3.7\ 10^{13}$	42	$1.3\ 10^{32}$	0.73	$2.6\ 10^{31}$	0.15
936	$6\ 10^{10}$	2	$5.6\ 10^{13}$	63	$2.9\ 10^{32}$	1.6	$6.0\ 10^{31}$	0.34
936	$9\ 10^{10}$	1	$8.4\ 10^{13}$	94	$1.2\ 10^{33}$	7	$1.3\ 10^{32}$	0.76
2808	$4\ 10^{10}$	11	$1.1\ 10^{14}$	126	$7.2\ 10^{31}$	<< 1	$7.9\ 10^{31}$	0.15
2808	$4\ 10^{10}$	2	$1.1\ 10^{14}$	126	$3.8\ 10^{32}$	0.72	$7.9\ 10^{31}$	0.15
2808	$5\ 10^{10}$	1	$1.4\ 10^{14}$	157	$1.1\ 10^{33}$	2.1	$1.2\ 10^{32}$	0.24
2808	$5\ 10^{10}$	0.55	$1.4\ 10^{14}$	157	$1.9\ 10^{33}$	3.6	$1.2\ 10^{32}$	0.24

R. Bailey

Optical Functions

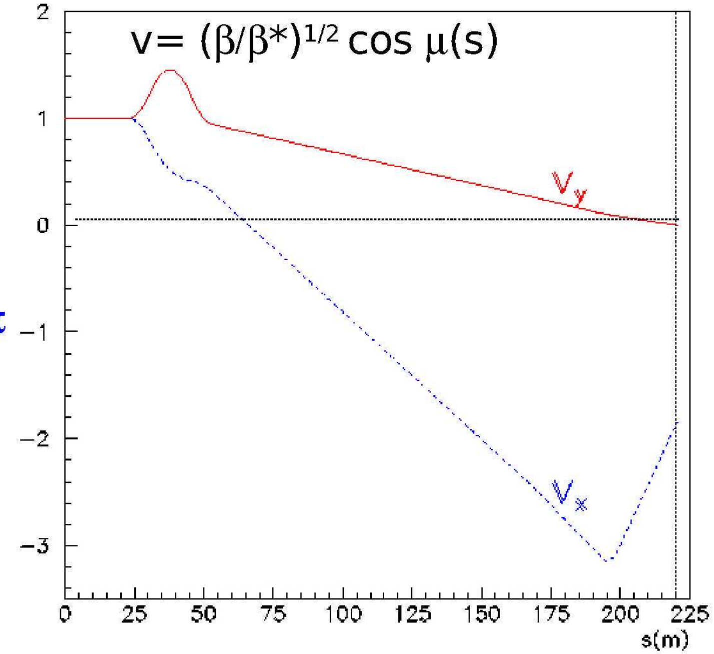


<u>Idea:</u>

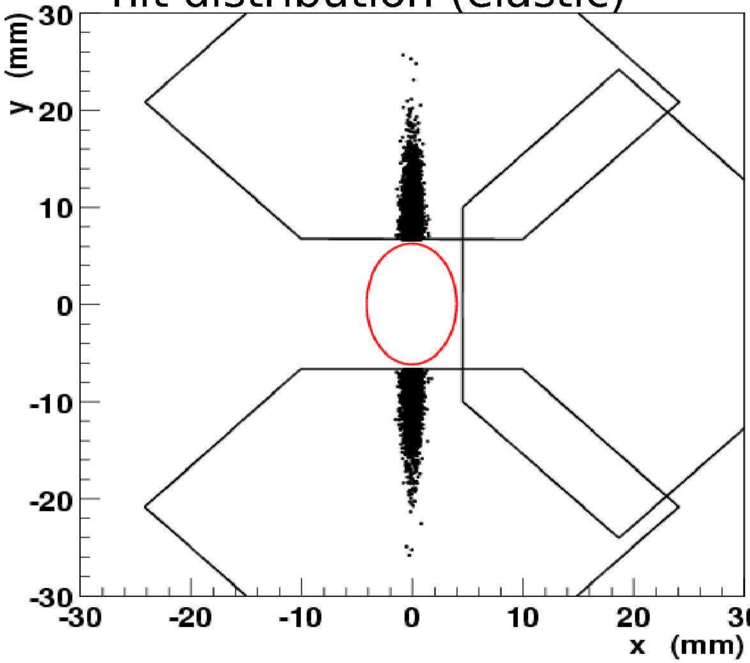
L_y large $\quad$ $L_x = 0$

$v_y = 0$

$\mu_y(220) = \pi/2$ $\quad$ $\mu_x(220) = \pi$



hit distribution (elastic)



$$x = \cancel{L_x \theta_x^*} + v_x x^* + D\xi$$

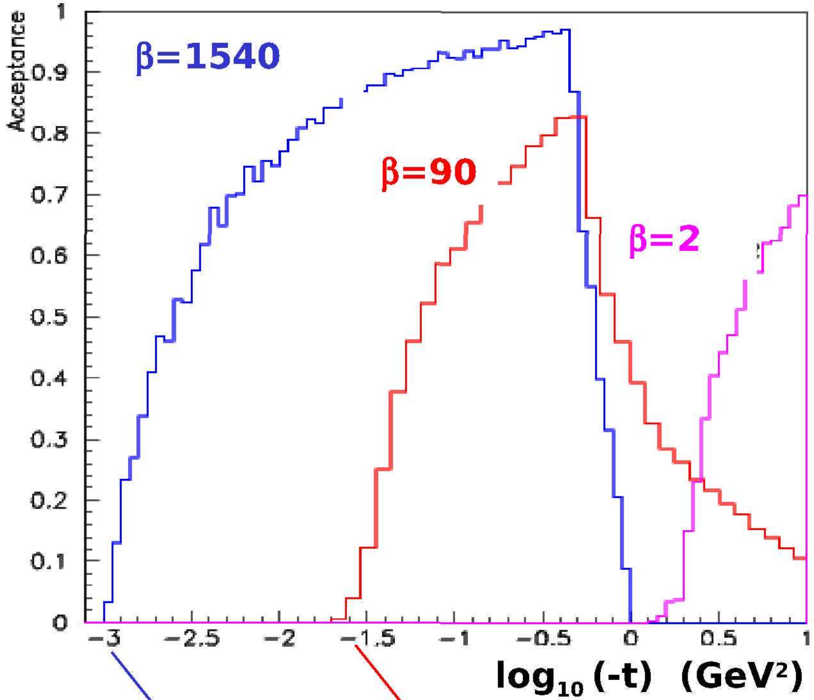
$$y = L_y \theta_y^* + \cancel{v_y y^*}$$

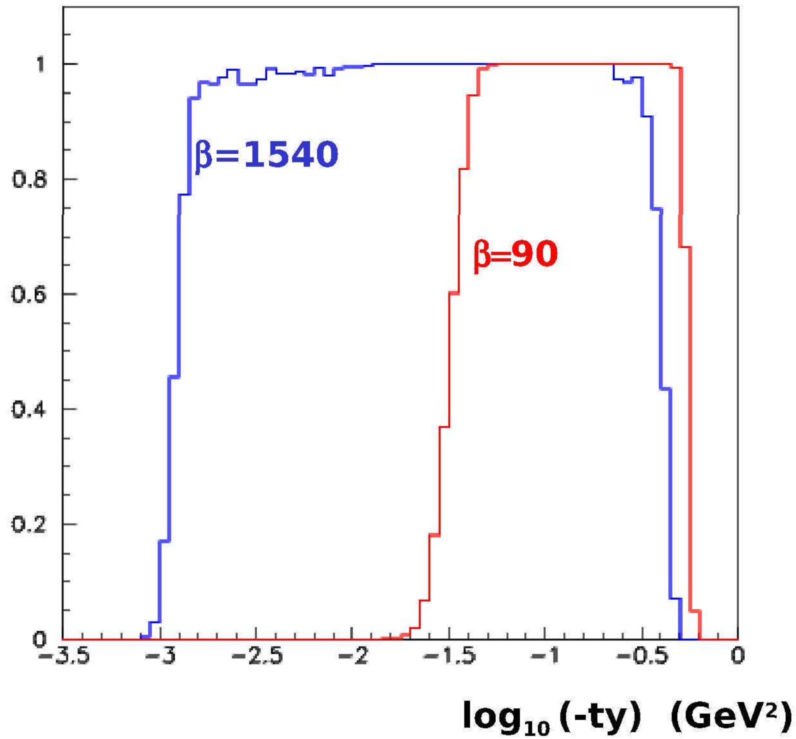
(x^*, y^*): vertex position

(θ_x^*, θ_y^*): emission angle

t-Acceptance at RP220 for Elastic Scattering

$t = t_x + t_y$ $t \sim -(p\,\theta)^2$ t_y



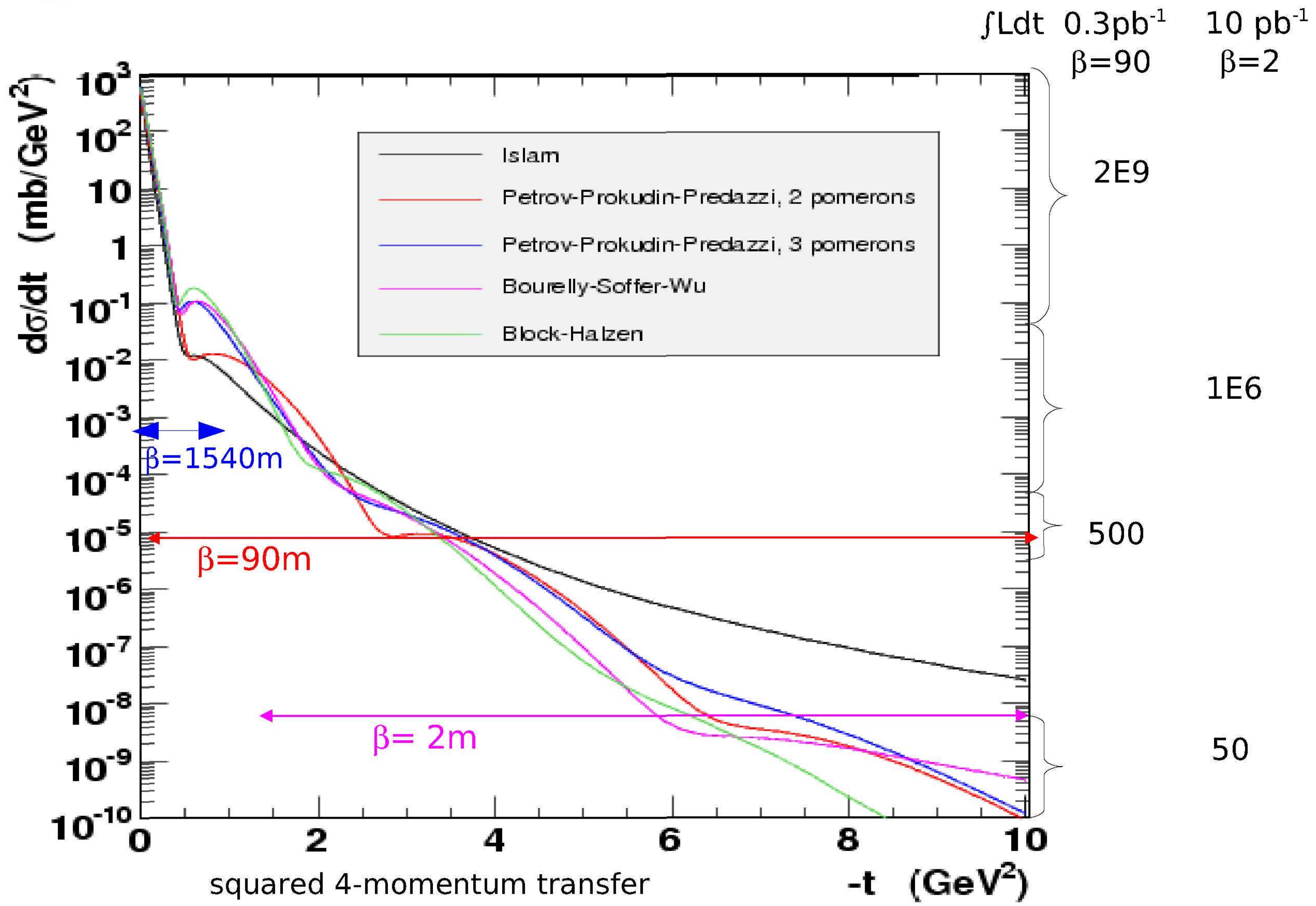


$10\sigma_{beam}$ = 0.8 mm   6.25 mm

+ 0.5 mm detector displacement

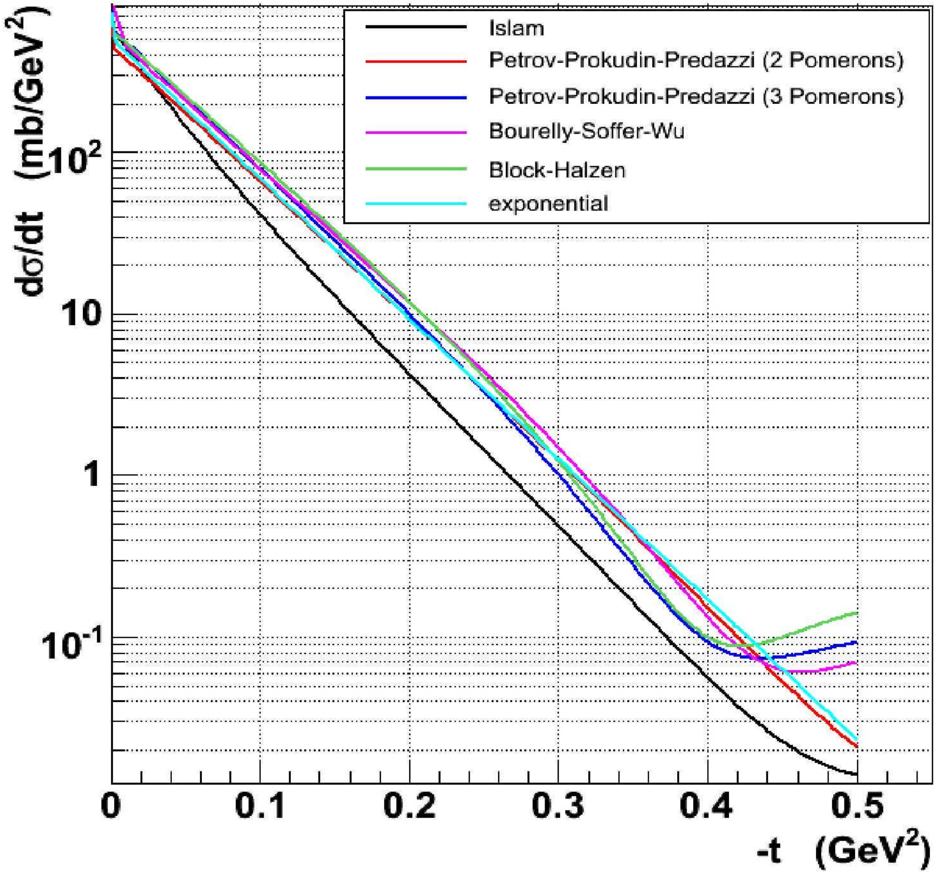
$\sigma(t_y) / t_y \sim 0.02\ \mathrm{GeV} / t_y^{1/2}$

Elastic Scattering

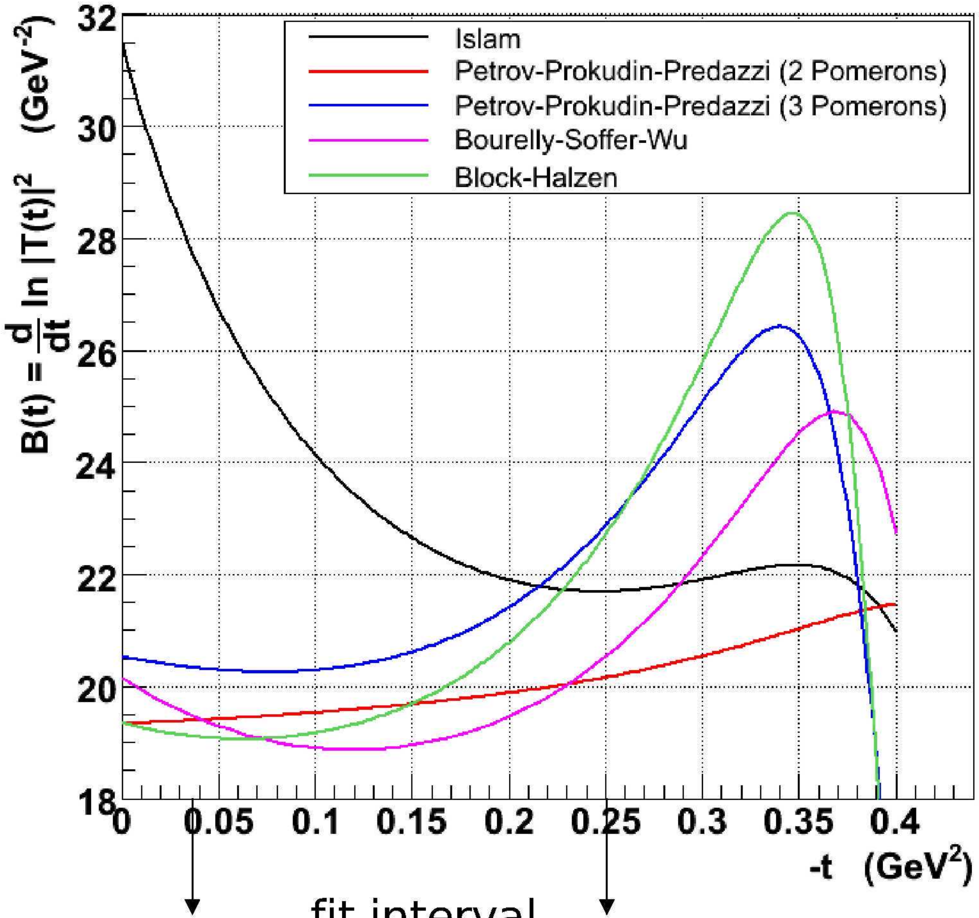


Elastic Scattering at low |t|

$d\sigma/dt = \exp[-B(t) \cdot t]$



Exponential Slope B(t)



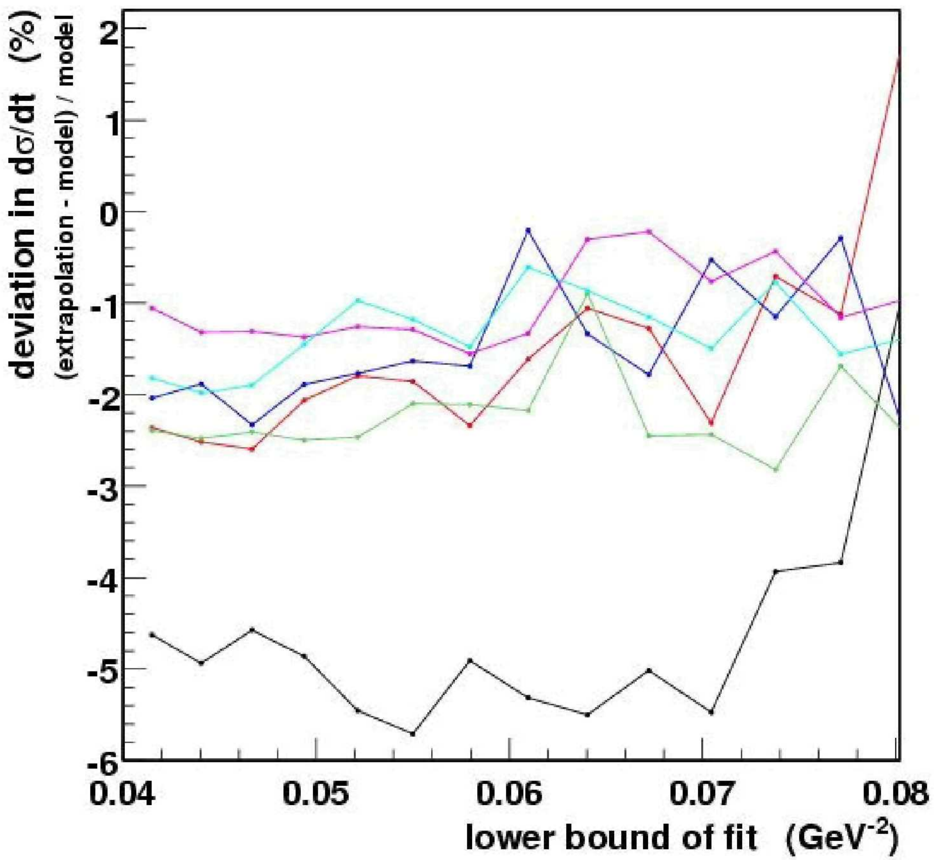
$\beta^* = 1540$ m: $|t|_{min} = 0.002$ GeV^2

$\beta^* = 90$ m: $|t|_{min} = 0.04$ GeV^2

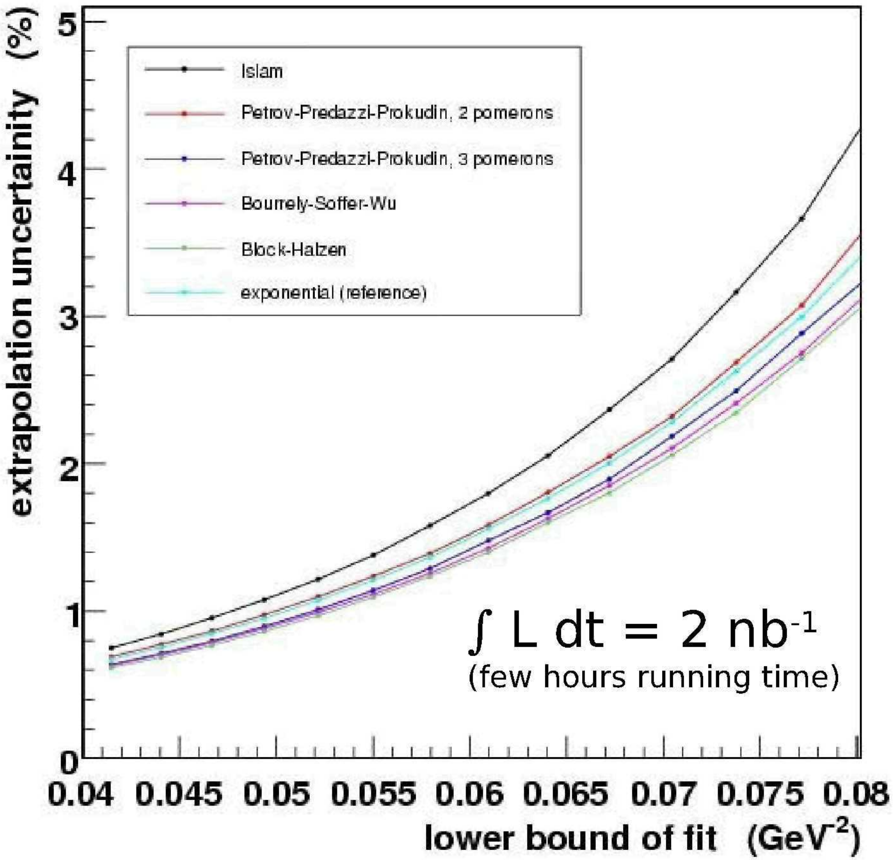
$B(t) = B_0 + B_1 \cdot t + B_2 \cdot t^2$

Extrapolation to the Optical Point ($t = 0$)

(extrapol. - model) / model in $d\sigma/dt |_{t=0}$



Extrapolation uncertainty

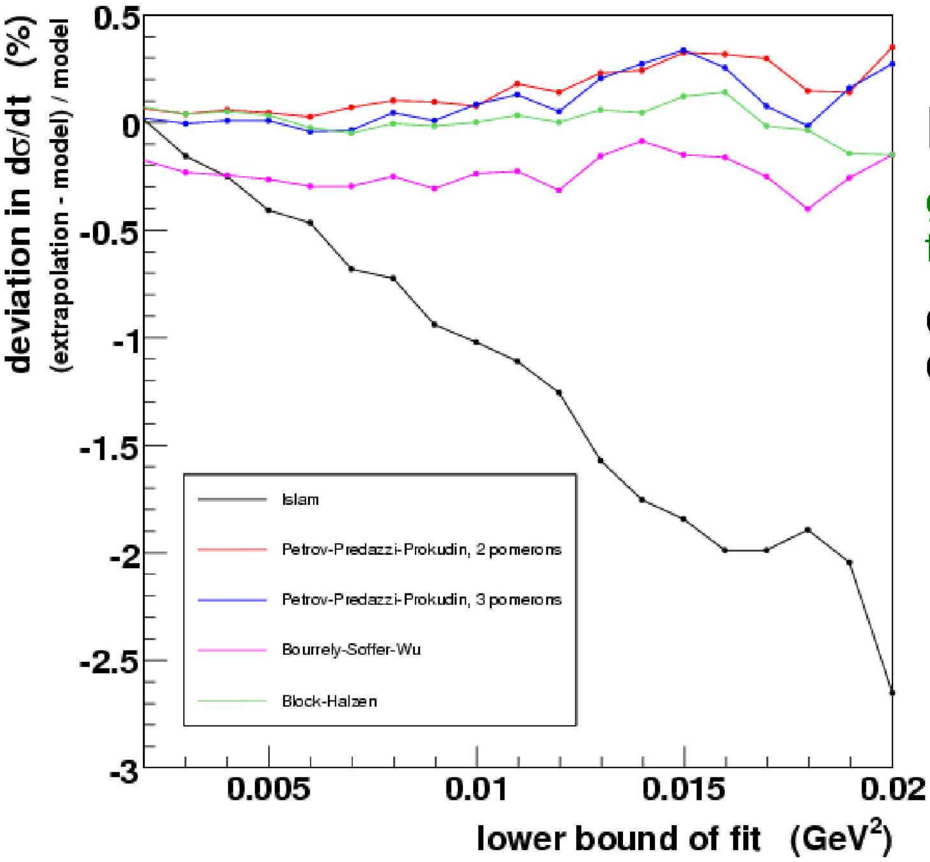


Common bias due to beam divergence : -2%

Spread of most of the models: ±1%

Systematic error due to uncertainty of optical functions: ± 3%

Extrapolation with the Optics $\beta^* = 1540$ m



|t|-acceptance down to 0.0012 GeV^2 →

good lever arm for choosing a suitable fitting function for the extrapolation to t = 0.

Complication:
Coulomb/nuclear interference must be included

For most models: extrapolation within ± 0.2 %.

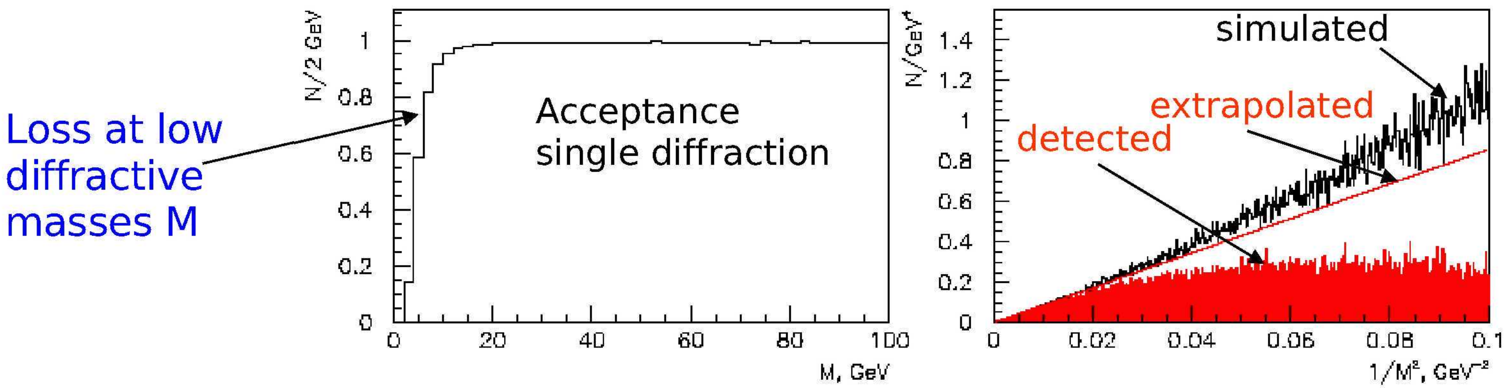
Islam model needs different treatment; to be distinguished in the visible t-range.

Measurement of the Total Cross section

Inelastic Rate (T1/T2) : Trigger Losses

	σ(mb)	losses (mb)	error after extrapolation (mb)
Minimum bias	58	0.06	0.06
Single Diffractive	14	3	0.6
Double Diffractive	7	0.3	0.1
DPE	1	0.2	0.02

Total Inel. **0.8 mb**



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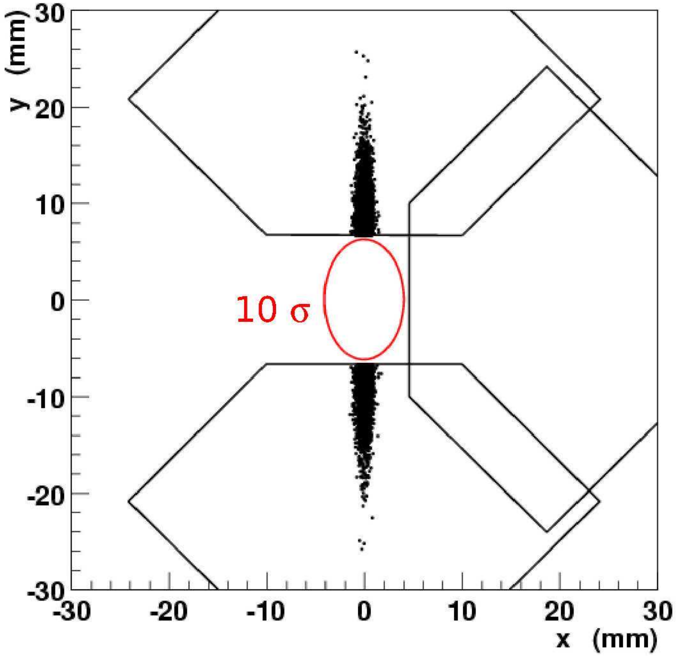
Extrapolation of the elastic cross section to t=0 β=90 (1540) m **≤ 4%** (0.5%)

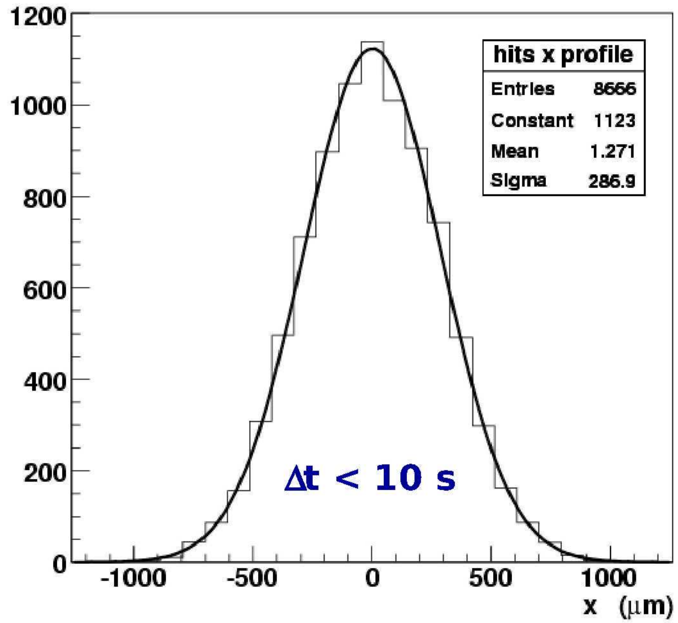
Elastic Rate " **0.6** (0.1) mb

$$\Delta\sigma_{tot}/\sigma_{tot} \approx 5\ \%\ (1\ \%)$$

Measurement of Beam Parameters

- Luminosity measurement (together with σ_{tot}): ±6%
- Beam profile measurement in x-projection at RP220 (elastic scattering)





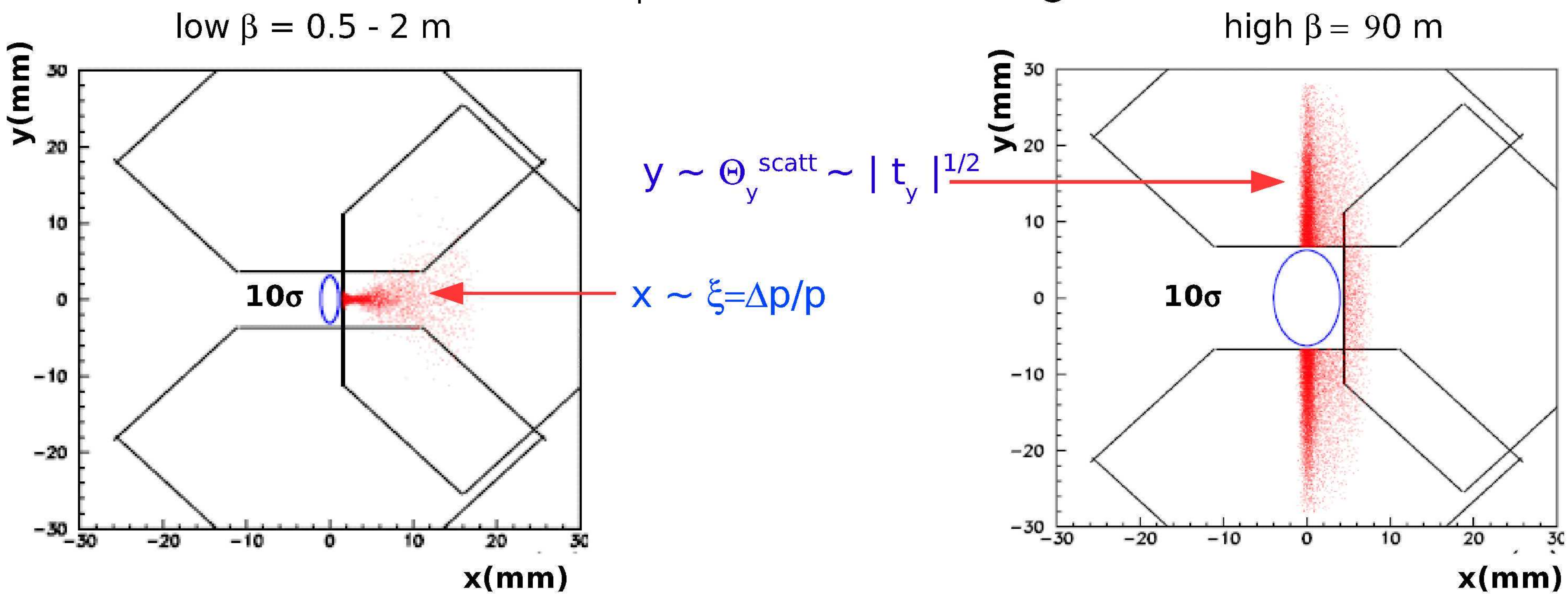
==> beam position measurement at RP220 with precision ~ 1μm every minute
to be compared with the machine's BPMs.

==> horizontal vertex position determination: $x = v_x x^*$

==> vertex distribution (shape and width)
==> assuming round beams: luminosity from beam parameters

Measurement of Diffractive Protons: the principle

Diffractive protons : hit distribution @ RP220

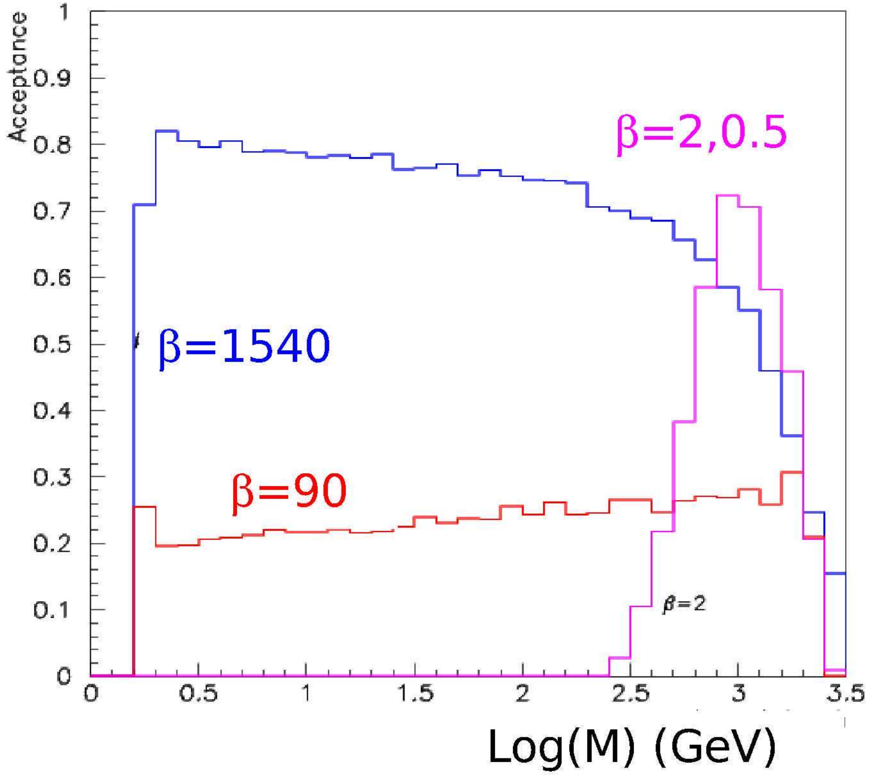


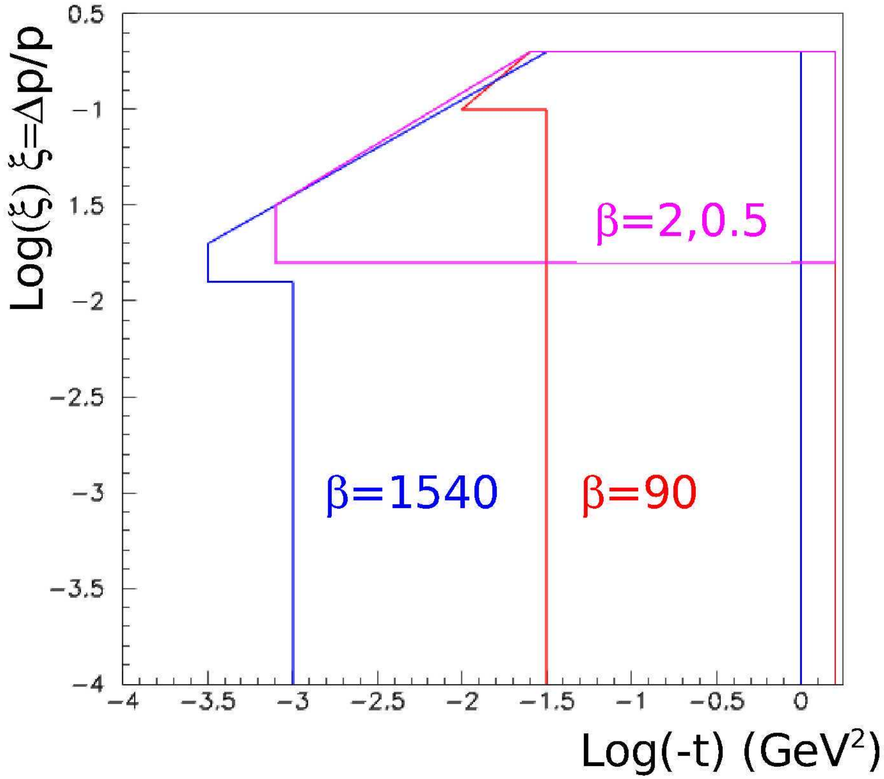
Detect the proton via:

its momentum loss (low β)

its transverse momentum (high β)

Diffractive protons





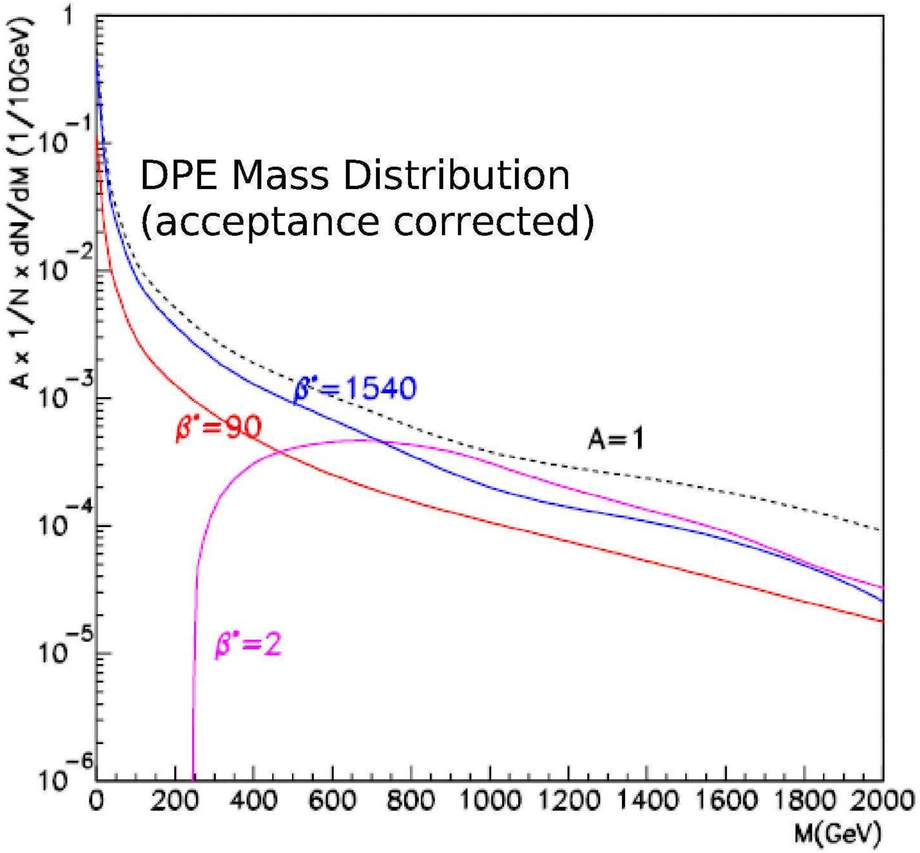
Diffractive protons detected	1-arm (incl. SD)	2-arm (incl. DPE)
	~50%	~30%
	~90%	~80%

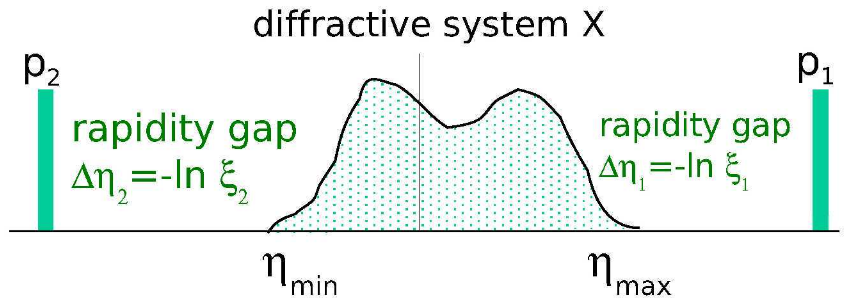
Soft Diffraction

Reconstruction of ξ via protons or rapidity gap ($\Delta\eta = -\ln\xi$):

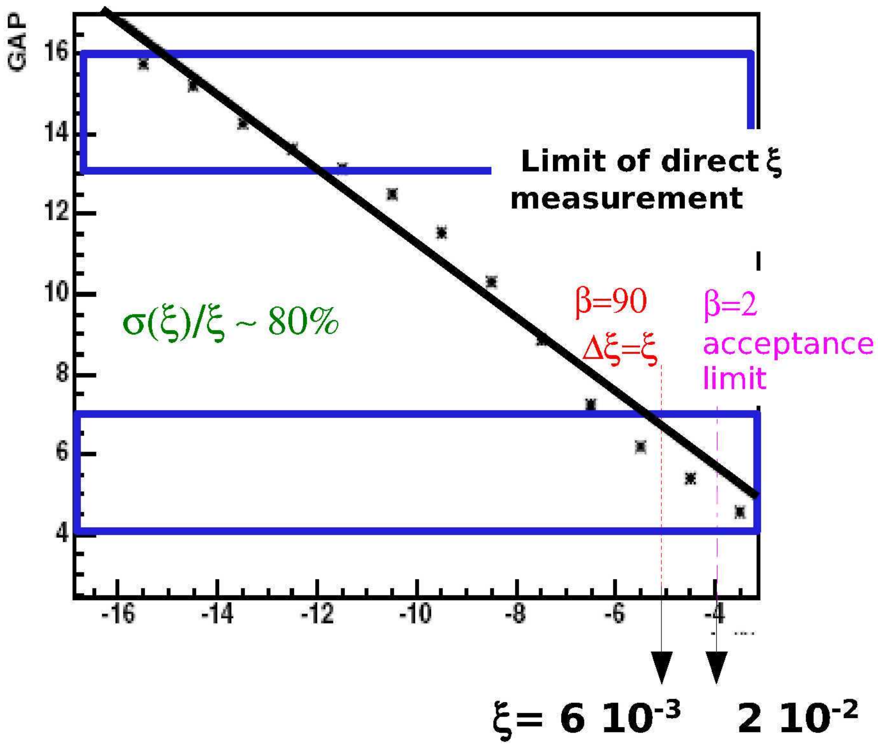
β= 90 m: $\sigma(\xi) \sim 6 \times 10^{-3}$ (without vertex knowledge)

(1540 m: $\sigma(\xi) \sim 9 \times 10^{-3}$)





Gap vs ln (ξ) **T1+T2**



==> various diffractive studies

(Single Diffraction and Double Pomeron Exchange)

To be extended later together with CMS

Summary (I)

TOTEM will be ready for data-taking at the LHC start:

Measure total pp cross-section (and luminosity)
with a precision of 5 % ($\beta^* = 90$ m)
[Ultimate precision : 1%]

Measure elastic scattering in the range $10^{-3} < t < 10$ GeV ^{2}

Soft Diffraction (SD, DPE)

Studies of forward particle production

Prospects for Diffractive and Forward Physics at the LHC

CERN/LHCC 2006-039/G-124
CMS Note-2007/002
TOTEM Note 06-5

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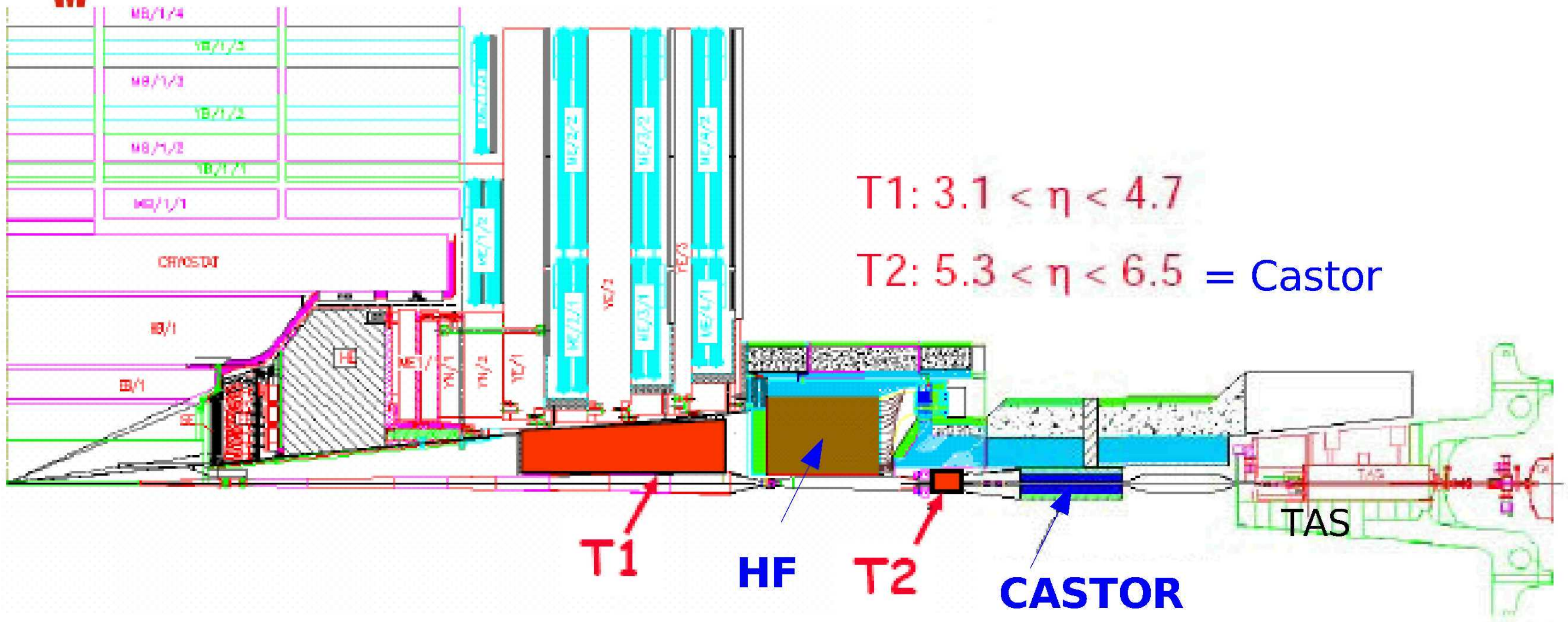
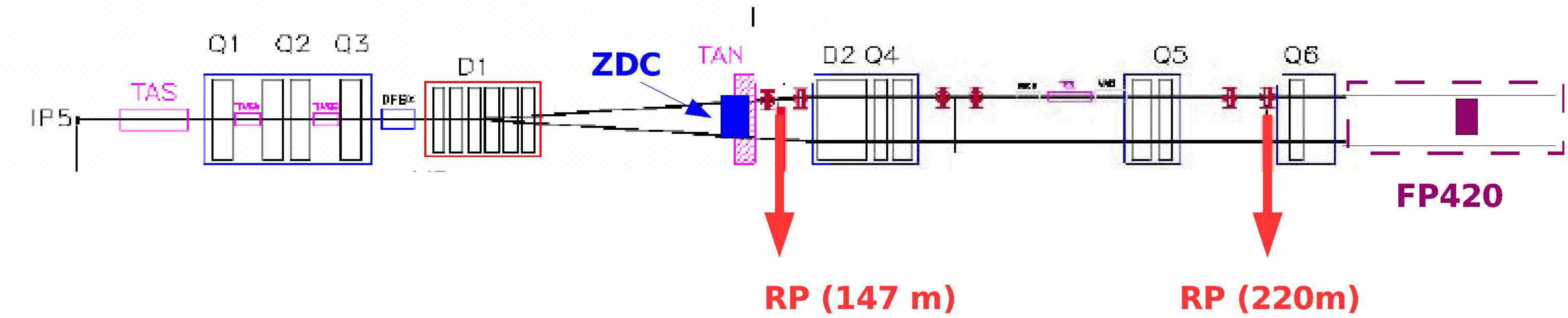
CMS & TOTEM & FP420

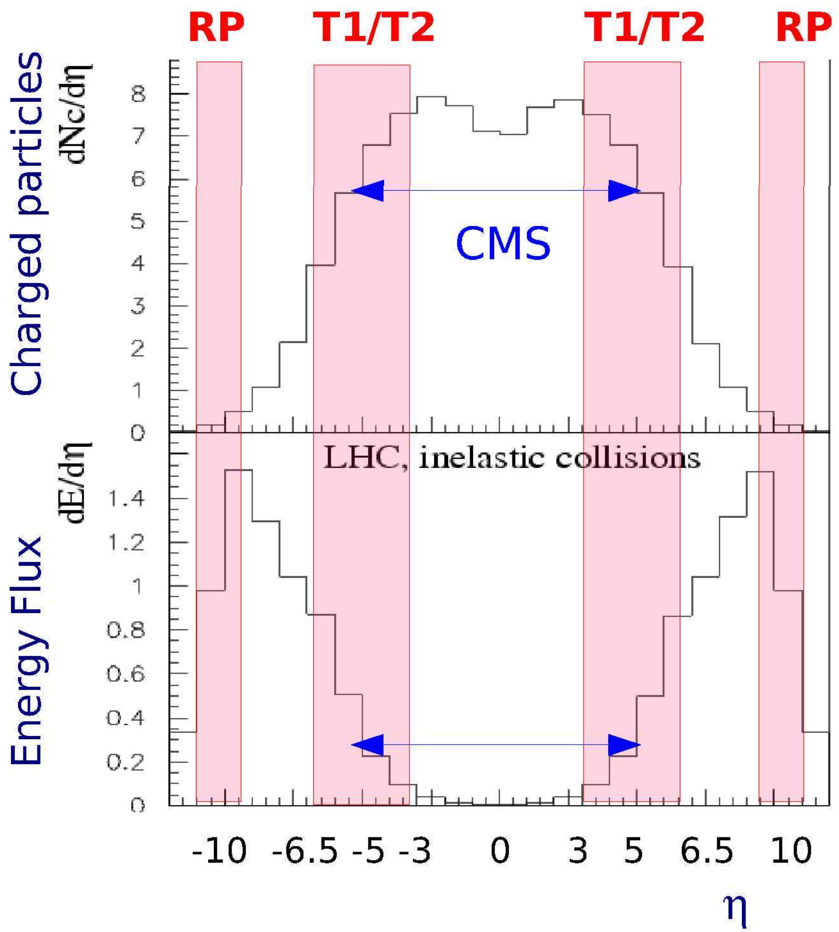




CMS/TOTEM common physics program

Largest coverage in pseudorapidity &

proton detection on both sides



Physics menu

Low Luminosity ($\leq 10^{32}$ cm^{-2}s^{-1}): low & high β^*

- Measure inclusive SD and DPE cross sections:
    - t, M_X dependence
    - Study of topology e.g. rapidity gap
- Measure semi-hard SD and DPE:
    - Onset of jet activity
- Muller-Navelet dijets
- Forward Drell-Yan
- Validation of Cosmic Ray generators

High Luminosity ($> 10^{32}$ cm^{-2}s^{-1}) : low β^*

- Measure SD and DPE in presence of hard scales (dijets, vector bosons, heavy quarks): dPDF, GPD

- $\gamma\gamma$ and γp phyics

High Luminosity ($> 10^{33}$ cm^{-2}s^{-1}) : low β^*

- Discovery physics in central exclusive production
    - SM or MSSM Higgs, other exotic processes

Contents of the common document

Includes important experimental issues in measuring forward and diffractive physics but not an exhaustive physics study

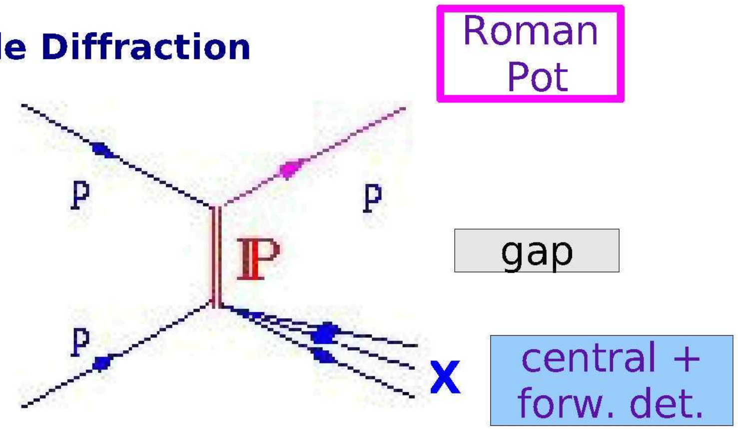
- Detailed studies of acceptance & resolution of the forward proton detectors
- Trigger
- Background
- Reconstruction of kinematic variables

Several exemplary processes are studied in detail

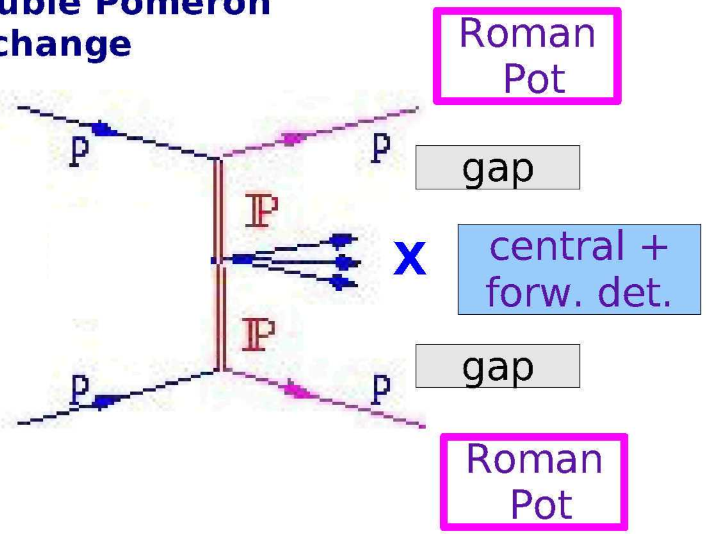
Ch 1: Introduction
Ch 2: Experimental Set-up
Ch 3: Measurement of Forward Protons
Ch 4: Machine induced background
Ch 5: Diffraction at low and medium luminosity
Ch 6: Triggering on Diffractive Processes at High Luminosity
Ch 7: Hard diffraction at High Luminosity
Ch 8: Photon-photon and photon-proton physics
Ch 9: Low-x QCD physics
Ch 10: Validation of Hadronic Shower Models used in cosmic ray physics

Diffraction: Physics Motivation

Single Diffraction



Double Pomeron Exchange



X=anything : dominated by soft physics

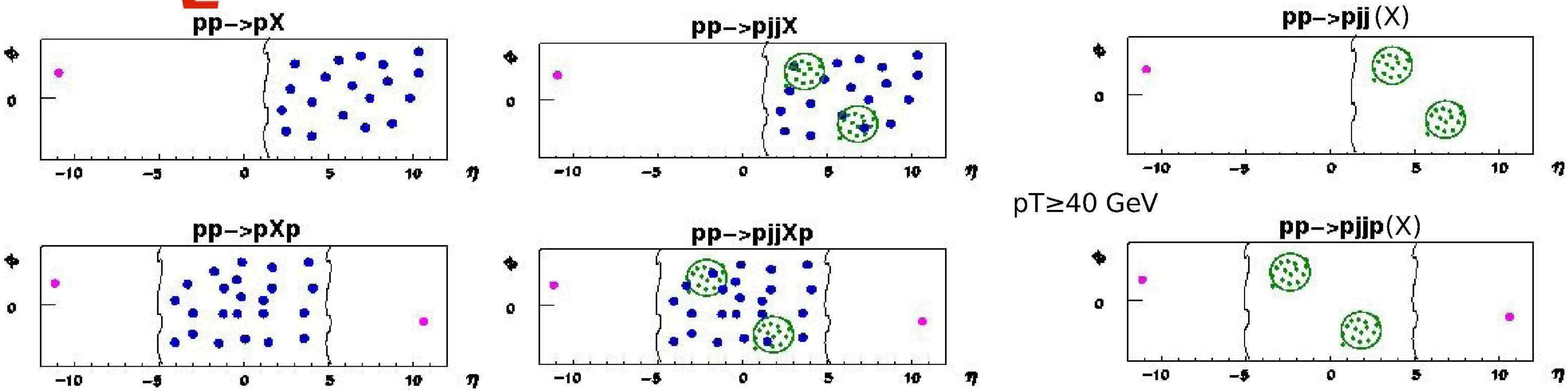
- **Measure fundamental quantities of soft QCD:**
  SD and DPE inclusive cross sections, their s, t, M_X dependences are fundamental parameters of non-perturbative QCD.

- **Contributes to the pile up.**

X includes jets, W's, Z's, Higgs (!): hard processes calculable in pQCD

- **Give info on proton structure (dPDFs and GPDs), QCD at high parton densities, multi-parton interactions, discovery physics**

Running scenario



soft diffraction | (semi)-hard diffraction | hard diffraction/exclusive processes

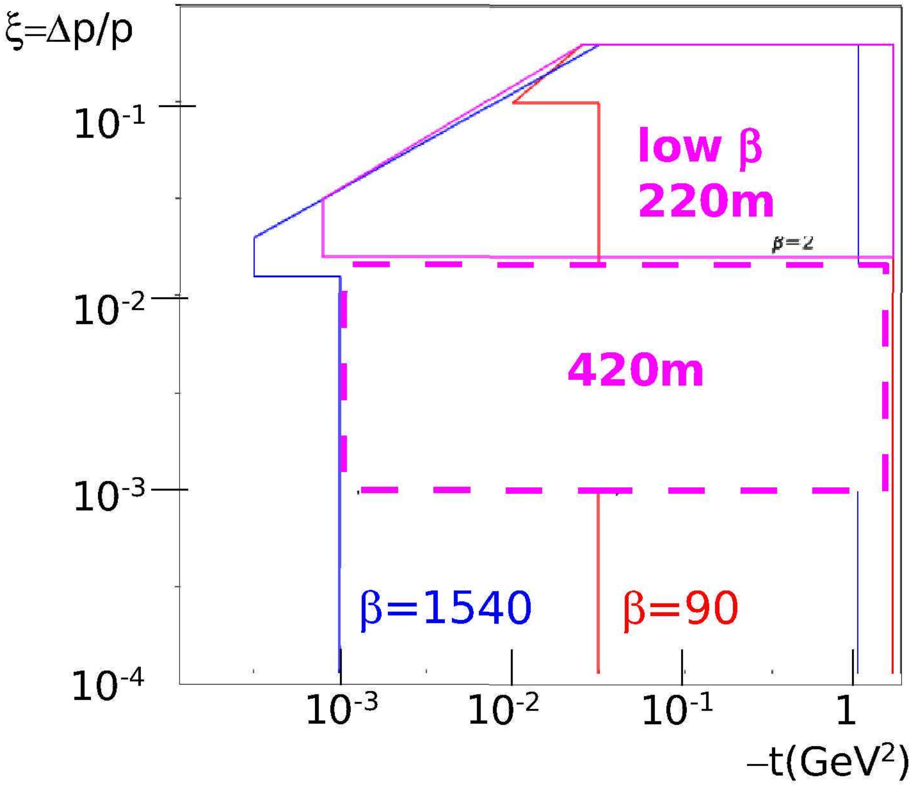
← Cross section | Luminosity →

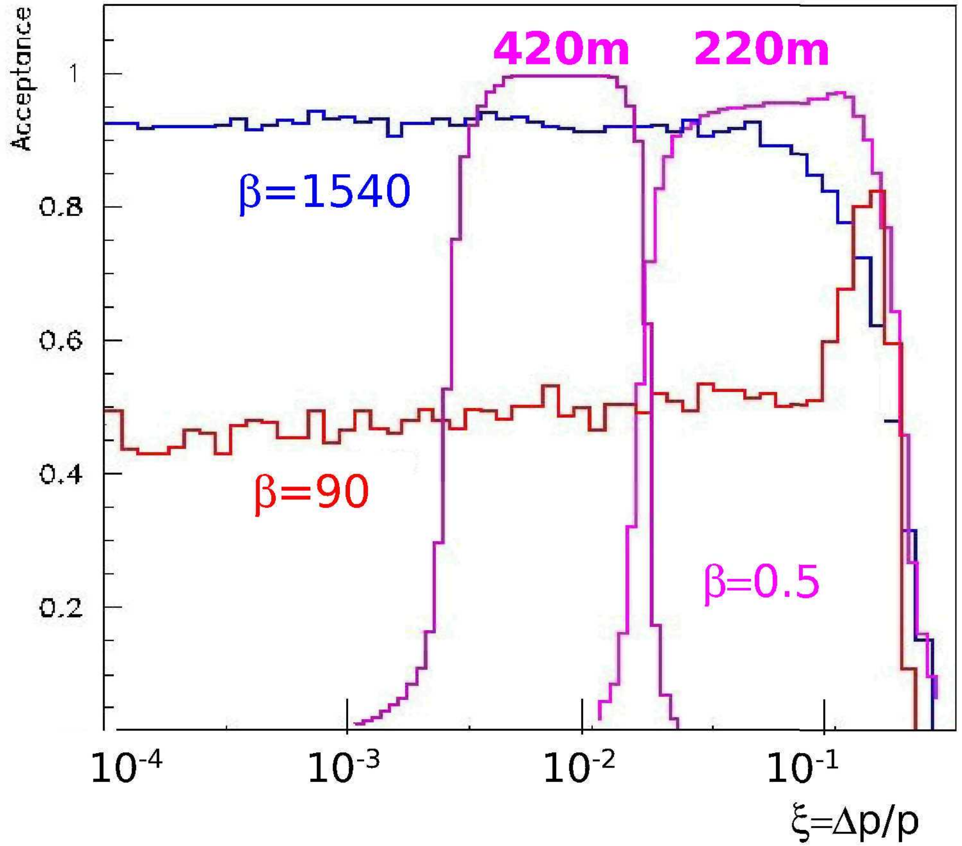
σ	mb	μb		nb
L ($cm^{-2} s^{-1}$)	10^{28}	10^{30}	10^{32}	10^{34}
β (m)	1540	90	2	0.5
	TOTEM runs		Standard runs	

The accessible physics depends on : luminosity

β (different proton acceptance)*

Measurement of Forward Protons: Acceptance





Measurement of Forward Protons: momentum resolution (low β)

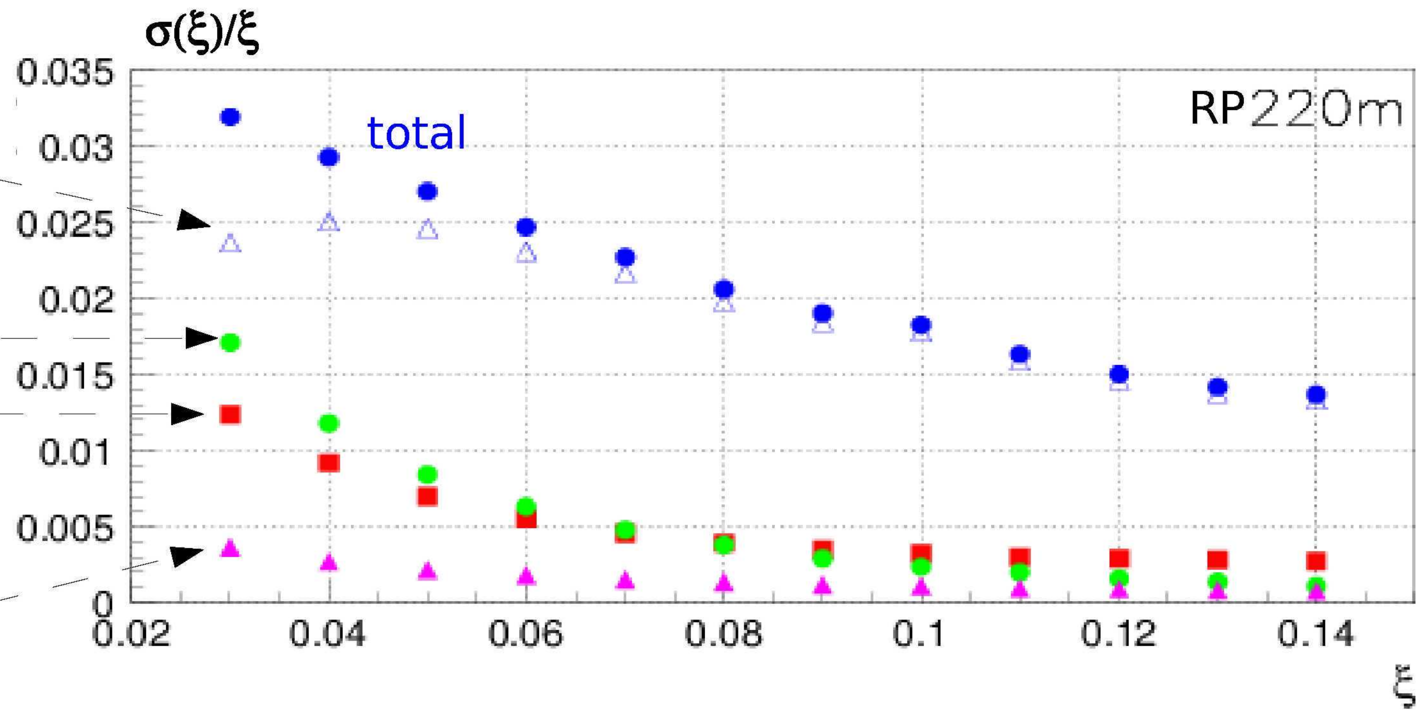
Individual contribution to the resolution:

Detector resolution (10μm)

Beam position res. (50μm)

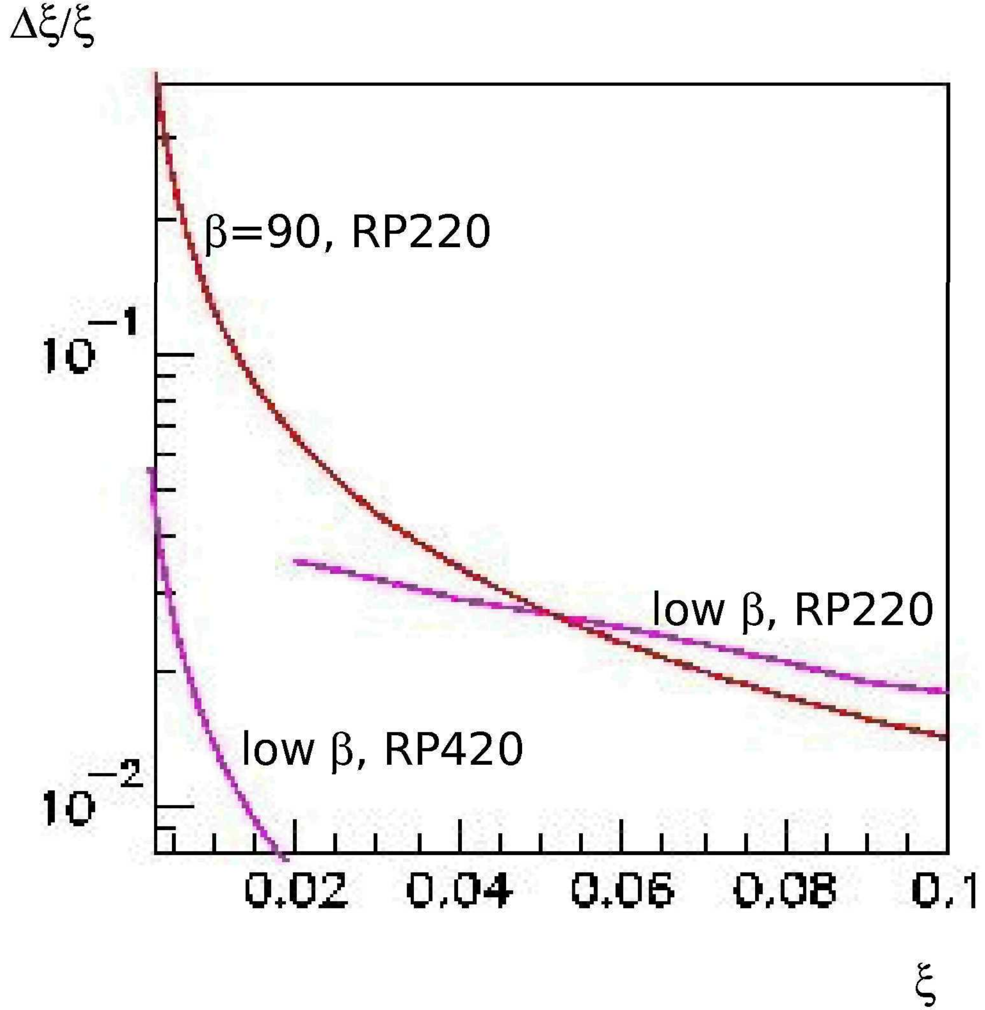
Vertex smear. (10μm)

relative beam energy spread (10^{-4})



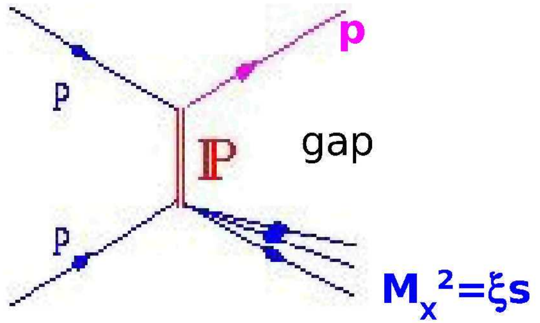
Studies available also for β=1540, 90, all RP stations

Measurement of Forward Protons: momentum resolution

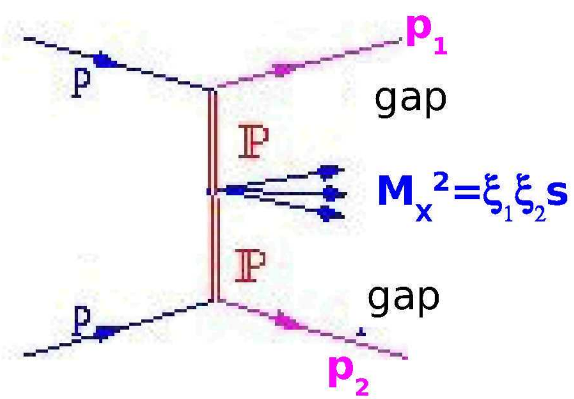


Diffraction at low luminosity (<10^{32} cm^{-2} s^{-1}): soft diffraction

Single Diffraction



Double Pomeron Exchange



Inclusive cross sections and their *t, M_X* dependence

Topology of the events

Measure ξ and central Mass via:

- proton(s)
- rapidity gap relation $\Delta\eta=-\ln\xi$
- calorimeters

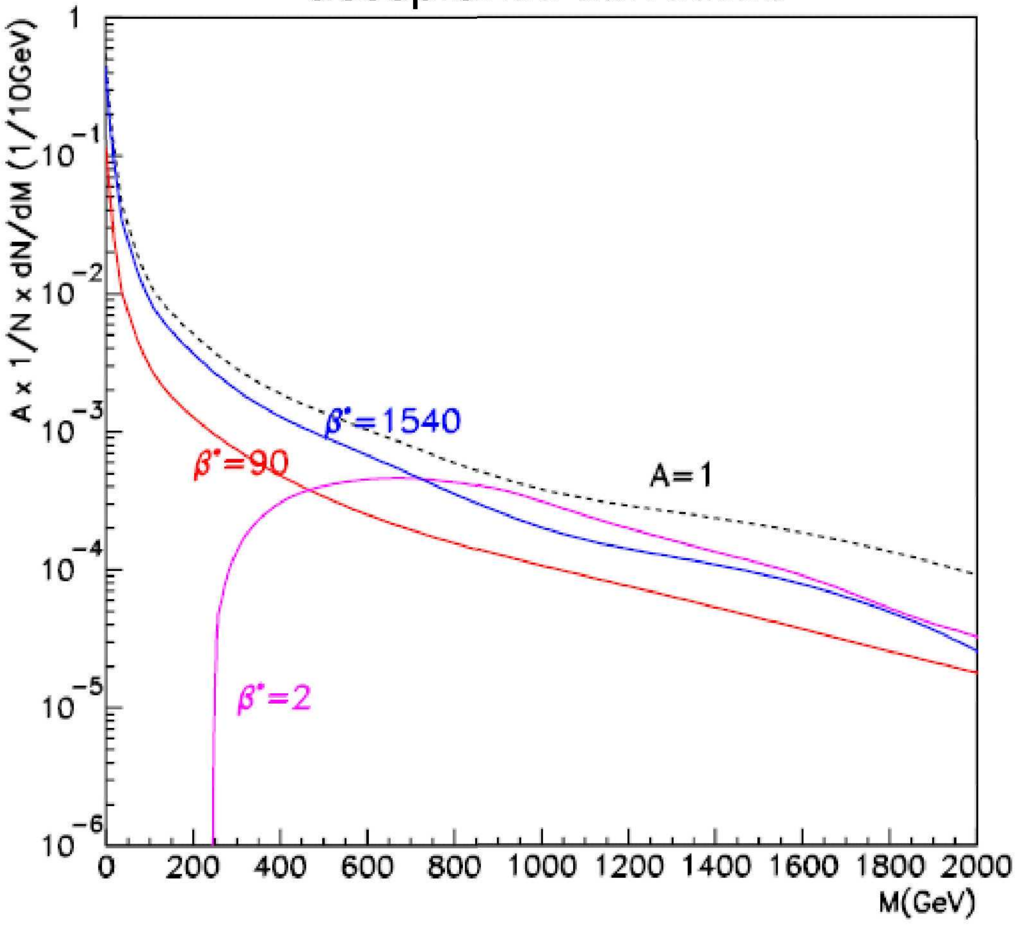
$$\xi=\sum_i E^i_T \exp(\mp\eta_i)/\sqrt{s}$$

Wide range t, ξ acceptance with special optics

These processes contribute to the pile-up at high luminosity

Diffraction at low luminosity: soft diffraction (DPE)

Differential Mass distribution, acceptance corrected



Number of event collected in a few days

β=90m ∫Ldt = 0.3 (pb^{-1}) :

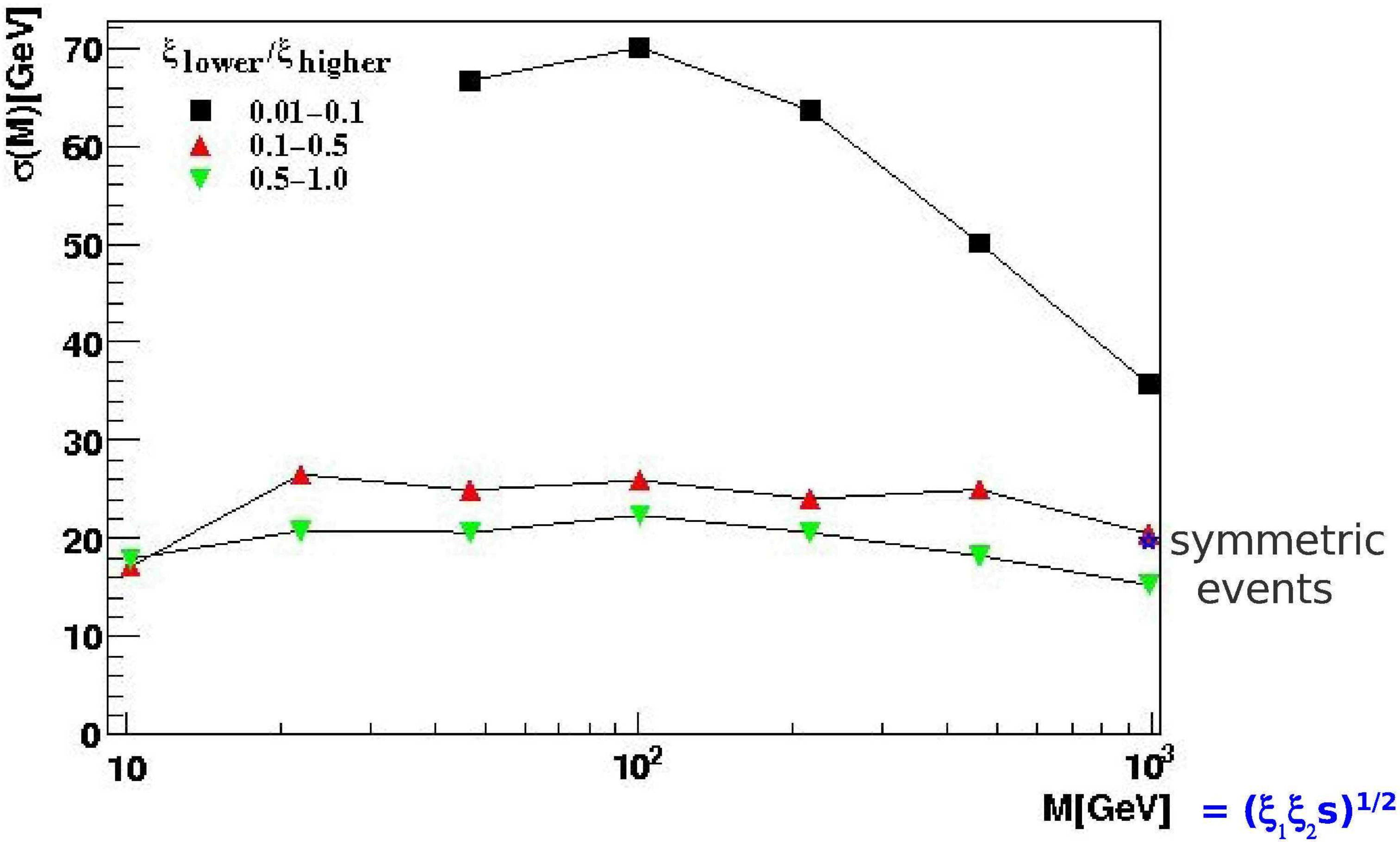
1<M<2000 GeV N ~ $6x10^7$

β=2m ∫Ldt = 10(pb^{-1}) :

M>300 GeV N ~ 10^8

Diffraction at low luminosity: DPE Central Mass Resolution

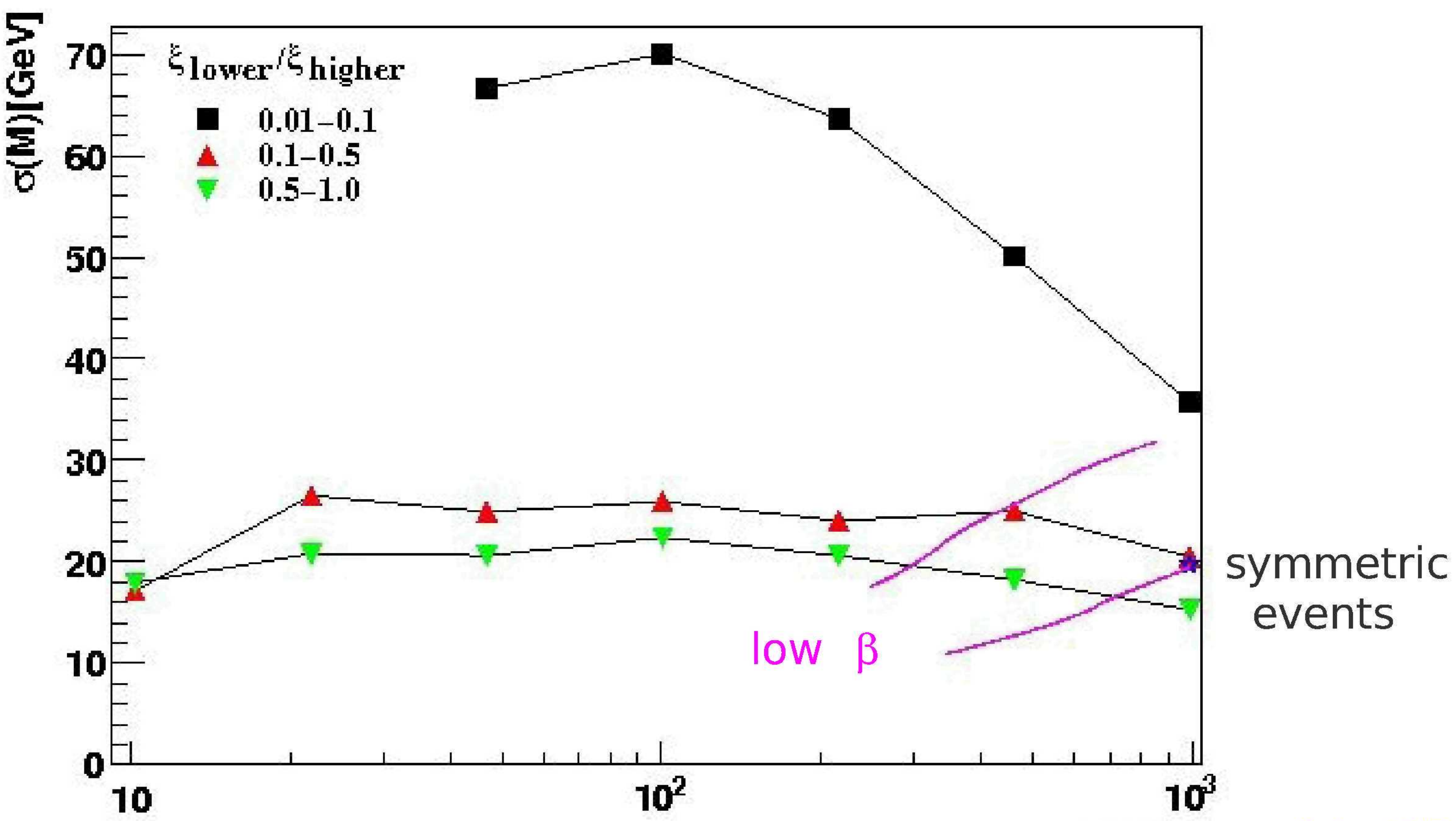
β=90m RP220



$= (\xi_1\xi_2 s)^{1/2}$

Diffraction at low luminosity: DPE Central Mass Resolution

β=90m RP220

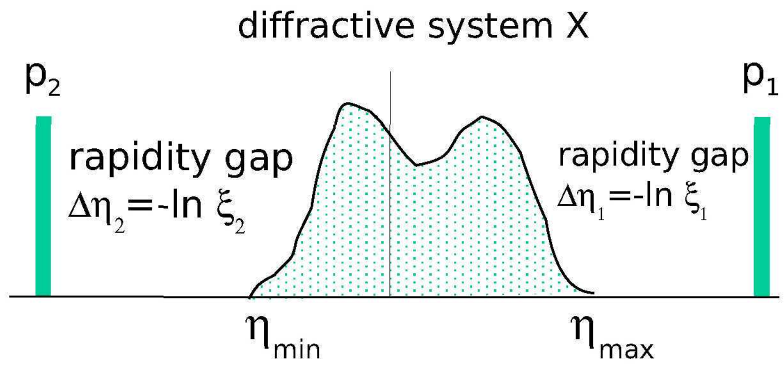


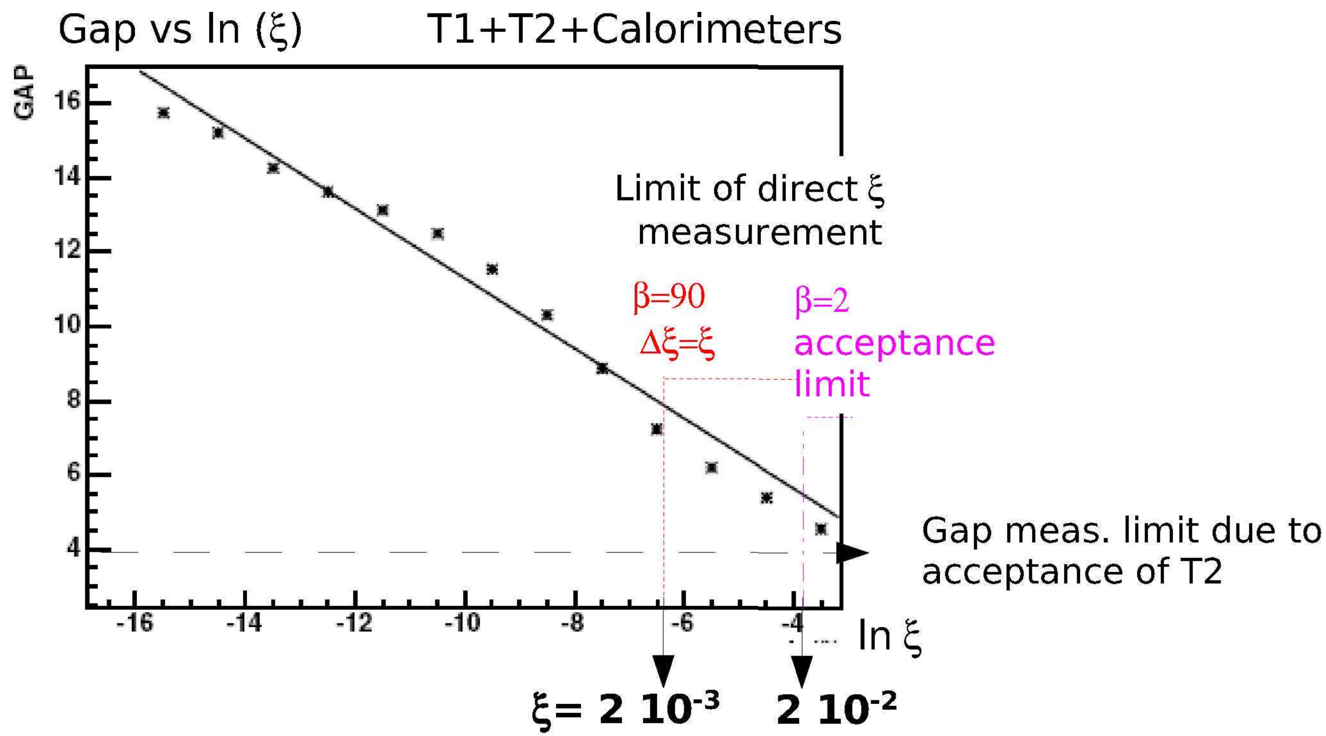
$= (\xi_1 \xi_2 s)^{1/2}$

Diffraction at low luminosity: rapidity gaps

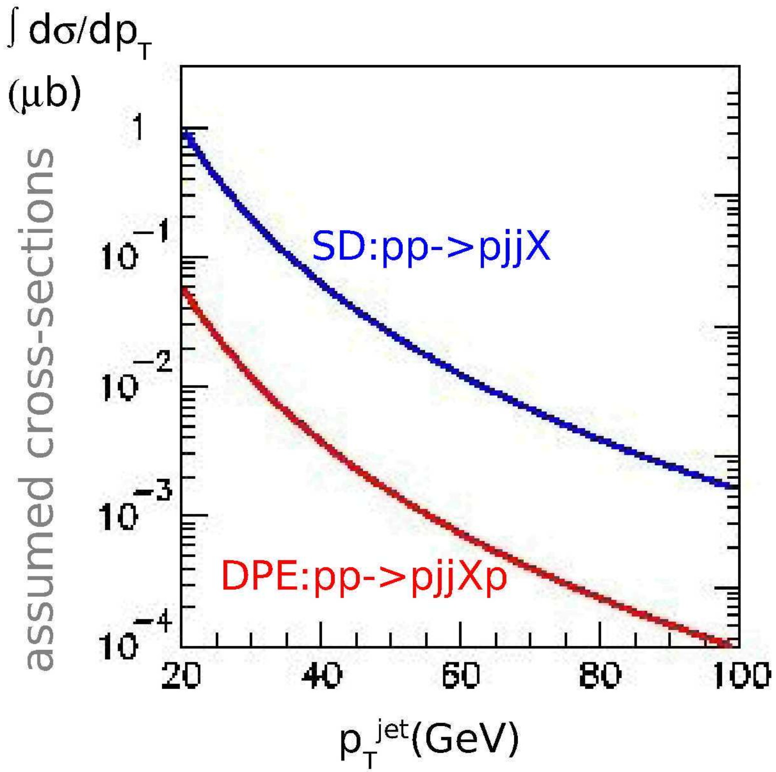
Measure ξ via rapidity gap: $\Delta\eta=-\ln\xi$

Achieved precision: $\sigma(\xi)/\xi \sim 80\%$





Diffraction at low luminosity: semi-hard diffraction



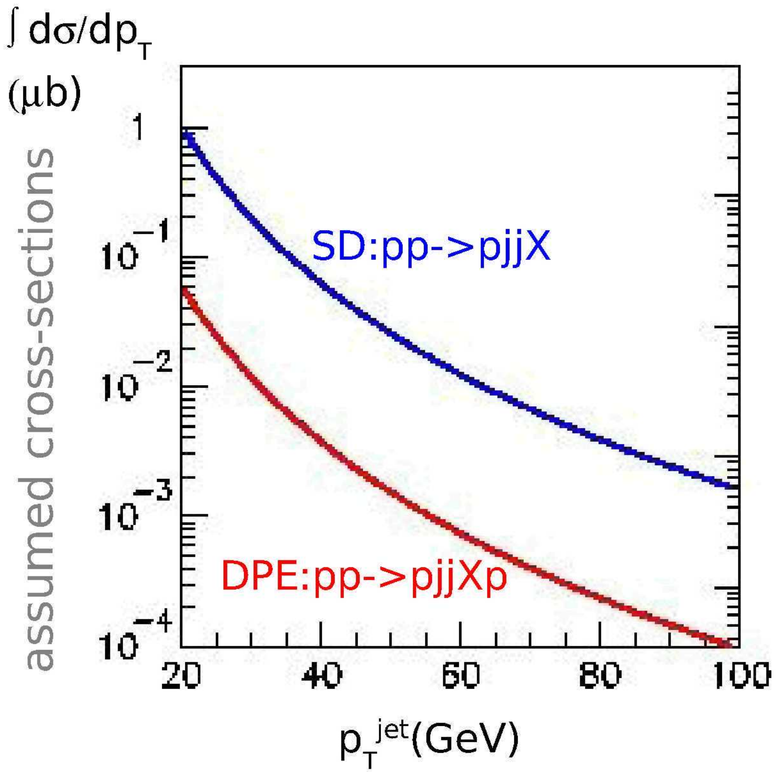
Measure the cross sections and their *t, M_X, p_T^{jet}* dependence

Topology of the events:
for example exclusive vs inclusive jet production

In addition to the previous methods,
ξ and central mass can be determined from calorimeter information:

$\xi = \sum_i E^i_T e^{\mp\eta i}/\sqrt{s}$ $\sigma(\xi)/\xi \sim 40\%$

Diffraction at low luminosity: semi-hard diffraction



		N event collected [acceptance included]
β=90	$\int Ldt$ = 0.3 (pb^{-1})	
SD:	pT>20 GeV	$6x10^4$
DPE:	"	2000
β=2	$\int Ldt$ = 100 (pb^{-1})	
SD:	pT>50 GeV	$5x10^5$
DPE:	"	$3x10^4$

Experimental issues in selecting diffractive events at High Luminosity

- Trigger is a major limiting factor for selecting diffractive events
- Background from non-diffractive events that mimic diffractive events because of protons from pile-up events

Trigger

- CMS trigger thresholds (jets) for nominal LHC running too high for diffractive events
- Use information of forward detectors to lower CMS jet trigger thresholds
- The CMS trigger menus now foresee a **dedicated diffractive trigger stream with 1% of the total bandwidth on L1 and HLT** (1 kHz and 1 Hz)

Luminosity $[cm^{-2}s^{-1}]$	# Pile-up events per bunch crossing	L1 2-jet rate [kHz] for $E_T > 40$GeV per jet	Total reduction needed	Reduction when requiring track in RP detectors at 220 m	
					$\xi < 0.1$
1×10^{32}	0	2.6	2	370	
1×10^{33}	3.5	26	20	7	15
2×10^{33}	7	52	40	4	10

single-sided 220m condition without and with cut on ξ

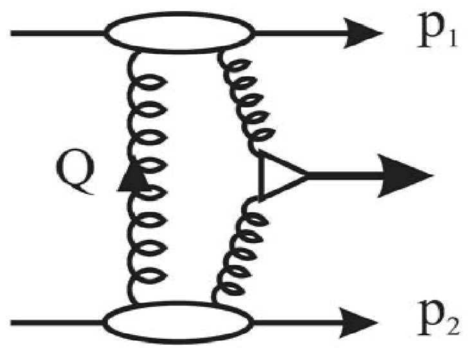
Achievable total reduction: (single-sided 220m) x 2 (jet iso) x 2 (2 jets same hemisphere as p)

L1 conditions on RP detectors provides a rate reduction sufficient to lower the 2-jet threshold to 40 GeV per jet AND being compatible with the CMS L1 bandwidth limits for luminosities up to 2x 10^{33} cm^{-1} s^{-1}

Much less of a problem is triggering with muons, where L1 threshold for 2-muons is 3 GeV

Trigger: Higgs

Central exclusive production pp->pHp with H (120GeV)->bb

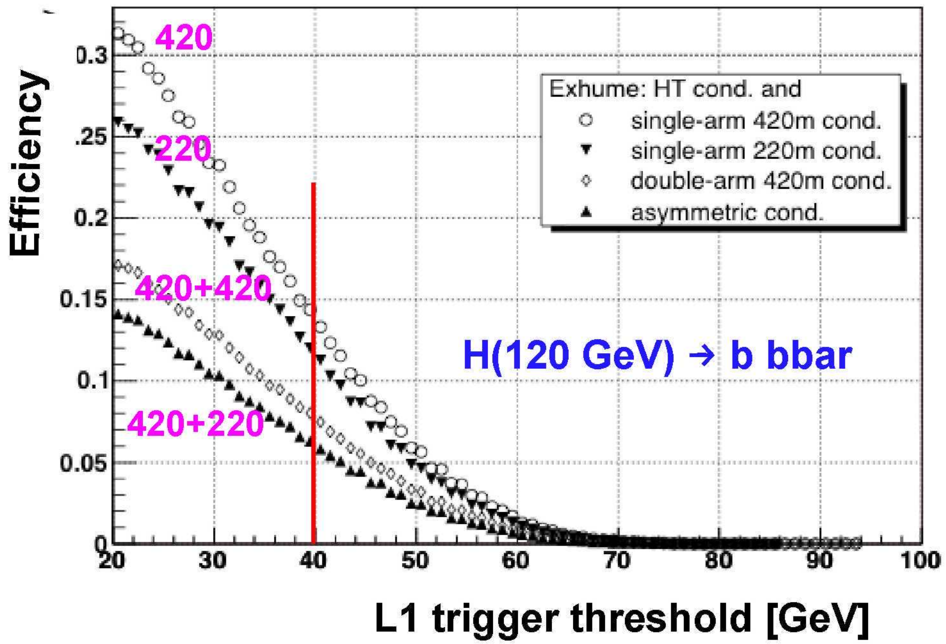


- In non-diffractive production hopeless, signal swamped with QCD dijet background
- Selection rule in CEP (central system is $J^{PC} = 0^{++}$ to good approx) improves S/B for SM Higgs dramatically
- In certain MSSM scenarios the signal cross section is three order of magnitude higher than for the SM case

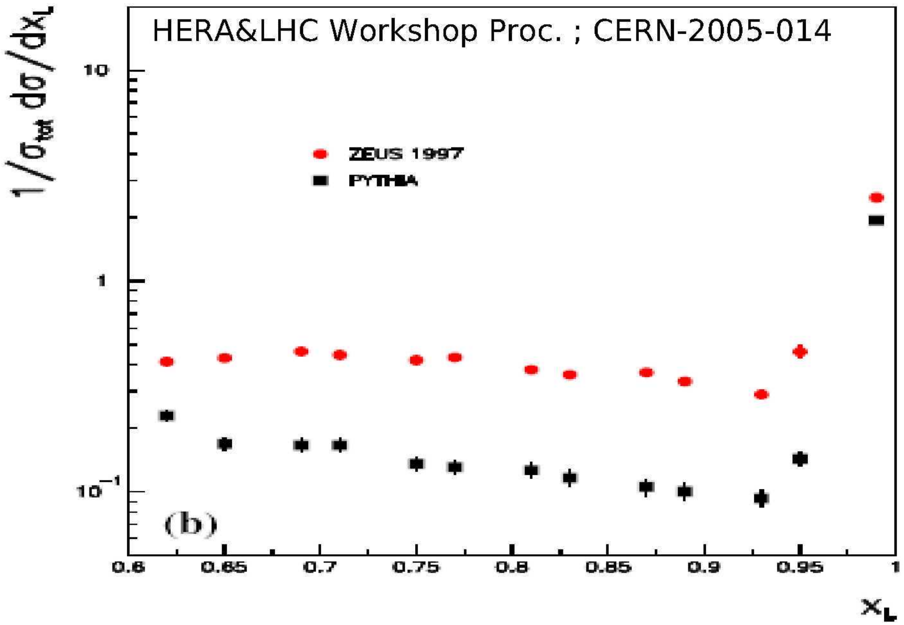
Level-1:
~12% efficiency with 2-jets (E_T>40GeV) & single-sided 220 m condition

HLT: Jet trigger efficiency **~7%**
To stay within 1 Hz output rate, needs to either prescale b-tag or add 420 m detectors in trigger

Additional **~10%** efficiency by introducing a 1 jet & 1μ(40GeV, 3GeV) trigger condition



Pile-up background



Number of PU events with protons within acceptance of near-beam detectors on either side:

~2 % with p @ 420m

~6 % with p @ 220m

Translates into a probability of obtaining a fake DPE signature caused by protons from PU:

lumi	$\langle N^{PU} \rangle$	420+420	220+220	220+420	Total
$1 \cdot 10^{33}$	3.5	0.003	0.019	0.014	0.032
$2 \cdot 10^{33}$	7.0	0.008	0.052	0.037	0.084

Eg at 2x 10^{33} $cm^{-2}s^{-1}$ -> fake DPE signature =10% -> independent of the type of signal.

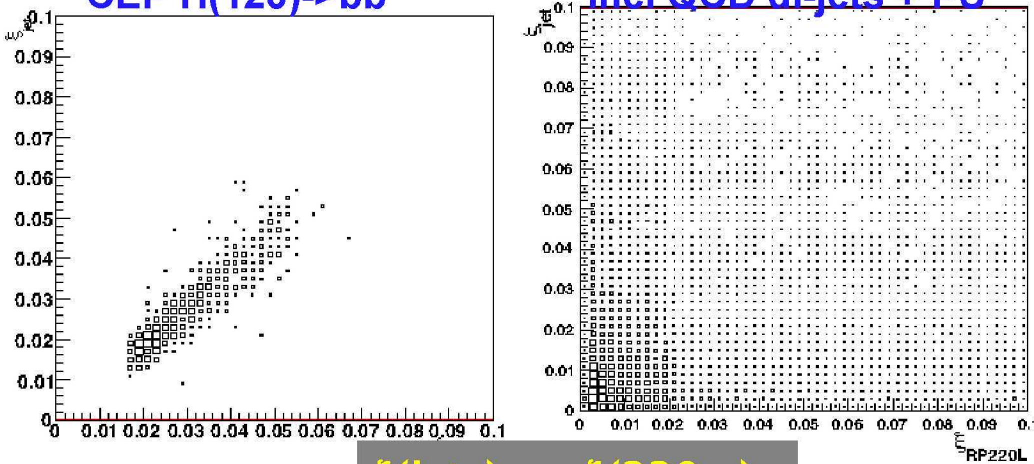
Depends critically on the leading proton spectrum at the LHC which in turn depends on size of soft rescattering effects (rapidity gap survival factor) !

Pile-up background

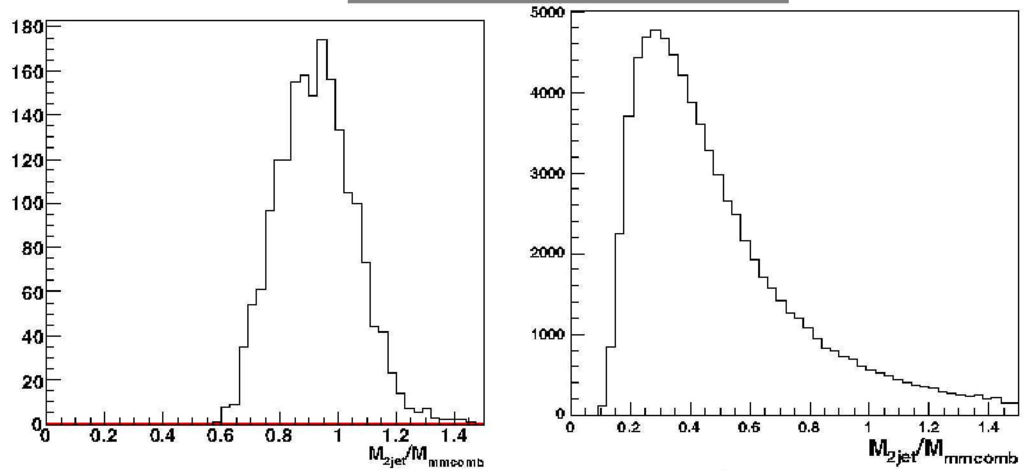
Can be reduced by:

Requiring correlation between
ξ, M measured in the central detector and
ξ, M measured by the near-beam detectors

Fast timing detectors that can determine whether the protons seen in the near-beam detector came from the same vertex as the hard scatter (currently R&D project)



ξ(jets) vs ξ(220m)



M(2-jets)/M(p's)

CEP of **H(120 GeV) → b bbar:**

Possible to retain O(10%) of signal up to 2×10^{33} cm^{2} s^{1} in a special forward detectors trigger stream

S/B in excess of unity for a SM Higgs and up to 1000 for a MSSM Higgs appears achievable

Forward Physics

Forward particle & energy flows

Production cross sections of neutral particles

Validation of hadronic air shower models

New phenomena (DCC...?)

Low-x QCD

Proton structure at low-x, Multi-parton scattering, Parton saturation, Colour Transparency

Study of the underlying event at the LHC
(crf P. Bartalini talk)
Multiple parton-parton interactions and rescattering effects accompanying a hard scatter
Closely related to gap survival and factorization breaking in hard diffraction

Photon-photon and photon-proton physics

Forward particle & energy flow

Measure:

Rapidity distribution (charged, neutral)

Energy distribution

Multiplicity & correlations

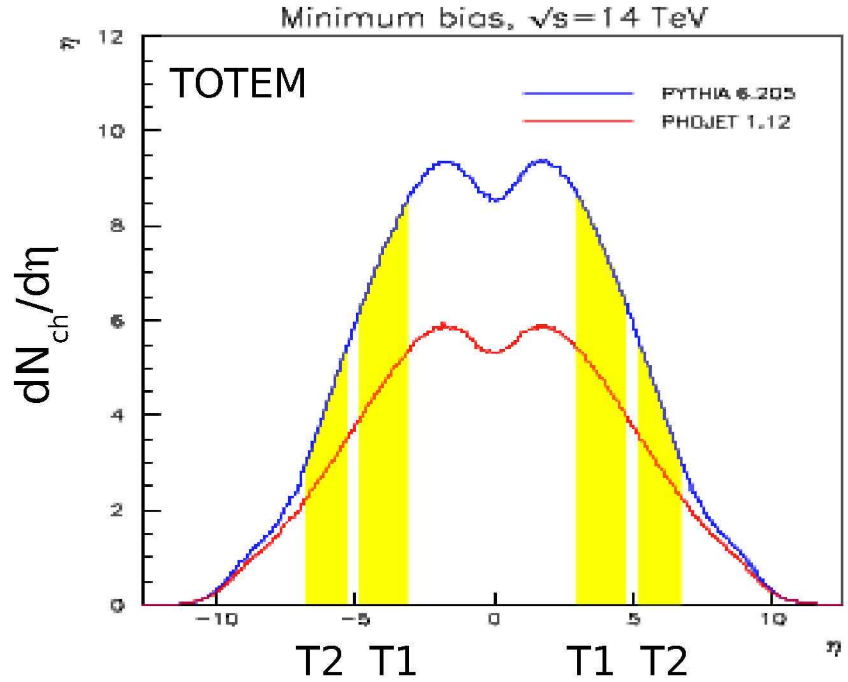
↓

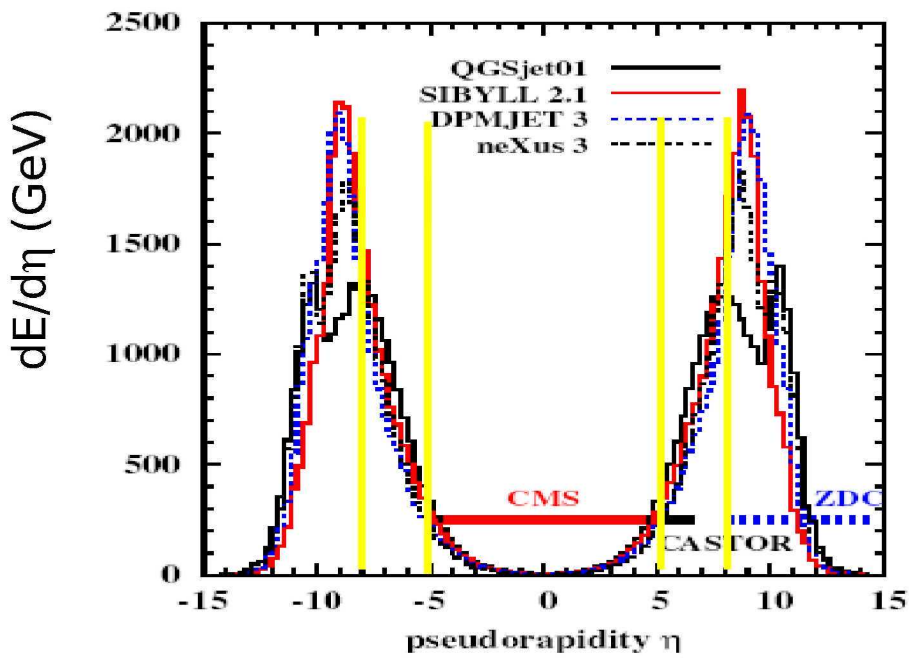
study long-range rapidity correlations and fluctuations of multiplicity

observe exotic phenomena? (DCC,....)

min bias physics

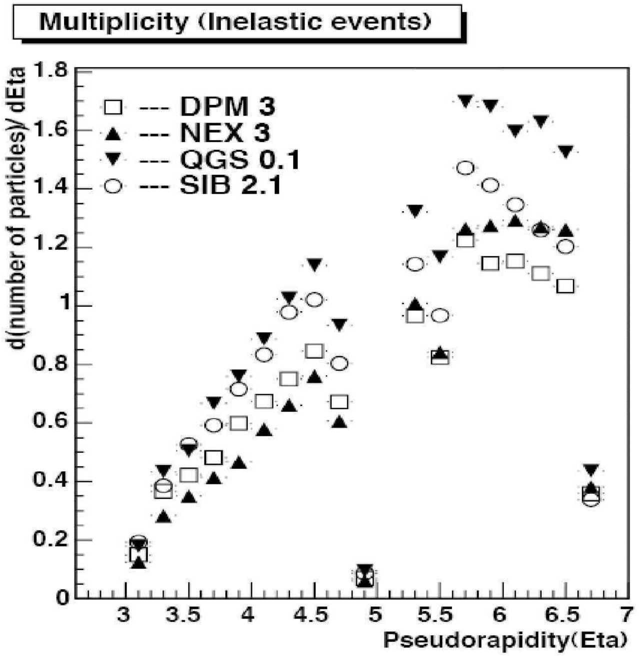
relevant for Cosmic Ray interpretation

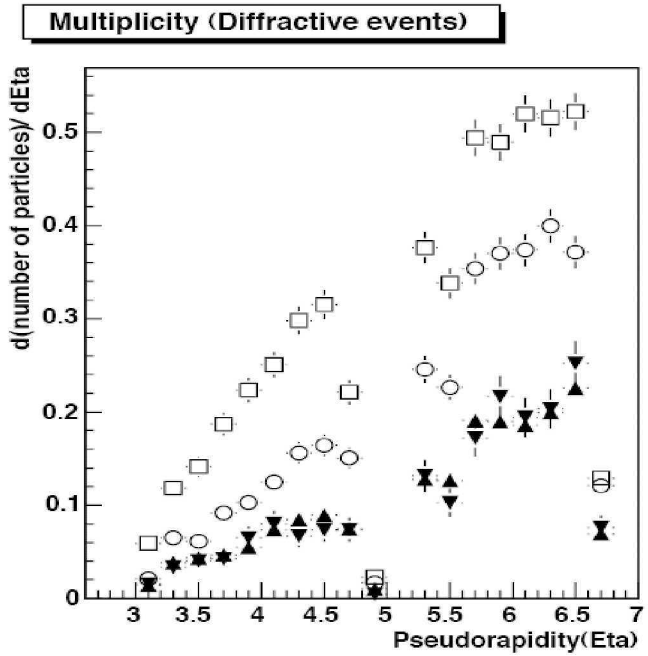




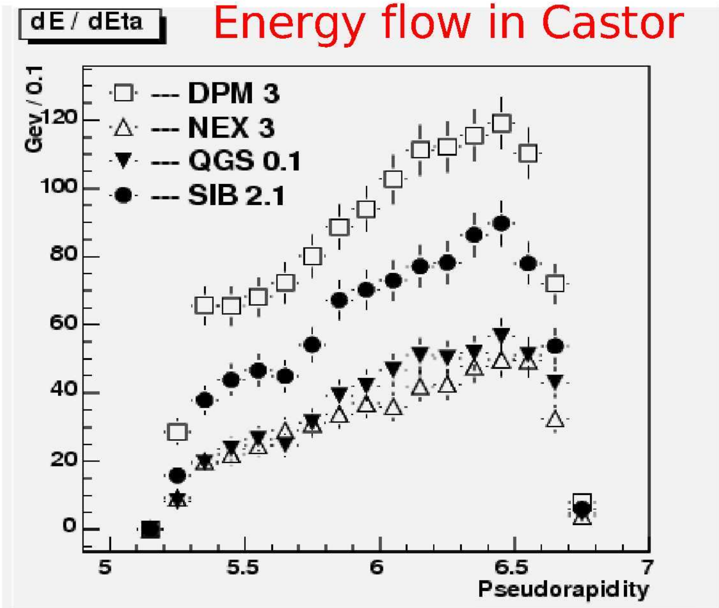
Forward particles & energy flow

Charged tracks in T1/T2





Energy flow in Castor



14 TeV => 10^{17} eV

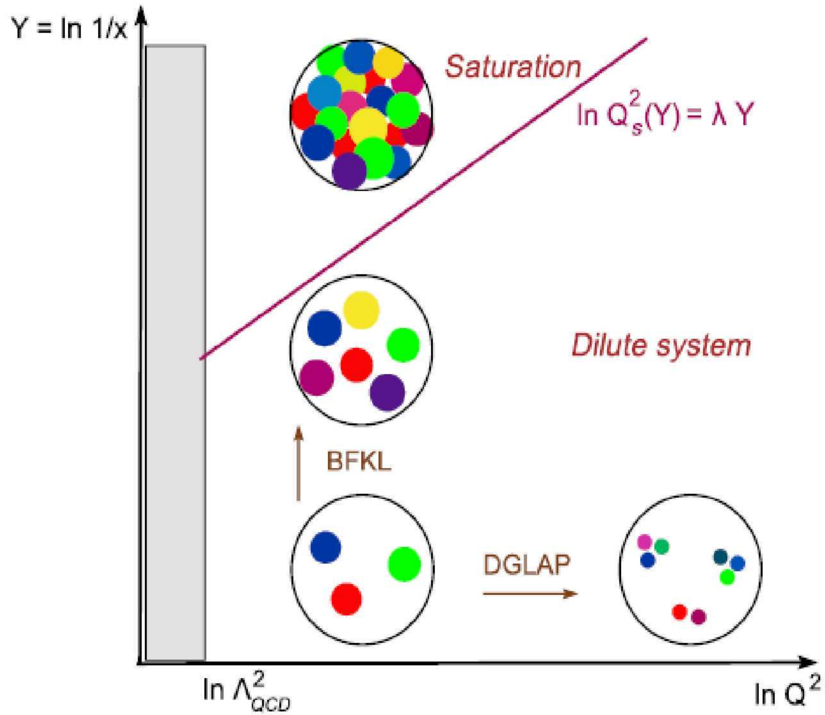
10^4 CR events / km^2 year =>

10^4 events /s @ LHC ($L=10^{29}$ cm^{-2} s^{-1})

Low-x QCD

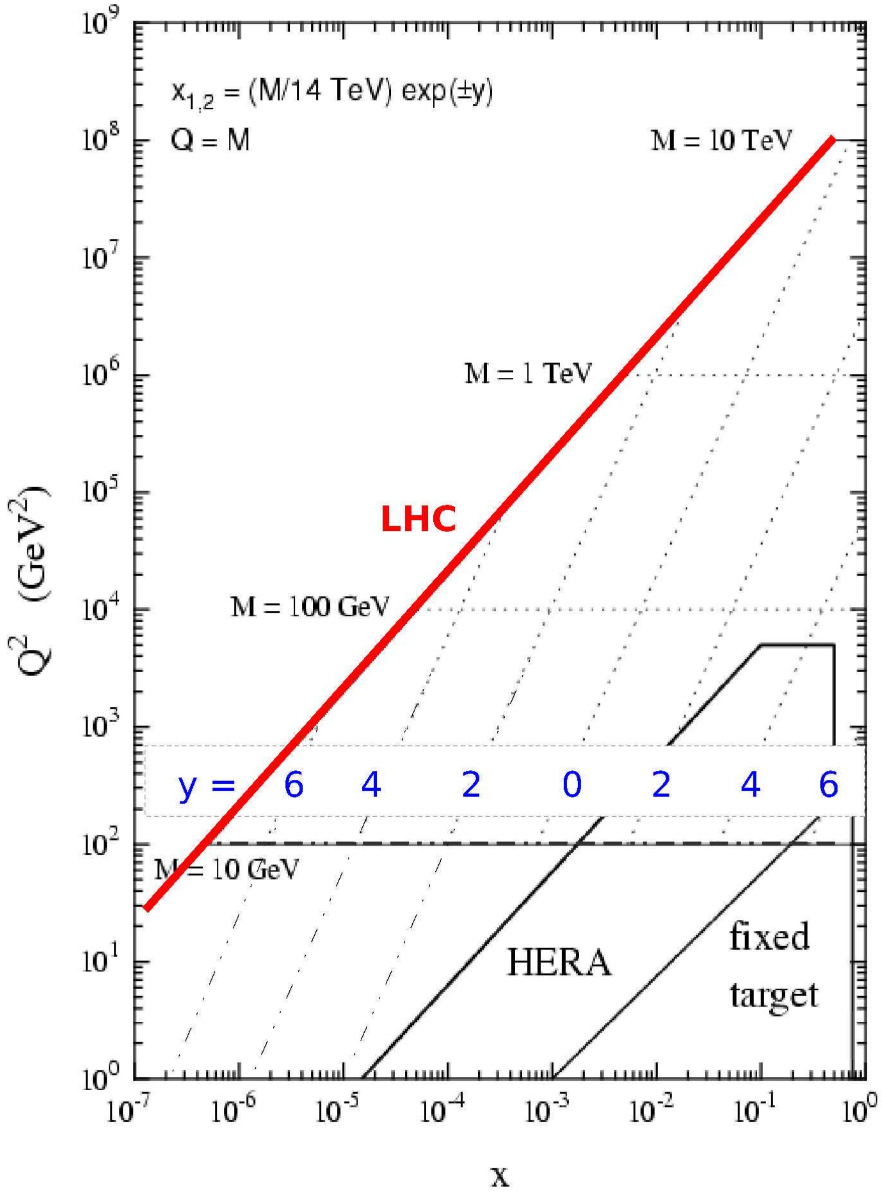
Quark and gluon density (PDF)
at small x_{Bj} (parton fractional momentum)

Pioneered by HERA, at LHC extend to lower x

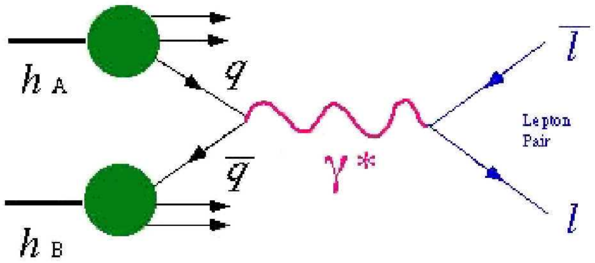


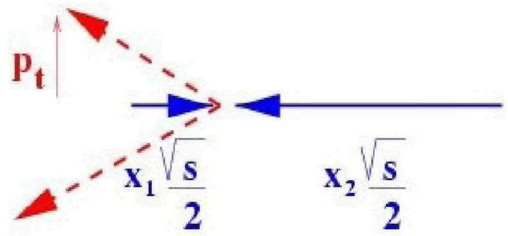
Direct information on PDF structure and evolution provided by:

- jets (sensitive to gluon density)
- Drell-Yan pairs (sensitive to quark density)

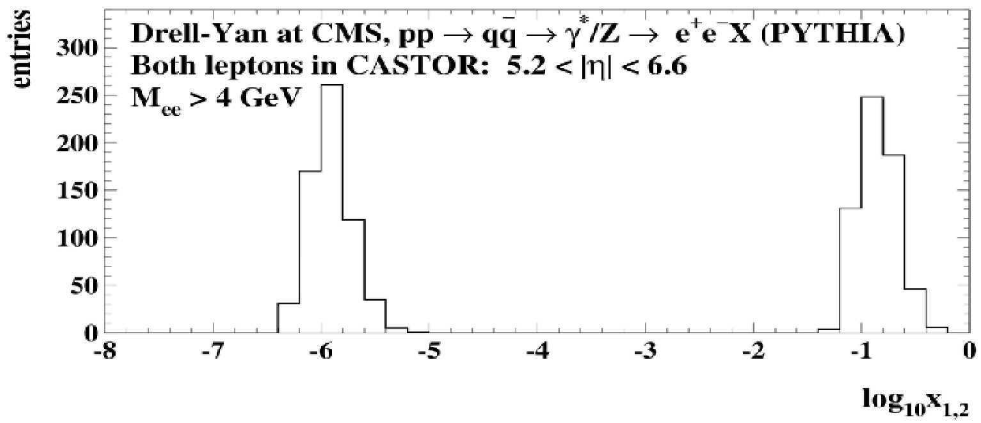


Forward Drell-Yan





Sensitive to low-x_{BJ} quarks density in proton in case of large imbalance of fractional momenta $x_{1,2}$ of leptons, which are then boosted to large rapidities

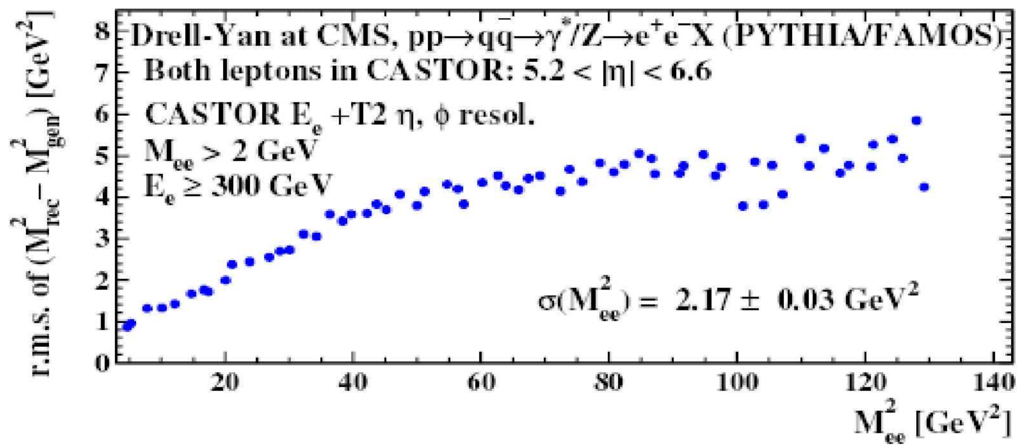


M^2(lepton pair) = sx_1x_2

$x_{1,2} = M/\sqrt{(s)}\ \exp(\mp y)$

Castor/T2 down to **$x_{BJ} \sim 10^{-6}$**

Measure angle of electrons with T2



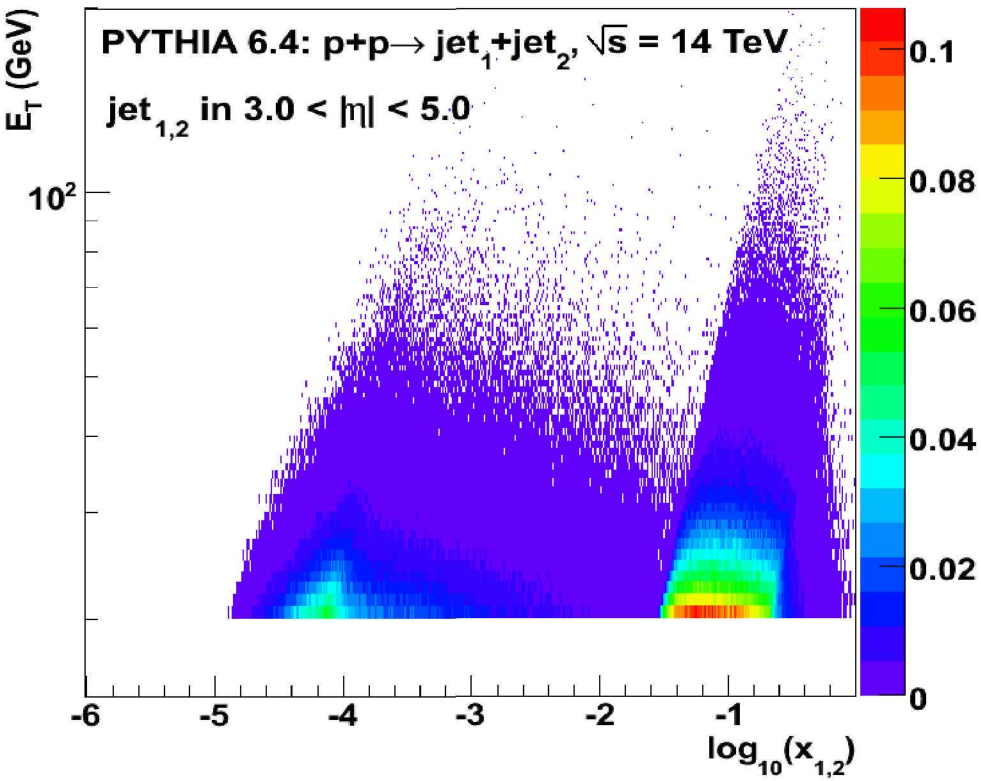
Forward jets

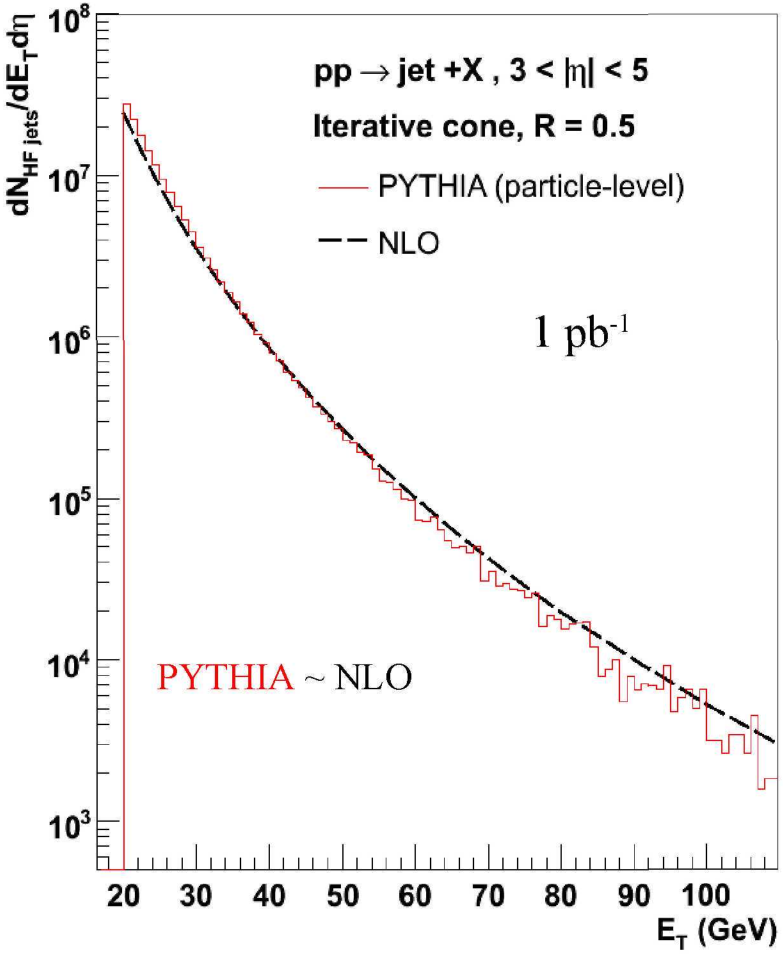
Inclusive forward "low-E_T" jet (p_T ~20-100 GeV) production:

$$p + p \rightarrow jet1 + jet2 + X$$

Jets in HF sensitive to $x \sim 10^{-4}$

Jets in Castor $x \sim 10^{-6}$

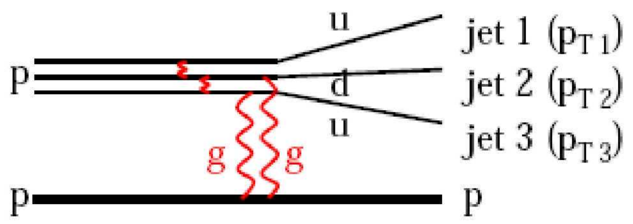


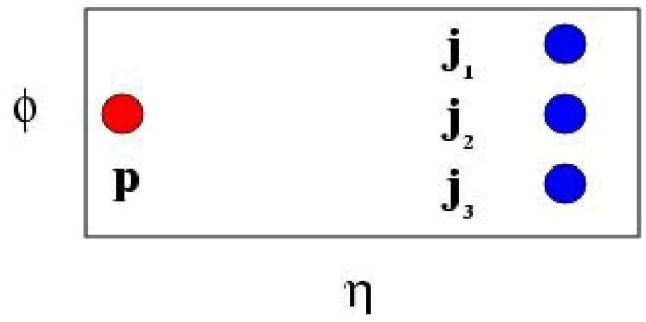


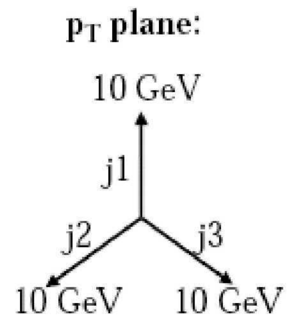
Large yields (~10^7 at ~20 GeV) !

Colour transparency

Single Diffraction pp→p+3jets



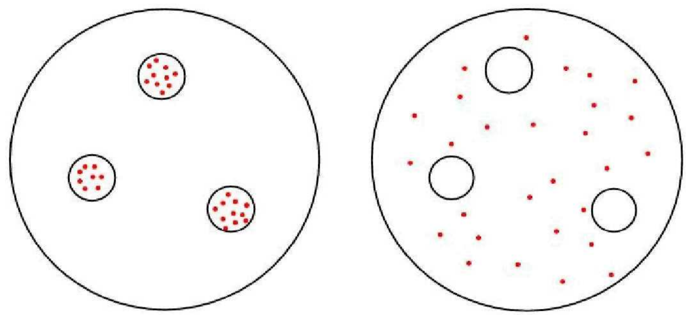




Estimated cross-section

$$\sigma_{3jets} \approx \left(\frac{5GeV}{p_{Tmin}} \right)^8 (10 \div 100)\, nb$$

Provide information about the short distance quark structure
Partons inside the quarks or outside?



a) b)

Example 3 jets at 10 GeV:
polar angle of jets ~ 4.3 mrad ⇨ η=6.1
jet separation ~ 7mrad ⇨ 10 cm in T2/Castor
jet width ~ 0.3-3 mrad ⇨ 0.4 - 4 cm in T2/Castor

proton $\xi(=\Delta p/p) \sim 10^{-6}$

Detect the proton (@ high β) + jets : 10 – 100 events in 0.3 pb^{-1}

Summary

Important experimental issues have been addressed in the common document:

Detailed studies of acceptance & resolution of the forward proton detectors for all scenarios

Machine induced background

Trigger of diffractive events

Pile-up

Summary

Low Luminosity ($\leq 10^{32}$ $cm^{-2}s^{-1}$): low & high β^*

- Measure inclusive SD and DPE cross sections:
  - t, M_X dependence
  - Study of topology e.g. rapidity gap
- Measure semi-hard SD and DPE:
  - Onset of jet activity
- Inclusive Forward jets, Muller-Navelet dijets
- Forward Drell-Yan
- Validation of Cosmic Ray generators

Running with TOTEM optics: large proton acceptance

No pile-up

High Luminosity (> 10^{32} $cm^{-2}s^{-1}$) : low β^*

- Measure SD and DPE in presence of hard scales (dijets, vector bosons, heavy quarks): dPDF, GPD

- $\gamma\gamma$ and γp phyics

Trigger limiting factor

Pile-up not negligible:
important source of background

High Luminosity (> 10^{33} $cm^{-2}s^{-1}$) : low β^*

- Discovery physics in central exclusive production
  - SM or MSSM Higgs, other exotic processes

Need additional forward proton detector