MEASURING FORWARD PHYSICS PROCESSES AT THE LHC

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THE PLAN

- **PART 1:**
  - WHAT DIFFRACTION?
  - SIGNATURES OF DIFFRACTIVE PROCESSES
- **PART 2:**
  - EXPERIMENTS & RESULTS AT THE LHC
  - FUTURE PLANS

WHAT DIFFRACTION?*

*For history in diffraction see the Appendix

DIFFRACTIVE SCATTERING PROBES THE HADRONIC VACUUM

- DIFFRACTIVE SCATTERING IS CHARACTERIZED BY VACUUM FLUCTUATIONS IN THE PERIFERY OF INITIAL STATE HADRONS
- HOW TO QUANTIFY THESE FLUCTUATIONS, THEIR CONTENT AND DYNAMICS?

SOFT DIFFRACTION DEALS WITH QUARK-GLUON STATES CONFINED WITHIN HADRONS

- QCD IS THE THEORY BEHIND – BUT IT IS USEFUL ONLY IN CASE PERTURBATION THEORY CAN BE USED AT SMALL DISTANCES HAVING A HARD SCALE IN p_T^2, Q^2!

⇒ SOFT – LONG DISTANCE – PROCESSES CANNOT BE CALCULATED – NEED PHENOMENOLOGICAL MODELS FOR:

σ_{tot} $\sigma_{elastic}$ σ_{diff} (= $\sigma_{SD}+\sigma_{DD}+\sigma_{CD}$)

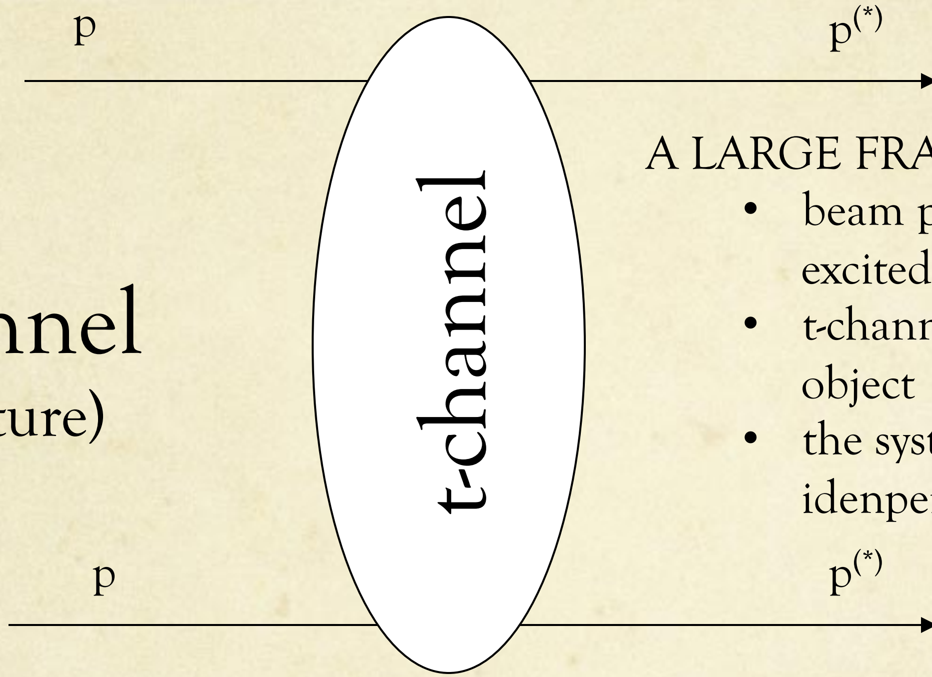
- AT LARGE DISTANCES CONFINEMENT FORCES TAKE OVER – BINDING FORCES BETWEEN QUARKS RESPONSIBLE FOR STATIC PROPERTIES OF HADRONS – DIFFRACTIVE SCATTERING TO PROBE THESE.

DIFFRACTIVE SCATTERING MAPS OUT CONFIGURATIONS OF PARTONS (QUARKS AND GLUONS) CONFINED WITHIN HADRONS

- SPACE-TIME EVOLUTION OF HADRON-HADRON SCATTERING

- QCD ASYMPTOPIA - QUARK-GLUON CONFINEMENT

DIFFRACTION IS DESCRIBED AS A PRODUCTION (s-channel) OR AS AN EXCHANGE (t-channel) PROCESS



s-channel
(this lecture)

A LARGE FRACTION OF EVENTS WITH:

- beam particles intact (elastic) or excited into a diffractive state *
- t-channel exchange of a colourless object
- the systems created hadronize idenpendently, produce rap gaps

Bjorken's definition (out of frustration?):
"A process which causes rapidity gaps that are not exponentially suppressed."
Can be viewed as an exchange process (t-channel/Regge model) or as a production process (s-channel) $\Rightarrow$ Optical analogy: Fraunhofer scattering.

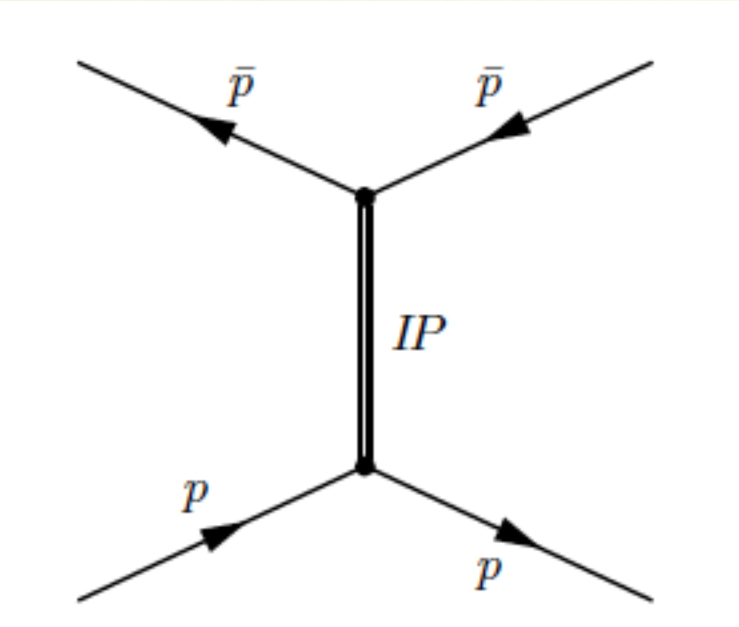
Remember the Mandelstam variables s, t, u?

DIFFRACTION HAS AN OPTICAL ANALOGY

- THE TWO APPROACHES BOTH USE AN ANALOGY TO (FRAUNHOFER) DIFFRACTION IN OPTICS:
  - MUELLER – REGGE MODEL*
  - GOOD – WALKER FORMALISM
- THESE MODEL APPROACHES ARE SUPPLEMENTED BY:
  - saturation models, semiclassical approaches, dipole models, perturbative QCD – BFKL, colour (re-)connection...

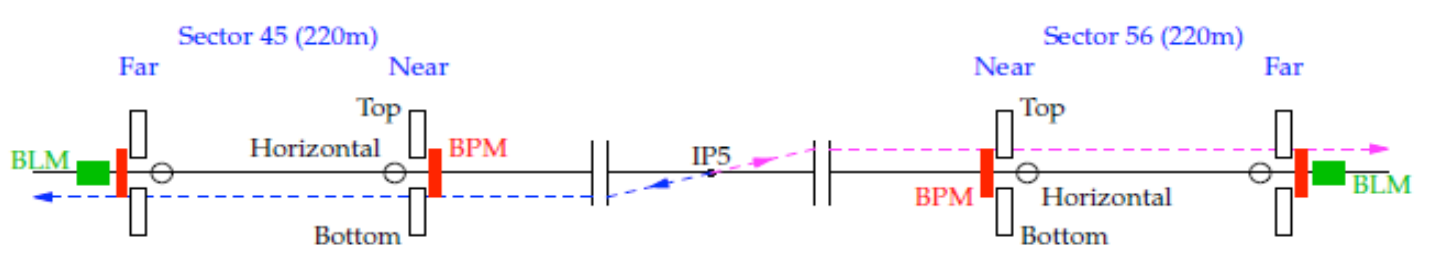
A number of lectures in this school on the subjects above!

ELASTIC SCATTERING IS DIFFRACTIVE



$$\bar{p}p \rightarrow \bar{p}p$$

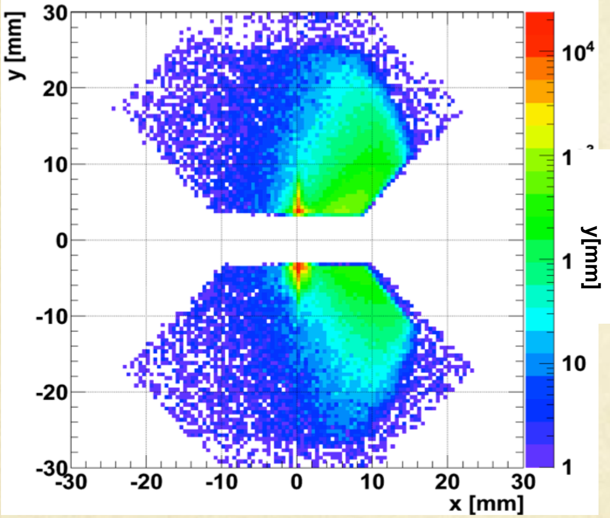
ELASTIC pp SCATTERING



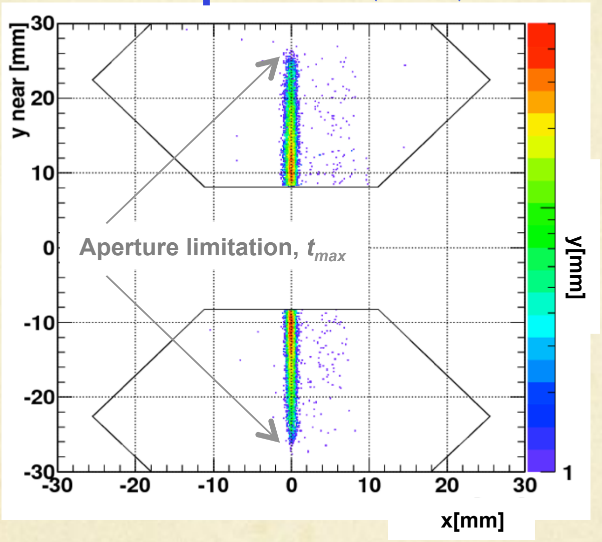
Sector 56

Sector 45

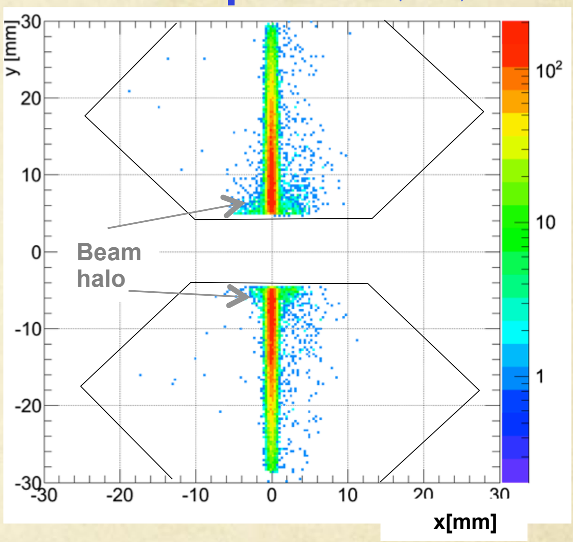
β^*=3.5m (7σ)

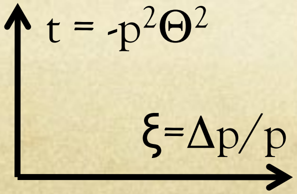


β^*=90m (10σ)



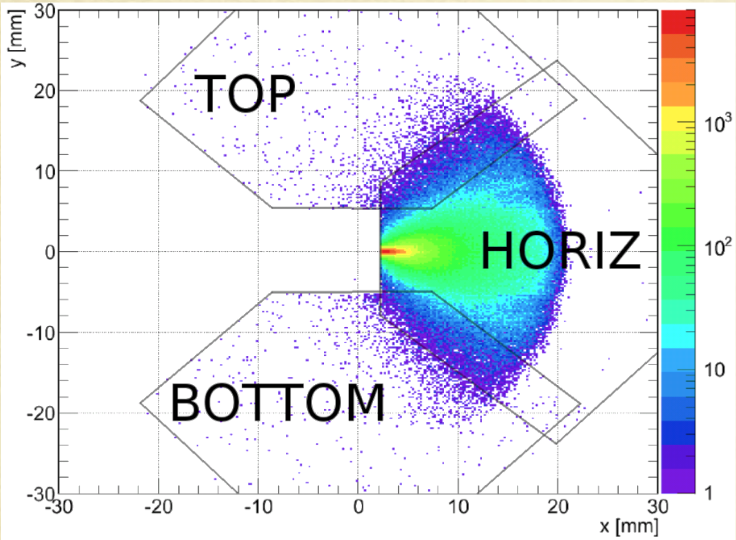
β^*=90m (5σ)





Two diagonals analysed independently

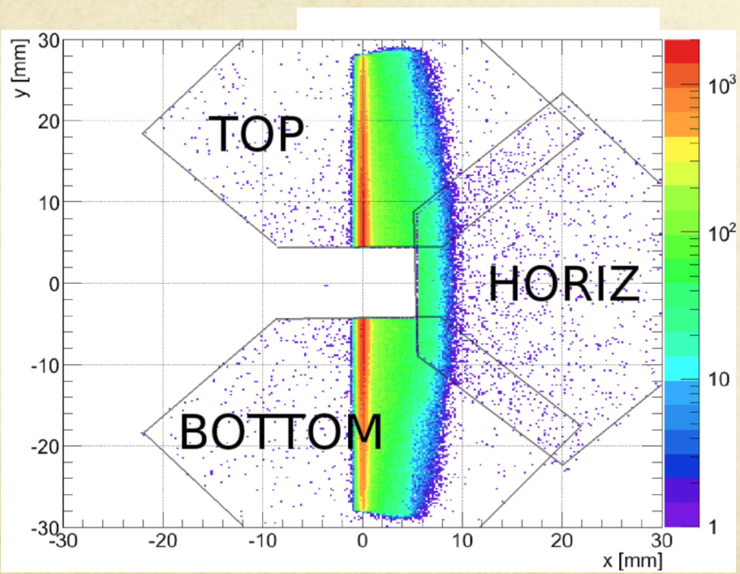
Leading forward protons at ±220 meters: Low & High β* (β*≈ 0.55m, 90m)



At low β* (nominal LHC beam optics) the protons are measured through their **horizontal** deviation from the beam axis.
The proton fractional longitudinal momentum loss, ξ, is proportional to the (horizontal) distance fom the beam axis:

$\xi = \Delta p/p \propto x$

- measurement sensitive to the transverse (x*,y*) position of the interaction vertex

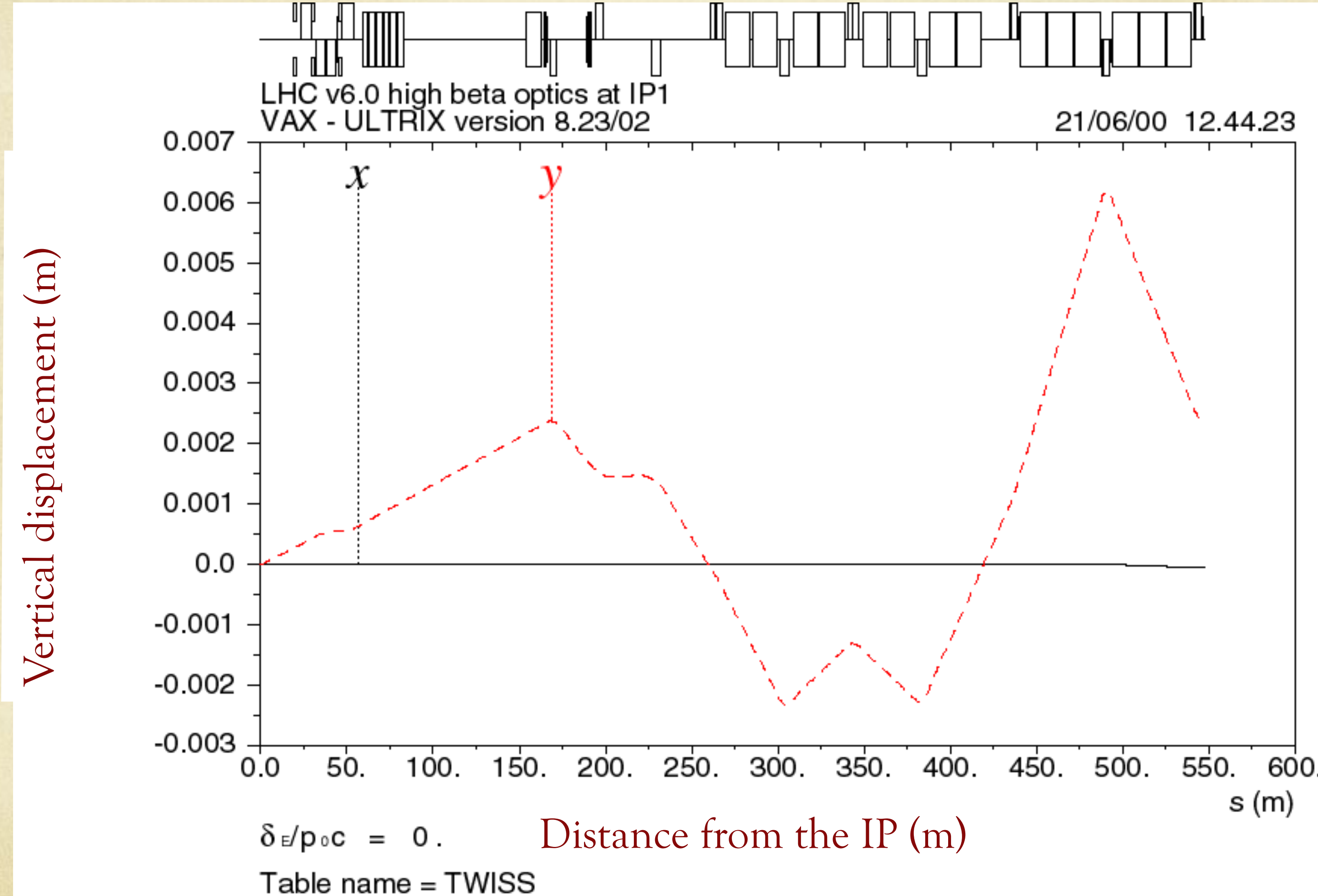


At high β* (β* ≈ 90m custom optics) the protons are measured through their scattering angle in **vertical** direction.

$\Theta_y \propto p_T \approx \sqrt{|t_y|}$

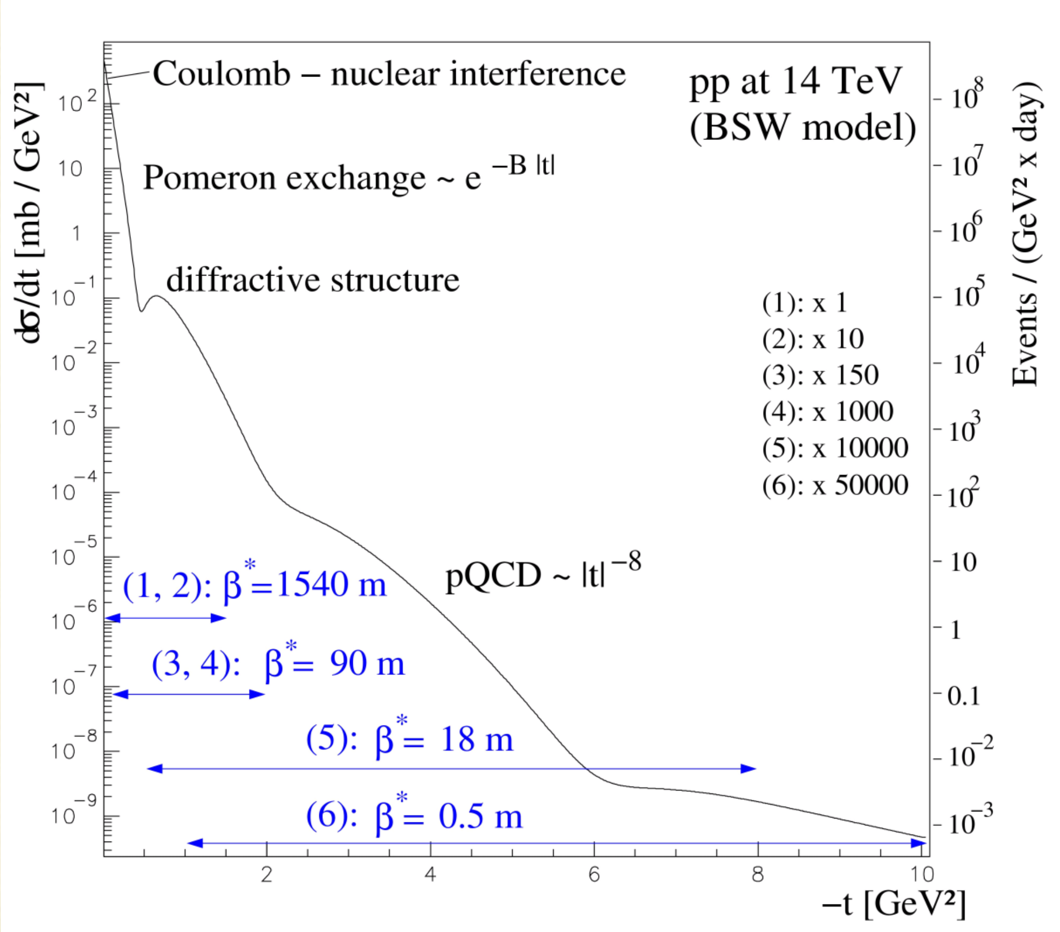
- measurement sensitive to the horizontal x* position of the interaction vertex in diffractive events
- horizontal vertex position obtained by measuring elastic events (if beams assumed to be symmetric in the transverse plane)

BEAM LINE AND RUN CONDITIONS



ELASTIC CROSS SECTION PROJECTS THE SHADOW OF A COMPLEX PROTON

12 orders of magnitude



$d\sigma_{el}/dt$ yields:

- pp *interaction radius* (slope of the $d\sigma_{el}/dt$ distribution)
- with the measurement of the total inelastic rate - the *total pp cross section*,
- a test of the *Coulomb-nuclear Interference* (expected to have an effect over *large* interval in −t).
- a measurement of the *ratio of the real and imaginary parts* of the forward pp scattering amplitude, ρ = ReA(s,t)/ ImA(s,t)

⇒ through dispersion relations, a precise measurement of ρ will constrain σ_{tot} at substantially higher energies

⇒ "SHADOW SCATTERING"

LUMINOSITY AND ELASTIC CROSS SECTION ALLOW TOTAL CROSS SECTION TO BE MEASURED

Luminosity relates the cross section σ and no. of events (N) of a given process by:

$$L = N/\sigma$$

A process with well known, calculable and large σ (monitoring!) with a well defined signature?   Need complementarity.

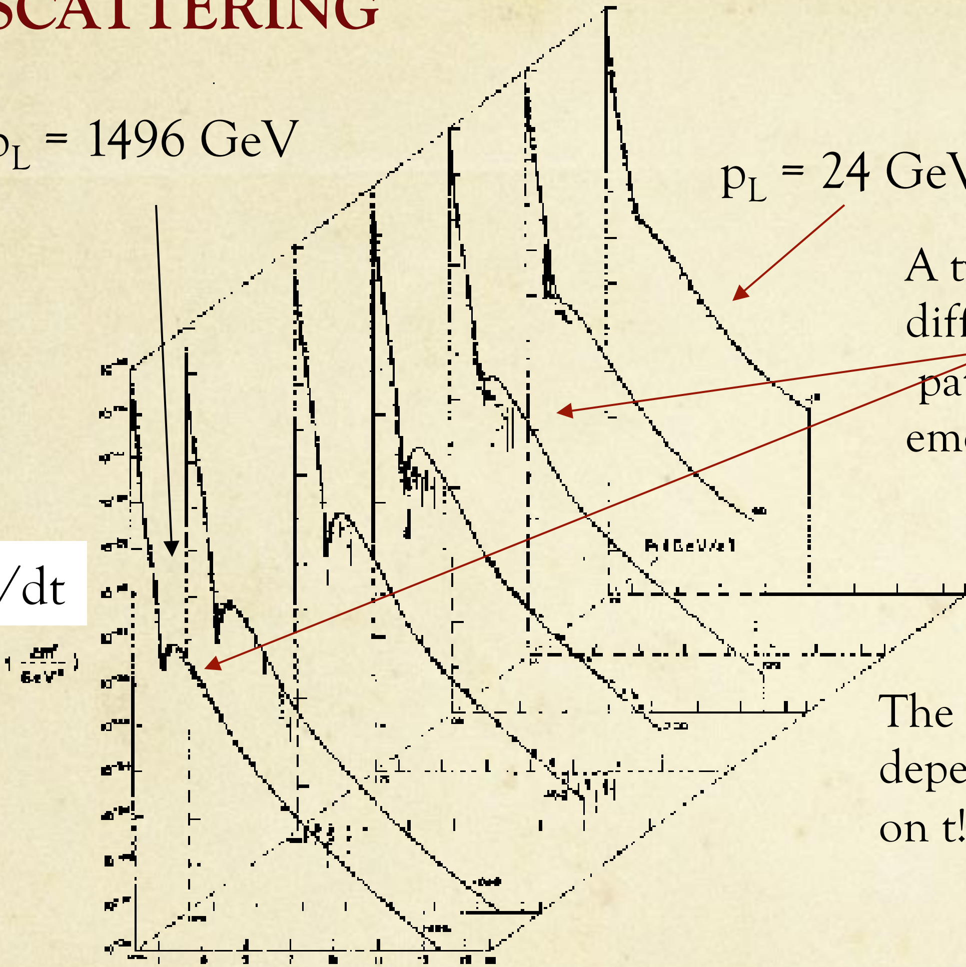
Measure simultaneously elastic (N_{el}) & inelastic rates (N_{inel}), extrapolate $d\sigma/dt \to 0$, assume ρ-parameter to be known (use the Optical Theorem*):

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

$N_{inel} = ?$ $\Rightarrow$ Need a hermetic detector.

$dN_{el}/dt|_{t=0} = ?$ $\Rightarrow$ Minimal extrapolation to $t \to 0$: $t_{min} \approx 0.01$

ISR RESULTS – CHARACTERISTICS OF ELASTIC SCATTERING



p_L = 1496 GeV

p_L = 24 GeV

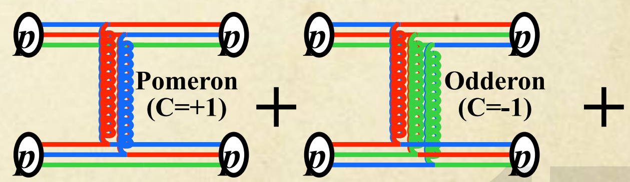
$d\sigma/dt$

$-t\ (\mathrm{GeV}/c)^2$

A typical diffraction pattern emerges.

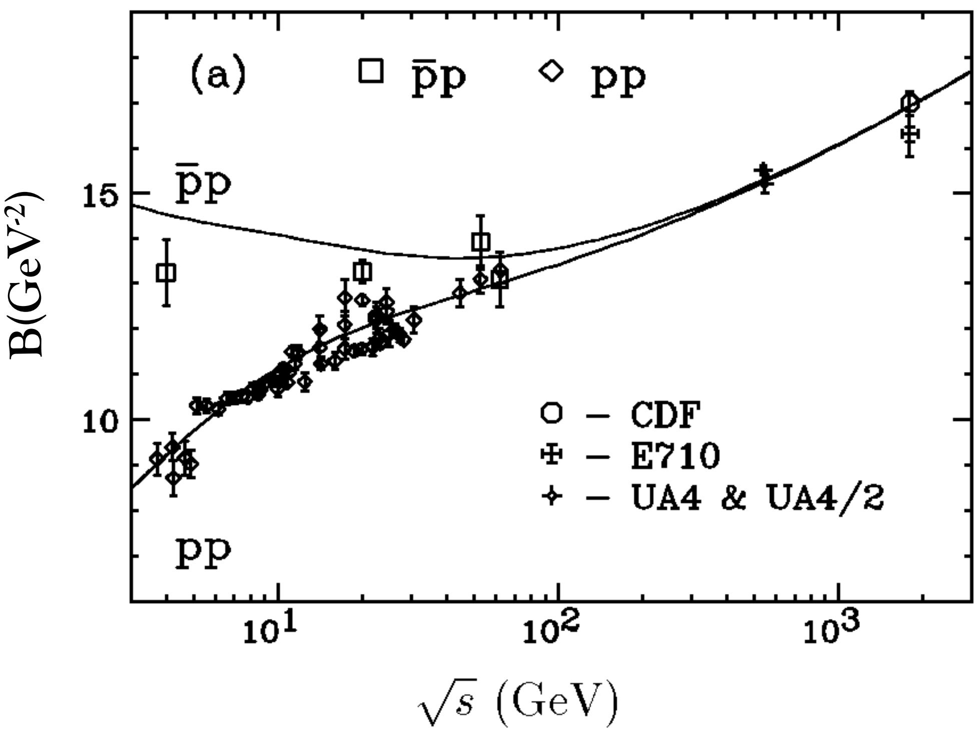
The local slope depends on t!

- diffractive peak *shrinks* – interference *dip* moves to smaller t
- at $-t \geq 1\ \mathrm{GeV}^2$ little $\sqrt{s}$ dependence, $d\sigma/dt \propto 1/t^8$ a la Donnachie&Landshoff
- exponential fall-off up to $-t \approx 10\ \mathrm{GeV}^2$?
- size of the interaction region $\propto B(s)$



-Where is the Odderon?

THE SLOPE PARAMETER B MEASURES THE pp INTERACTION RADIUS



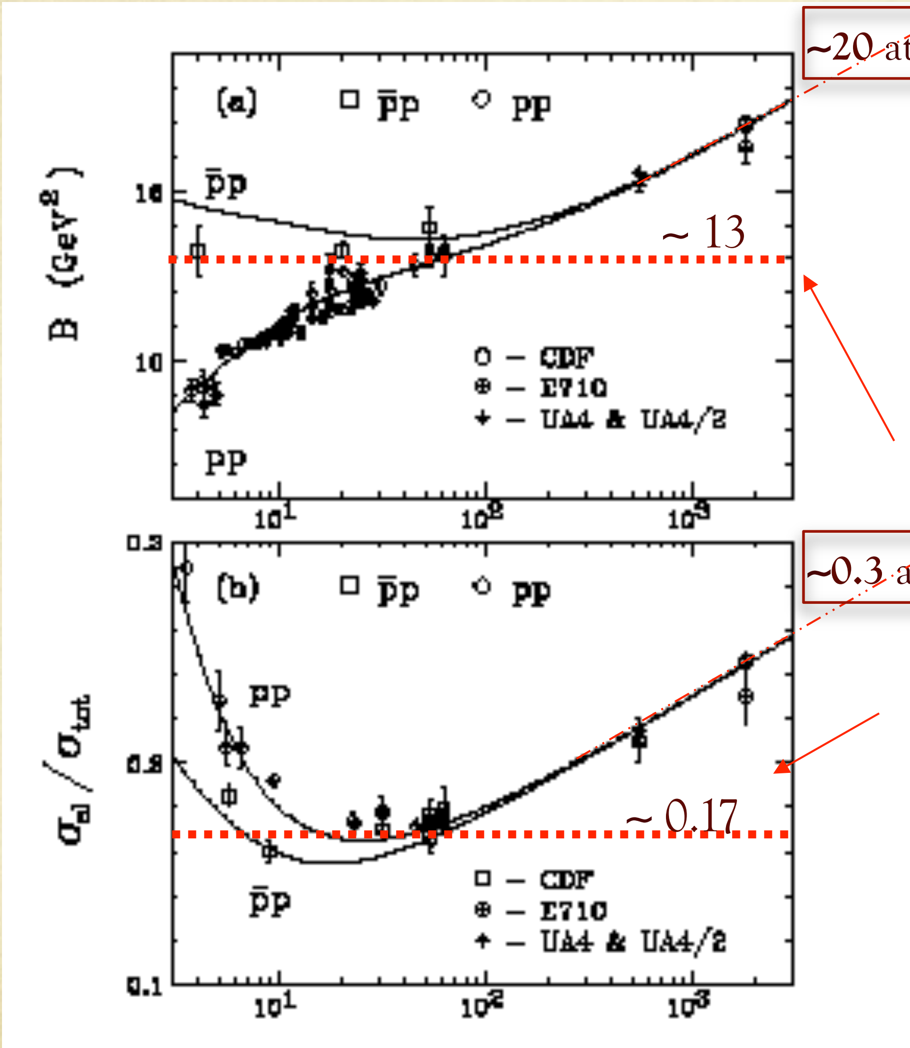
$t < 0.13\ GeV^2$

A.Covolan, J. Montanha and K. Goulianos, Phys. Lett. B 389(1996)176.

WHERE IS THE BLACK DISC LIMIT? – AN EARLY ESTIMATE

B~32 at the black disc limit?

The black disc limit reached at 10^8 GeV?



~20 at the LHC, <b^2> ≈ 1.6fm^2

Forward elastic slope shrinks
⇒ effective interaction radius of proton grows (∝ lns)

The values of the slopes agree with the optical picture, i.e. with a fully absorbing disc of radius R for which B = $R^2/4$.

For a proton with $R \approx 1/m_\pi$ (m_π = π meson mass):
B ≈ 13 GeV^{-2}

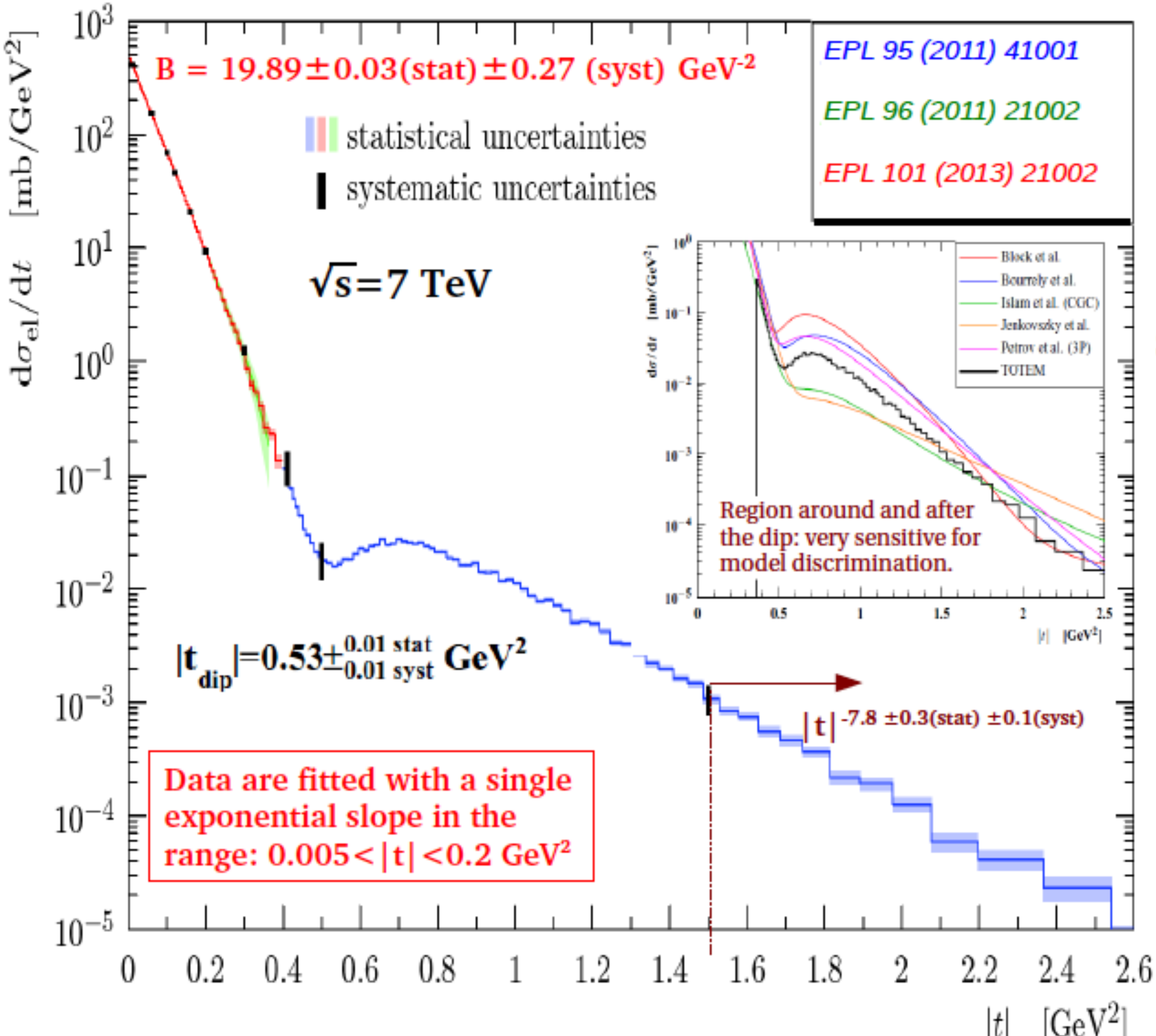
~0.3 at the LHC

However: Scattering on a black disc: **σ_{el}/σ_{tot} = ½**, while the data (at √s corresponding to B ~13 GeV^{-2}) gives **σ_{el}/σ_{tot} = 0.17…**
⇒ **the proton is semi-transparent**
⇒ QCD colour transparency!

Mixture of scattering states with different absorption probabilities is required for diffractive scattering to take place.

RO/ CERN 2006

Elastic scattering results: $5\cdot10^{-3}<|t|<2.5$ GeV^2@ 7 TeV



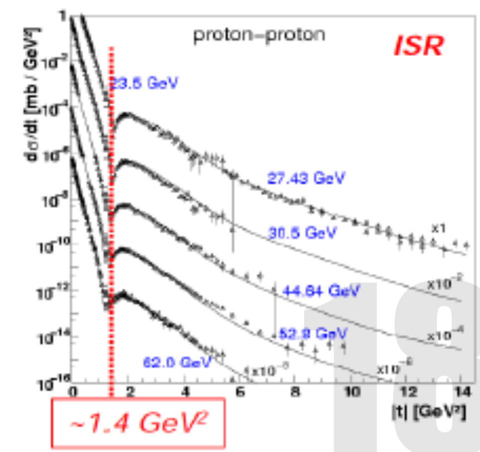
$0.36<|t|<2.5$ GeV^2

$0.02<|t|<0.33$ GeV^2

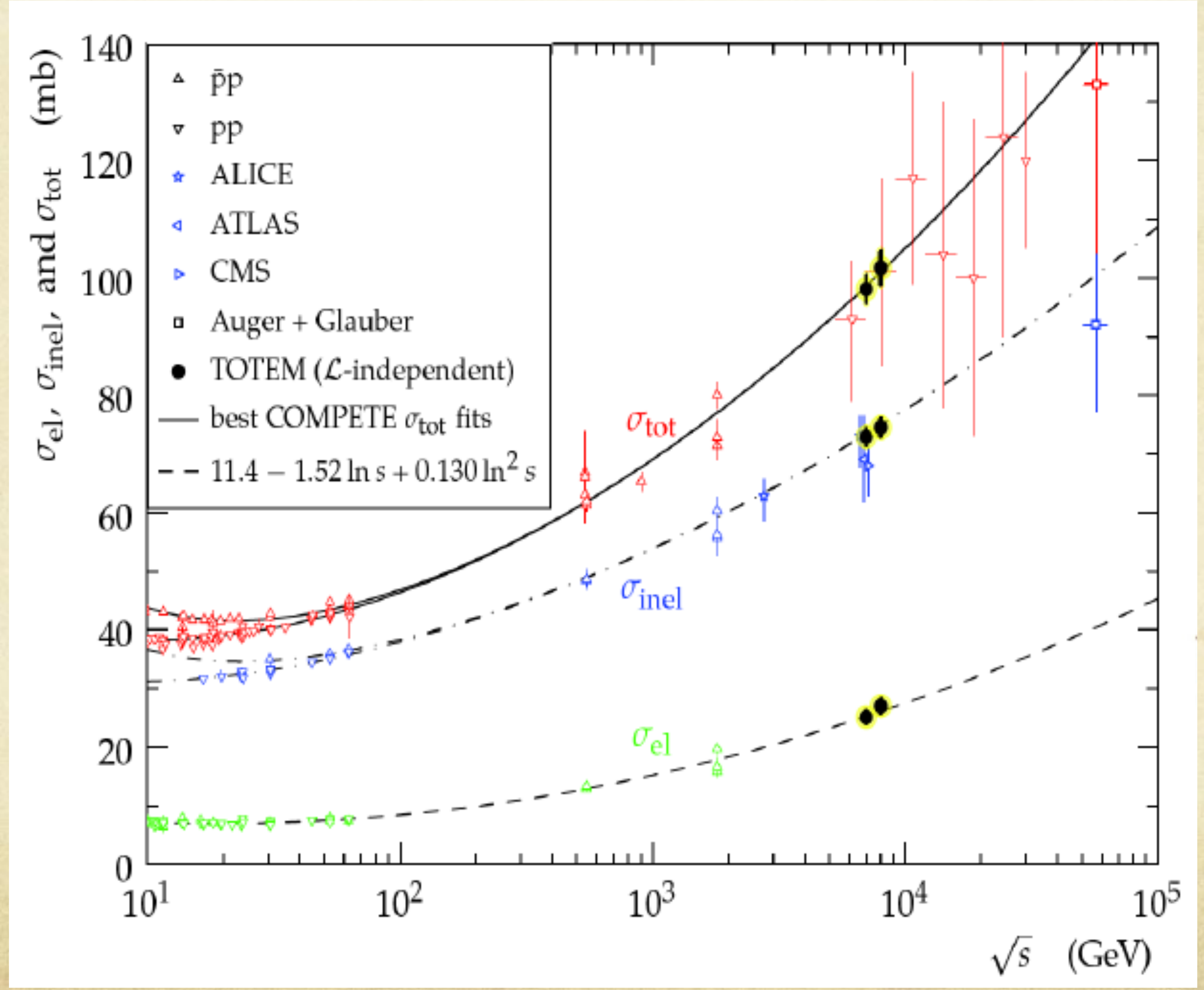
$5\cdot10^{-3}<|t|<0.4$ GeV^2

Shrinkage of the forward peak:

- minimum moves to lower |t| with increasing CM energy
- exponential slope grows with the CM energy



SUMMARY OF CROSS SECTION MEASUREMENTS AT THE LHC

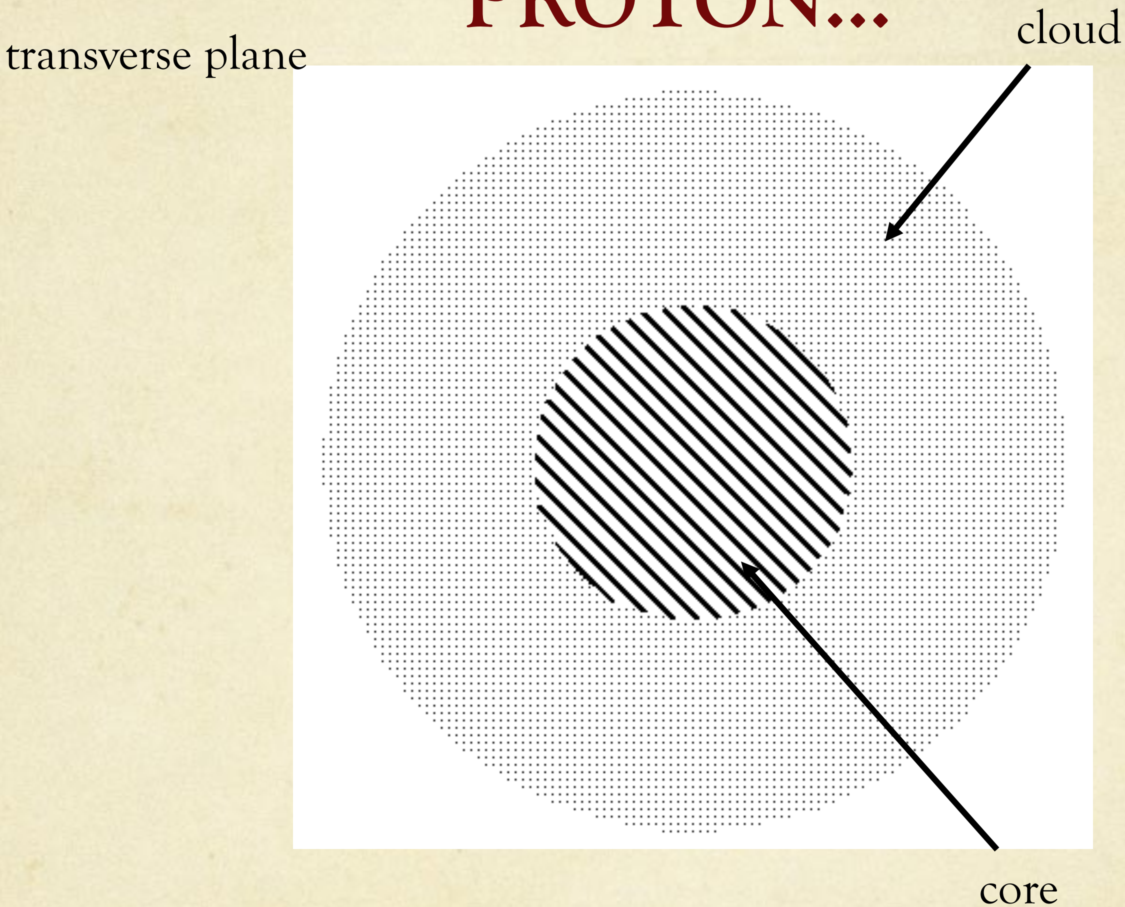


MUELLER-REGGE AND GOOD-WALKER APPROACH BOTH HAVE AN OPTICAL ANALOGY – FRAUNHOFER SCATTERING*

- **A coherent phenomenon** that occurs when a beam of light meets an obstacle with dimensions comparable to the wavelength of incoming light.
- As long as the *wavelength is much smaller than the dimension of an obstacle*, there is a geometrical **shadow**.

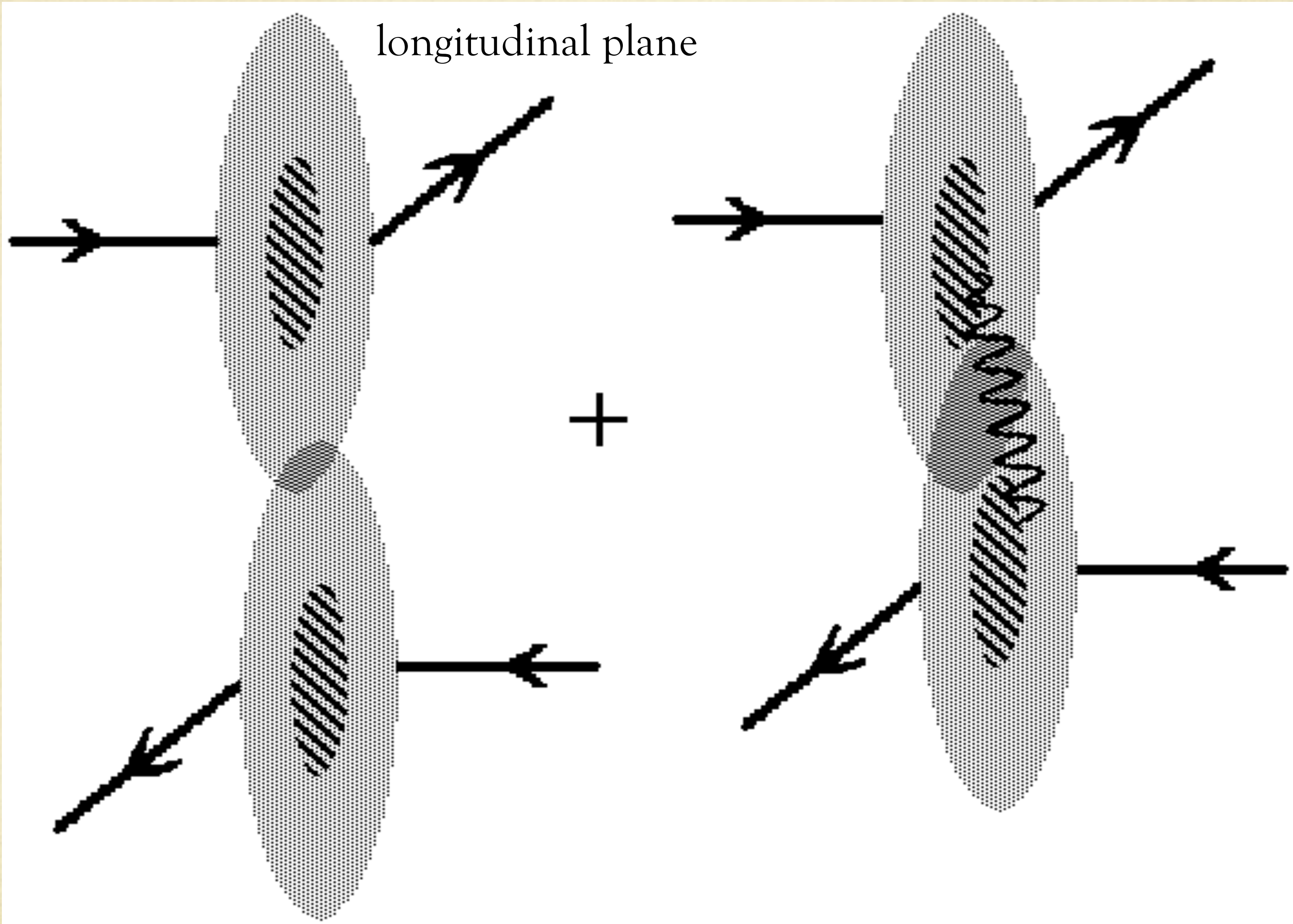
Optical analogy by the Landau school: (L.D. Landau and I.Y. Pomeranchuk, Zu.Eksper.Teor.Fiz.24(1953)505, E.Feinberg, NC suppl.3(1956)652, A.I. Akhiezer and Y.I. Pomeranchuk, Uspekhi, Fiz.Nauk.65(1958)593, A. Sitenko, Uspekhi, Fiz.Nauk. 67(1959)377, V.N. Gribov, Soviet Jetp 29(1969)377.)

GEOMETRICAL PICTURE OF PROTON…



proton at rest – what happens in a high energy collision?

LORENTZ CONTRACTED PROTONS INTERACT

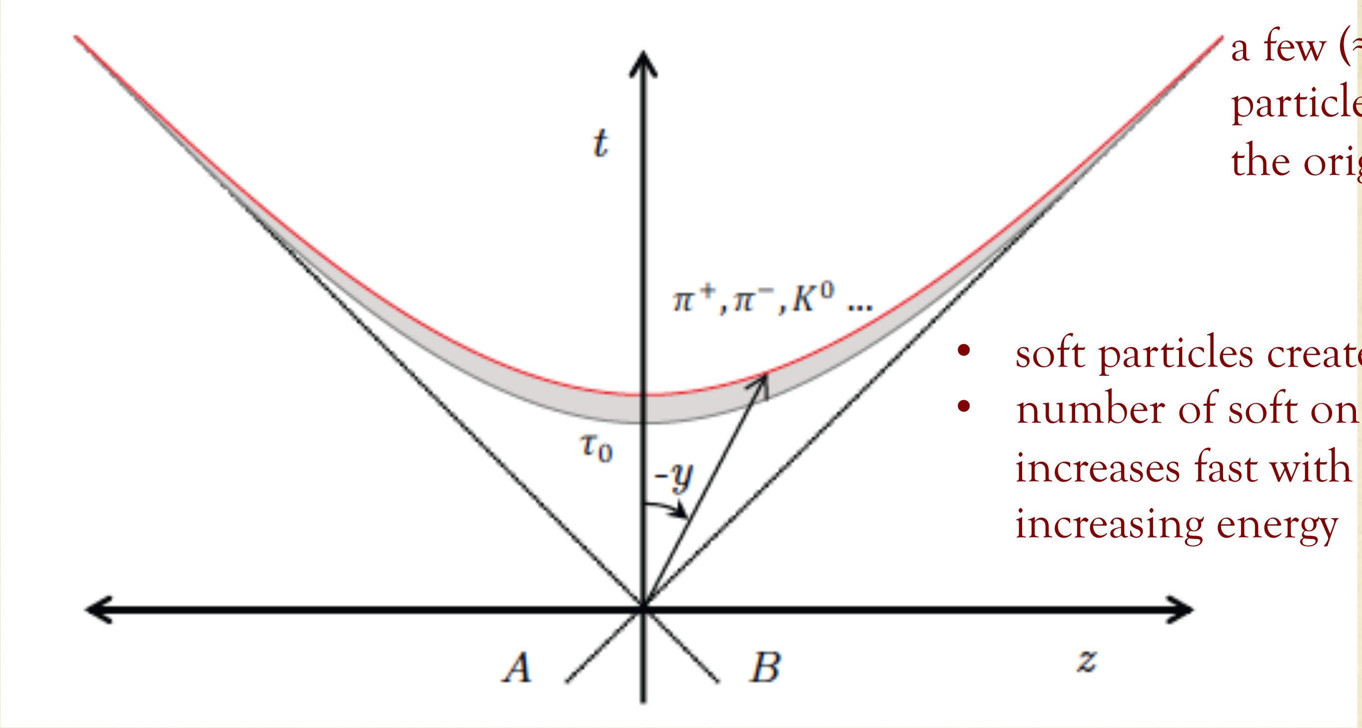


SOFT DIFFRACTION

HARD DIFFRACTION

SIGNATURES OF DIFFRACTIVE SCATTERING

SPACE-TIME EVOLUTION

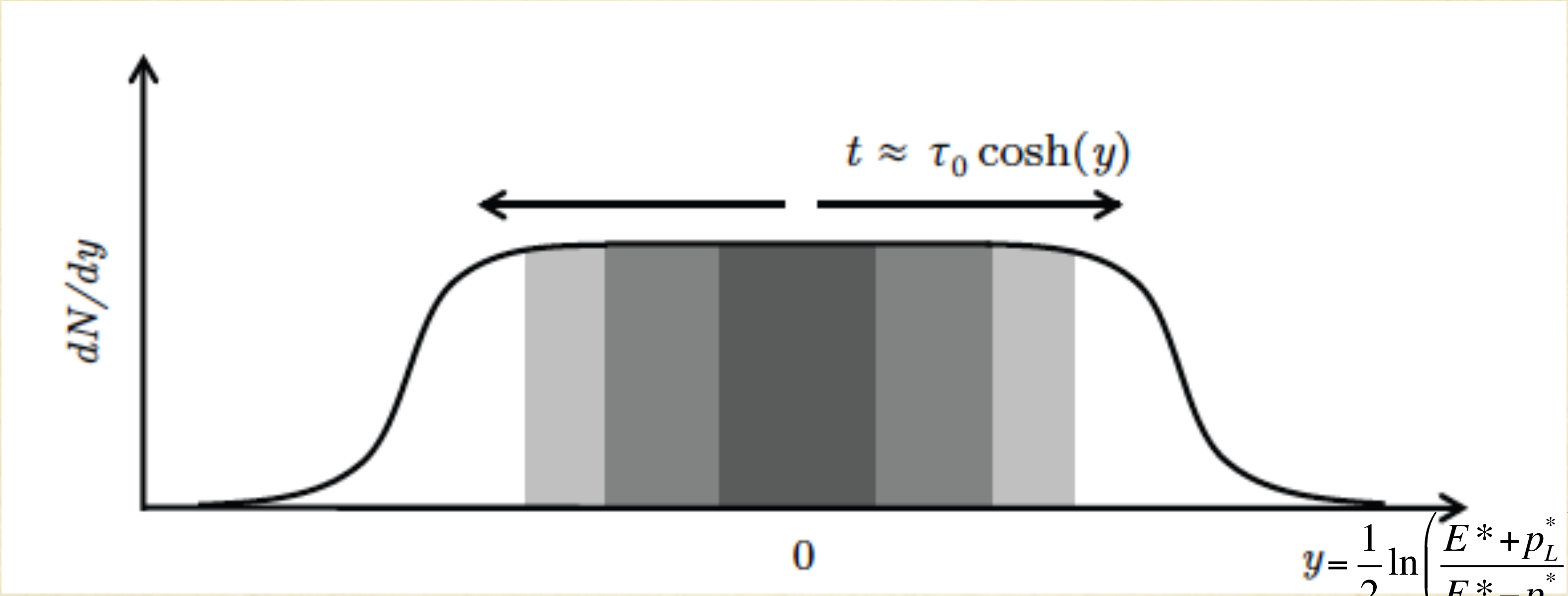


a few (≈ 3) fast particles remember the original parton

- soft particles created first!
- number of soft ones increases fast with increasing energy

Hadron collision as a chain reaction initiated by wee partons: At first, only a small c.m.s. domain of partons within $|\Delta y| \approx 1$ around y=0 is excited. Subsequent to this initial excitation, de-excitation "cooling" takes place by $\tau_0 \approx$ 1fm/c through hadron emission that, in turn, excites neighbouring domains with a characteristic time of $t \approx \tau_0 \cosh(y)$.

RAPIDITY SPACE – TIME WINDOW TO HADRON-HADRON SCATTERING



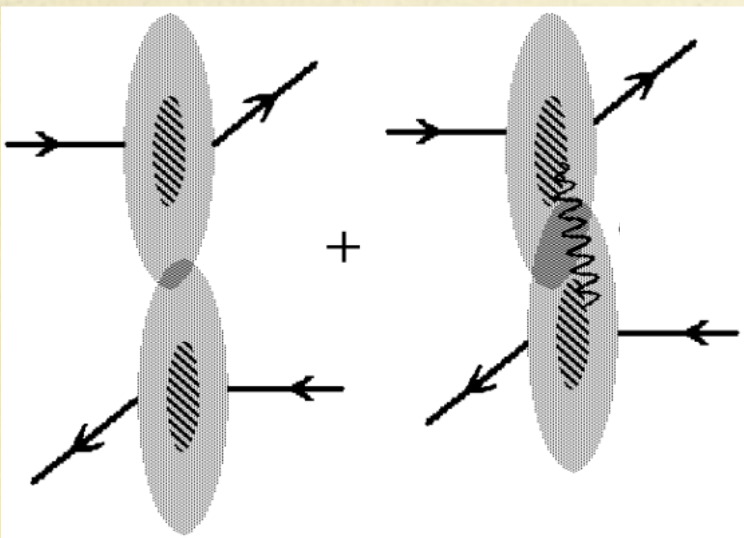
$$y = \frac{1}{2}\ln\left(\frac{E^* + p_L^*}{E^* - p_L^*}\right)$$

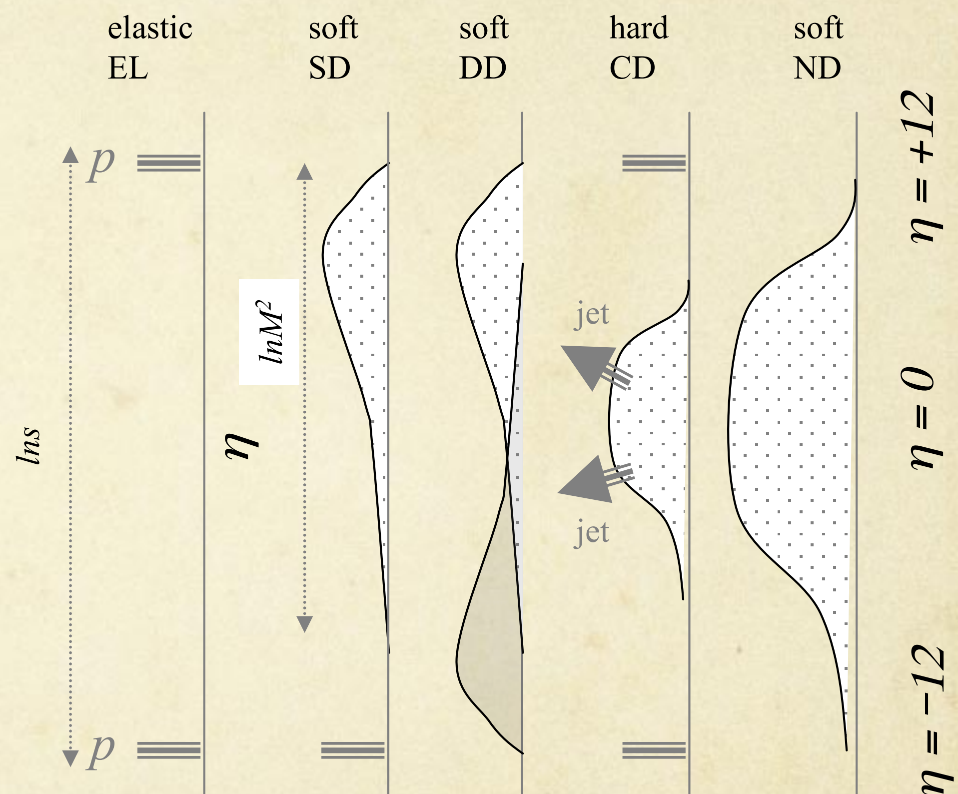
Assume that the colliding hadrons are Lorentz contracted into narrow discs. In collision, hadrons are formed and fill up the kinematically allowed longitudinal momentum space. A uniform rapidity distribution of final state particles results.

PROFILES OF DIFFRACTIVE SCATTERING AS SEEN IN THE RAPIDITY SCREEN

soft diffractive scattering

hard diffractive scattering





-low & high masses pose a problem!

pseudorapidity axis $\eta = -\ln(\tan(\theta/2))$

SIGNATURES

- TRADITIONALLY, LOOK FOR LARGE RAPIDITY GAPS (LRGs) OF $\Delta\eta \geq 3$ UNITS
- CORRESPONDS TO $\xi = 1 - p_z^f/p_z^i = M_X^2/s \leq 0.05$
- REQUIRE NO TRACKS OR ENERGY DEPOSITS WITHIN THE LRG
- HARD DIFFRACTION: Jets, heavy quarks, W's,..

RAP GAPS AS OBSERVABLES

- PARTON RE-SCATTERINGS
- CALORIMETER NOISE, LACKING TRACK E_T/p_T ACCEPTANCE...
- FLUCTUATIONS IN THE QCD CASCADES PRODUCED IN NON-DIFFRACTIVE EVENTS
- KINEMATICAL OVERLAPS IN RAPIDITY (DUE TO LIMITED PHASE SPACE)
- LACKING ANGULAR COVERAGE

FOR SEEING THE RAP GAPS, NEED GOOD COVERAGE in p_T: $\min(p_T) \leq 100$ MeV

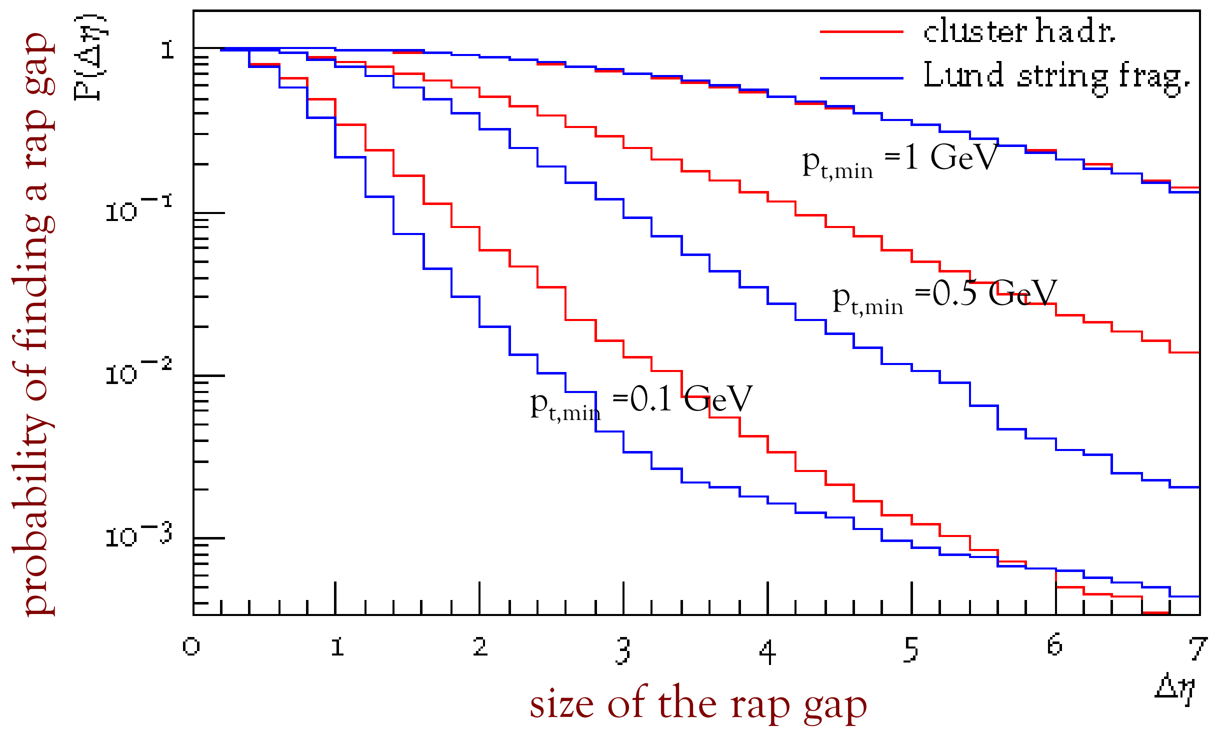


Fig. 4. Probability for finding a rapidity gap (definition 'all') larger than $\Delta\eta$ in an inclusive QCD event for different threshold $p_\perp$. From top to bottom the thresholds are $p_{\perp,\mathrm{cut}} = 1.0$, 0.5, 0.1 GeV. Note that the lines for cluster and string hadronisation lie on top of each other for $p_{\perp,\mathrm{cut}} = 1.0$ GeV. No trigger condition was required, $\sqrt{s} = 7$ TeV.

SURVIVAL OF RAPIDITY GAPS

How do the rapidity gaps - created by colourless pomeron exchange - survive (1) inelastic interactions of the spectator partons, (2) soft ”parasite” gluon emissions?

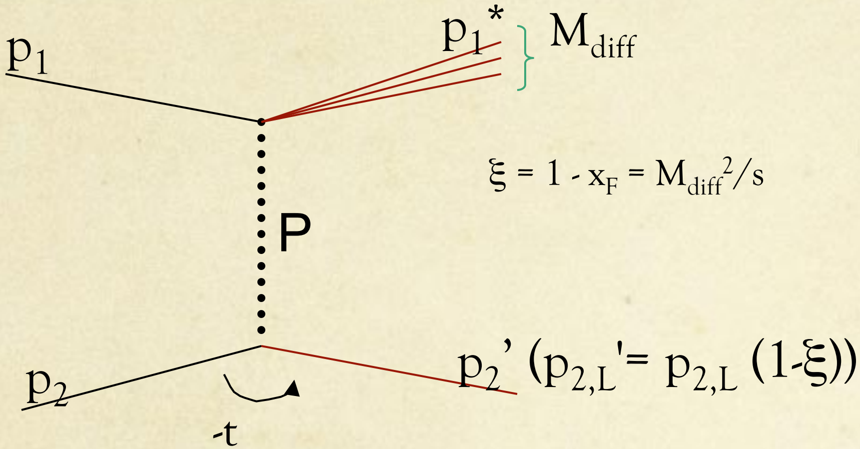
In impact parameter, b_t, space: The amplitude of the diffractive process under study is $M(s,b_t)$. The probability that there is *no extra inelastic interaction* is:

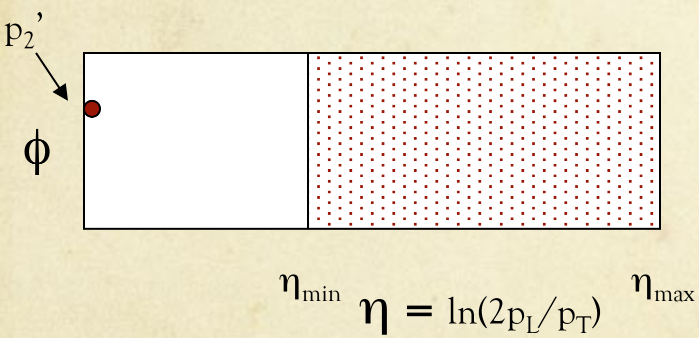
$$S^2 = \int \left|M(s,b_t)\right|^2 \exp\left[-\Omega(b_t)\right] d^2 b_t \,/\, \int \left|M(s,b_t)\right|^2 N d^2 b_t$$

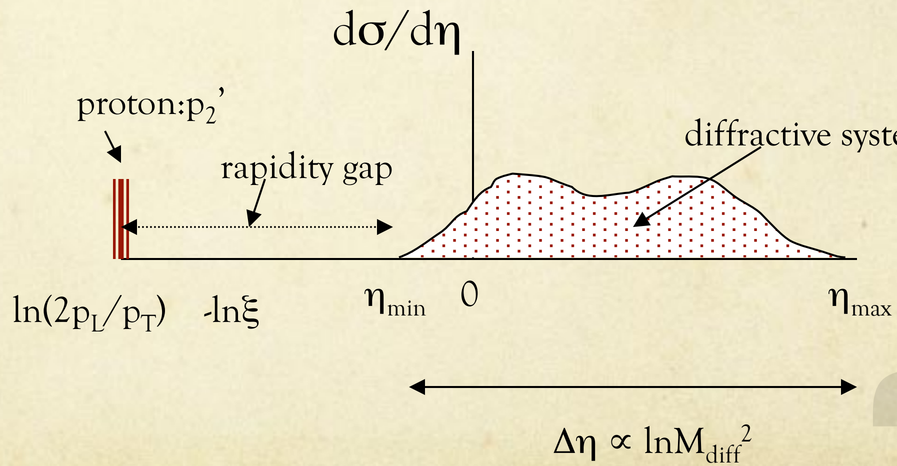
where $\Omega(b_t)$ is the opacity (optical density) of the interaction and $N=\exp(-\Omega^o)$ the normalizing factor where Ω^o denotes the relevant opacity evaluated at $\Omega = 0$.

The survival probability, S^2, depends strongly on the spatial distribution of the constitutents of the relevant subprocess.

SINGATURES: SINGLE DIFFRACTION





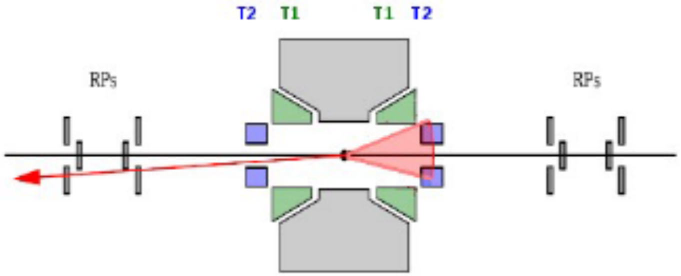


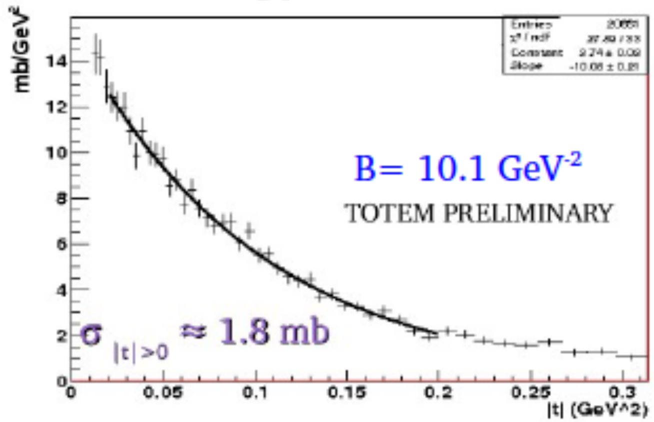
$$\Delta\eta \approx 2\ln(\sqrt{s}/M_{diff}) \geq 3$$

Soft Single Diffractive cross section (7 TeV)

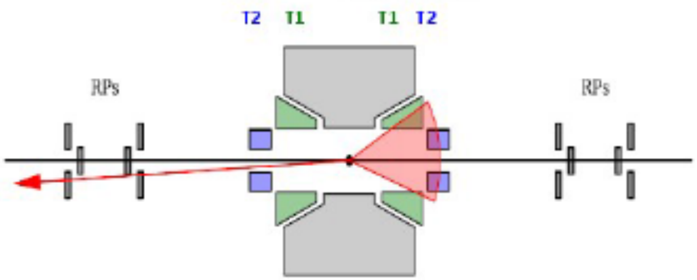
$d\sigma/dt \sim C \cdot e^{Bt}$

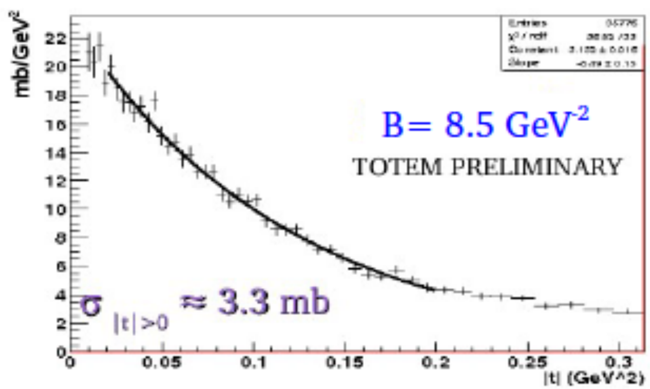
Low Mass
M=3.4 - 8 GeV



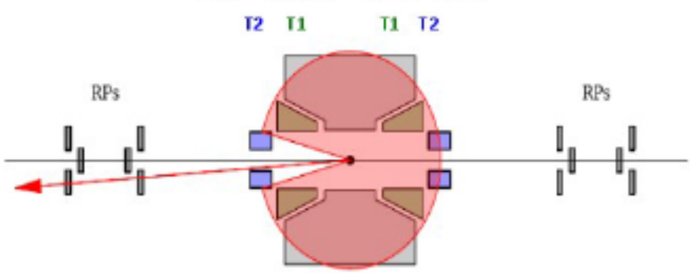


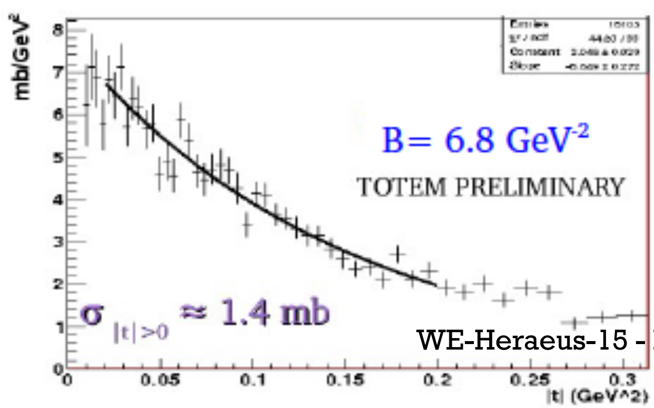
Medium Mass
M=8 - 350 GeV





High Mass
M=0.35 - 1.1 TeV





Corrections include:
- Trigger efficiency
- Reconstruction efficiency
- Proton acceptance
- Background subtraction
- Extrapolation to t=0

Missing corrections:
- Class migrations
- Effects due to resolutions and beam divergence

- Estimated uncertainties: B~15% σ~20%

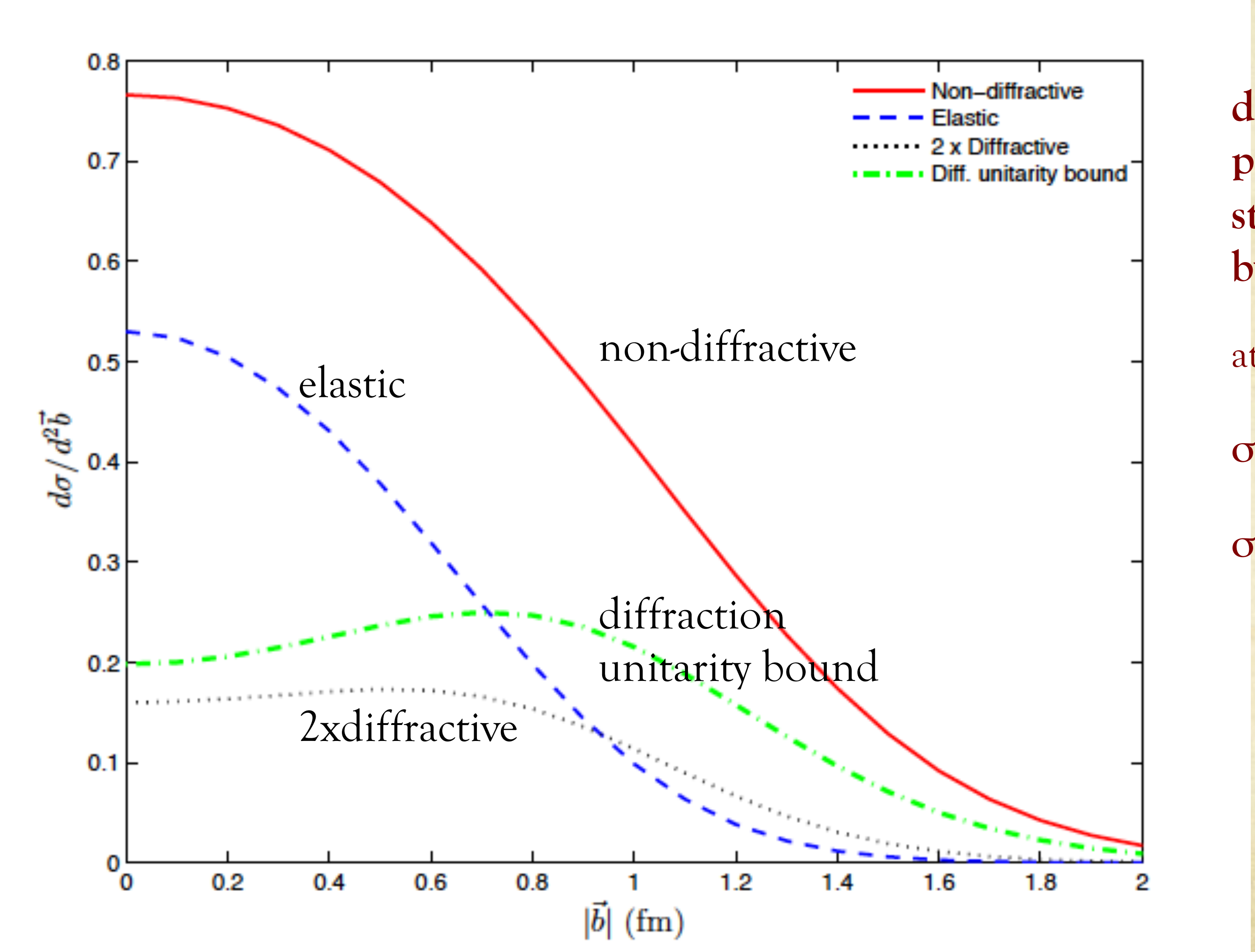
Preliminary:
$\sigma_{SD} = 6.5 \pm 1.3$ mb
($3.4 < M_{SD} < 1100$ GeV)

Very high masses measurement ongoing

GOOD-WALKER APPROACH TO DIFFRACTIVE HADRON SCATTERING

- HADRONS CONSIDERED AS QUANTUM MECHANICAL SUPERPOSITIONS OF QUARK-GLUON STATES
- HADRON-HADRON INTERACTIONS OCCUR BETWEEN THE QUARK-GLUON STATES EXTENDED IN SPACE AND TIME
- A HADRON-HADRON INTERACTION IS CALLED DIFFRACTIVE, IN CASE THE SCATTERING PROCESS CAN BE DESCRIBED AS AN ABSORPTION OF THE HADRON WAVE FUNCTION BY THE NUMBER OF AVAILABLE INELASTICS SCATTERING MODES – DIFFRACTION IS "SHADOW" SCATTERING"

PROTON-PROTON SCATTERING IN THE IMPACT PARAMETER SPACE



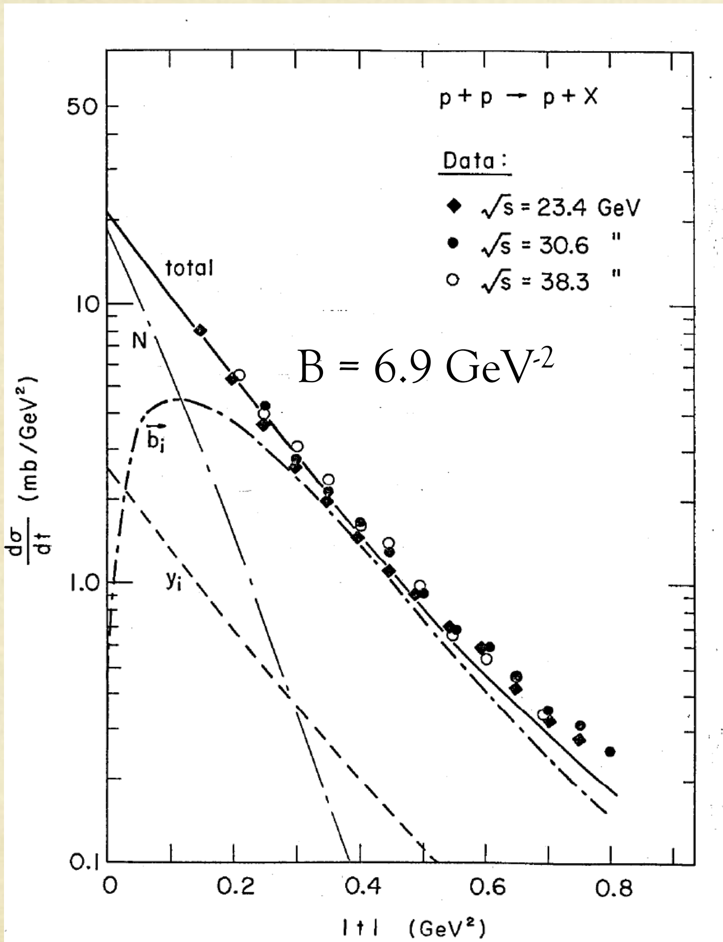
diffraction is peripheral – strongly influenced by unitarity

at $\sqrt{s} \approx 1\text{TeV}$ and $b \approx 0$,

$\sigma_{el} \approx \frac{1}{2}\, \sigma_{tot} \approx \frac{1}{4}$

$\sigma_{diff}^{inel} \leq 0.01$

DIFFRACTION AT THE ISR ($0.95 < x_F < 1.0$)

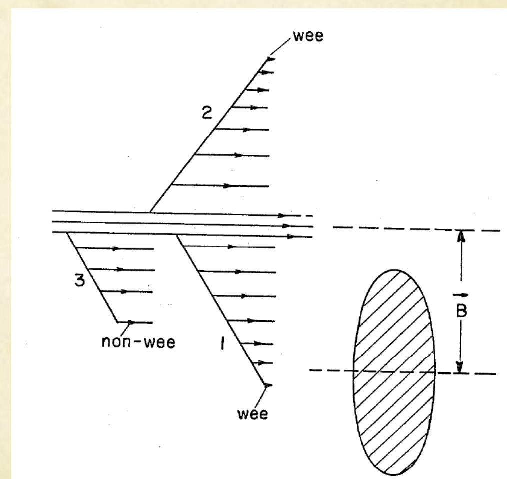


Miettinen & Pumplin, PRD 1978

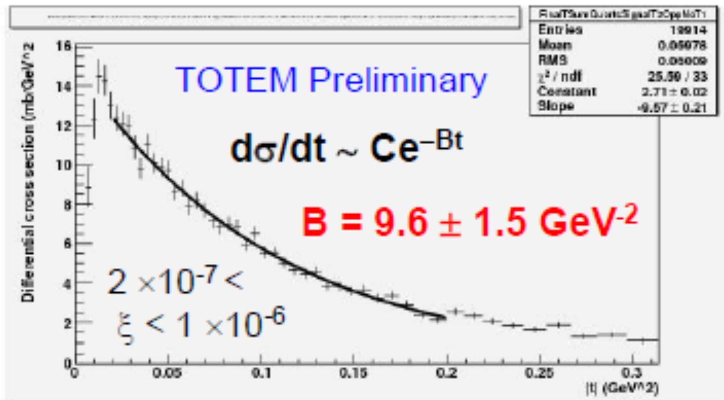
Diffraction due to peripheral interactions;
fluctuations in :

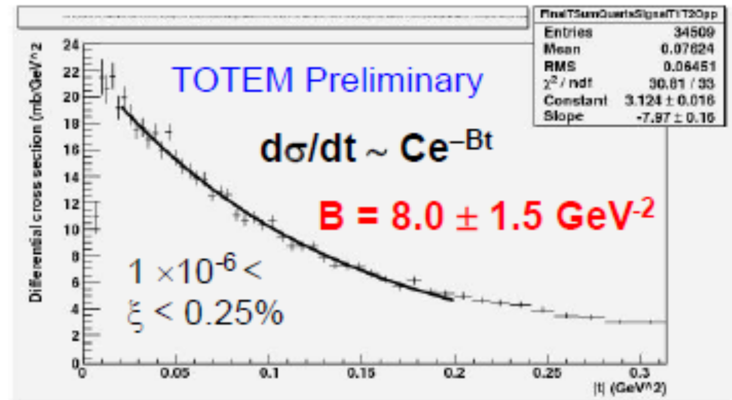
- impact parameter 45%
- number of 45%
- rapidities 10%

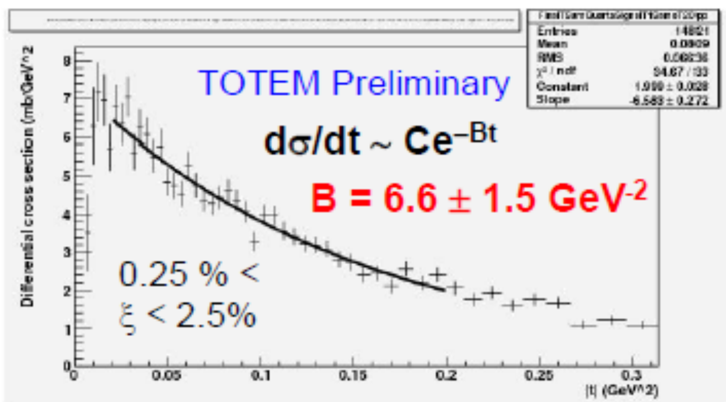
of the wee partons.



SINGLE DIFFRACTION: dσ/dt vs. ξ







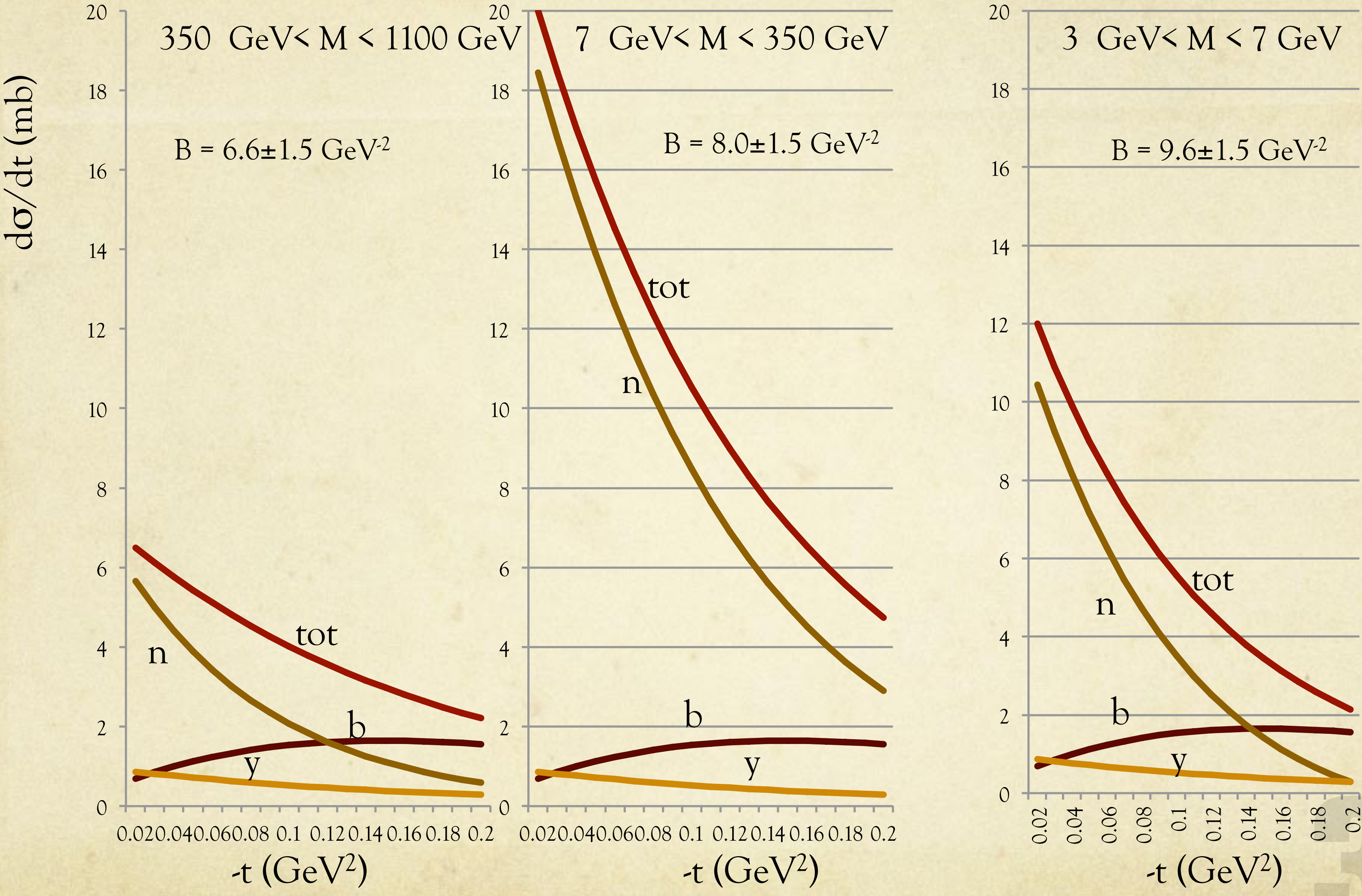
t-distributions still to be corrected for beam divergence & effect of ξ on proton ϕ-acceptance correction

$$\frac{d\sigma_{SD}^{class\ i}}{dt} = e^{-B_i t} - \text{backgr.}$$

$$\sigma_{SD}(\xi > 2\times10^{-7}) = \sum_i \int_0^\infty dt \frac{d\sigma_{SD}^{class\ i}}{dt}$$

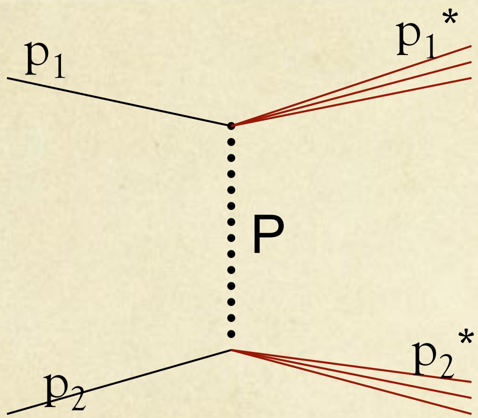
Note: There is a minimum value of –t: $|t_{\min}| = \left[(M_X^2 - m_p^2)/2p\right]^2$

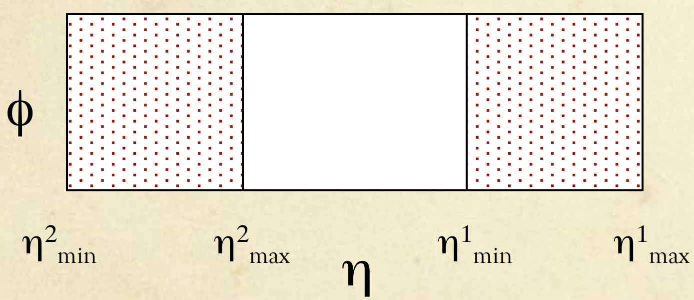
DIFFRACTION at LHC vs. Miettinen&Pumplin model

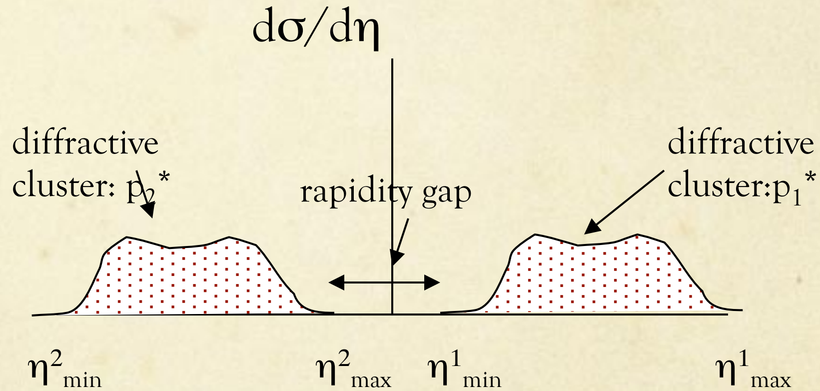


At small diffractive masses (small ξ values), fluctuations in **number of wee states** grows in relative importance vs. b- or y- fluctuations

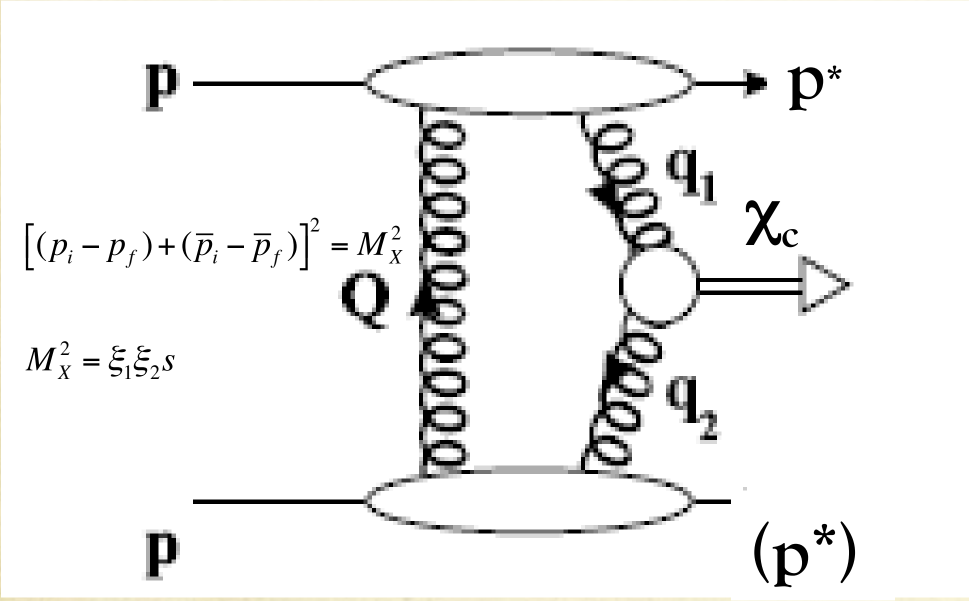
SIGNATURES: DOUBLE DIFFRACTION







CENTRAL EXCLUSIVE PRODUCTION



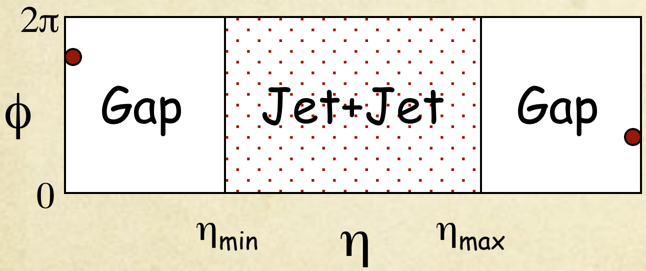
CEP transforms LHC into a gluon factory, 1/3000 pure gluon jets

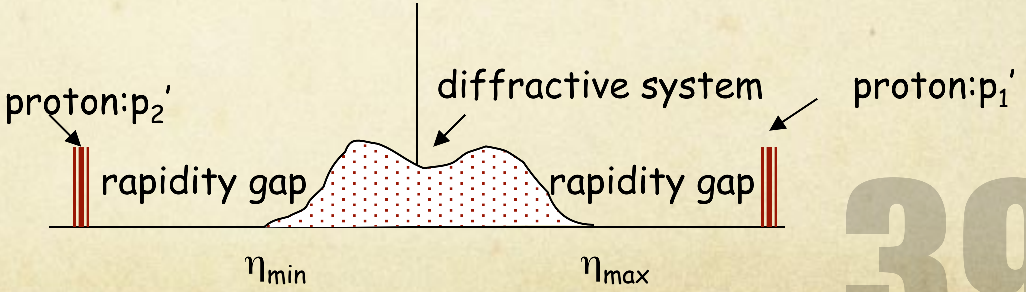
$J^{PC} = 0^{++}, ..$

Measure the parity $P = (-1)^J$: $d\sigma/d\varphi \propto 1 + \cos 2\varphi$

Is well identified whenever forward rapidities are well covered – FSCs&ZDCs – and **pile-up** is under control – $L \leq 10^{30}\ cm^{-2}s^{-1}$

ALICE event rates ~ 200 kHz ⇒ large statistics during the nominal LHC runs

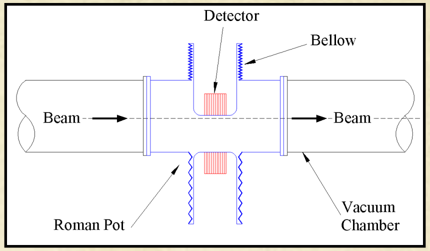




see the poster by Sofia Patomäki

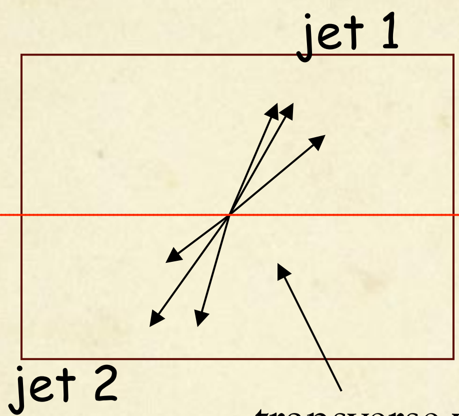
MASS X IN $p_1p_2 \to p_1' + X + p_1'$ MEASURED AS:

$$M_X^2 = (p_1 + p_2 - p_1' - p_2')^2$$

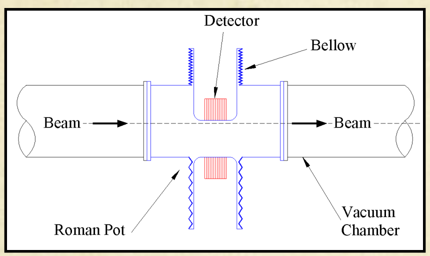


p_1'

- fwd neutron or a deflected proton measured here



p_2'



-beam energy spread?

- transverse vx position?

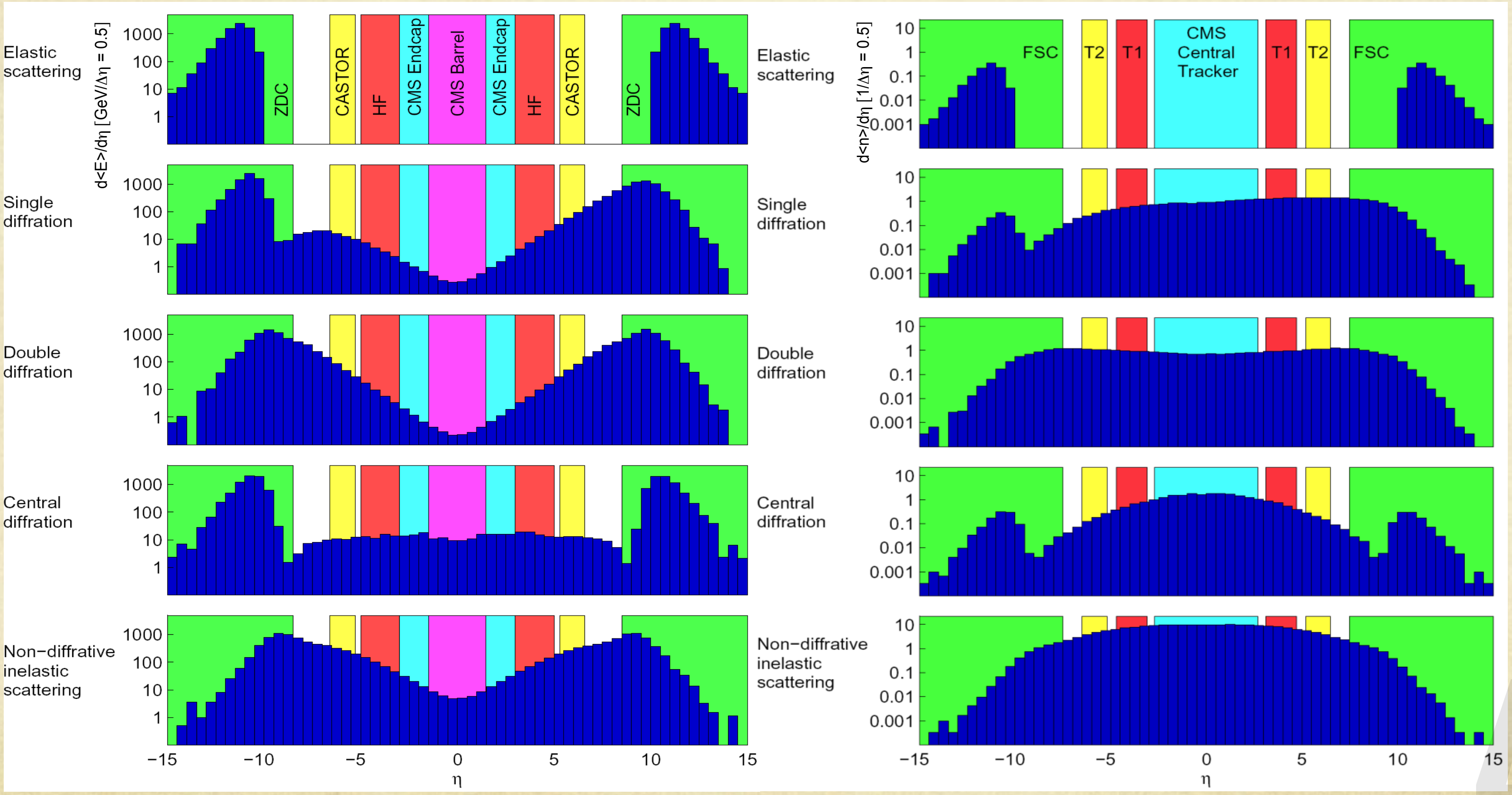
- leading neutrons or protons on both sides

- a central system separated by rap gaps

AVAILABLE DETECTOR INFORMATION vs. RAPIDITY – INPUT TO MULTIVARIATE EVENT CLASSIFICATION

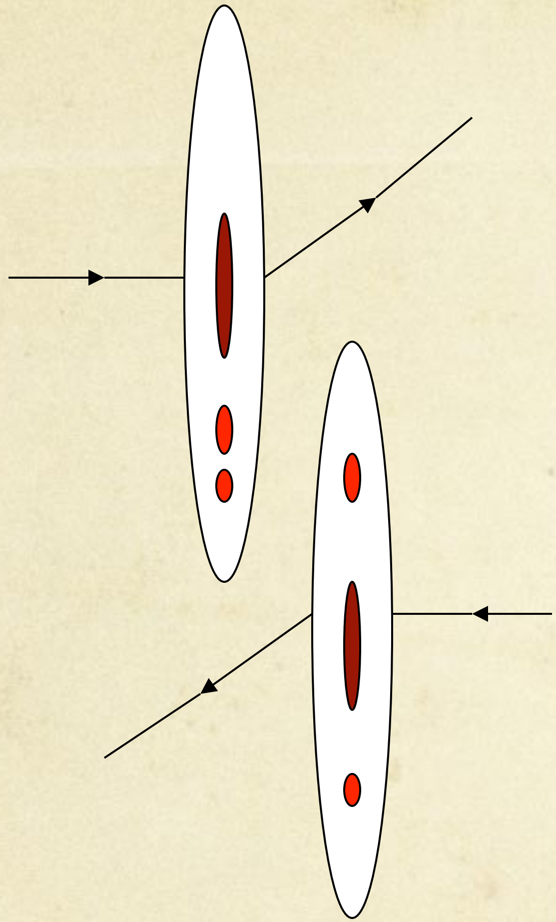
ENERGIES

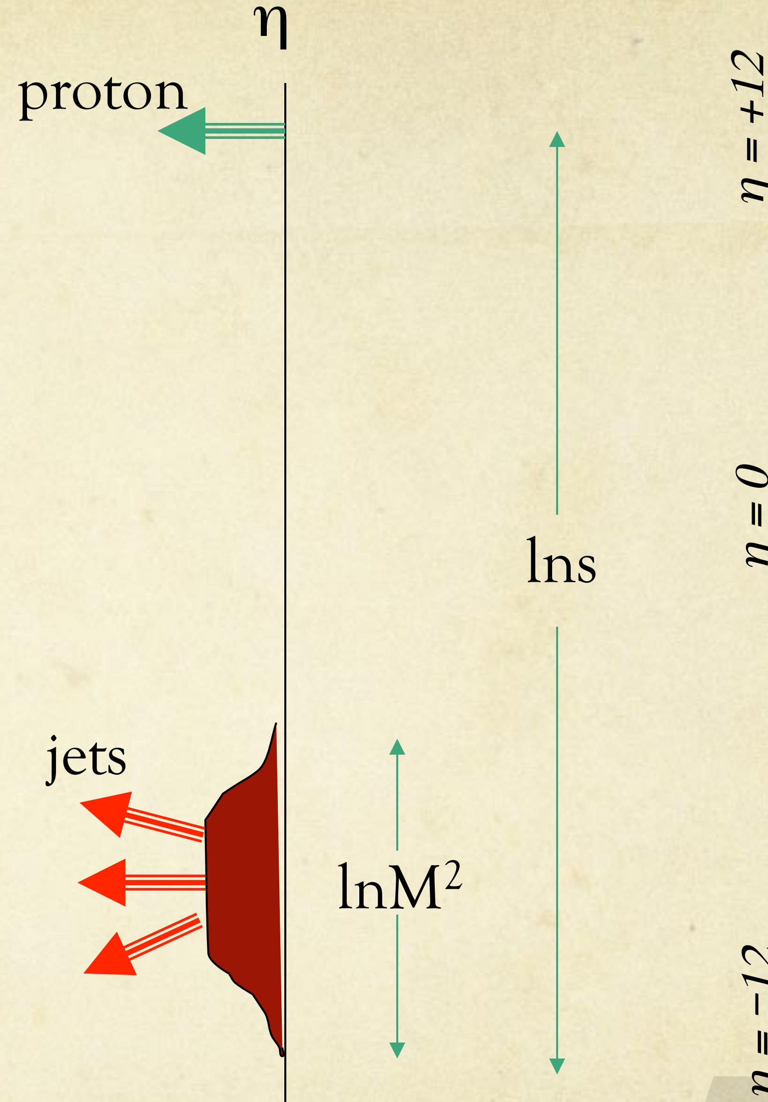
MULTIPLICITIES



see the talk by Mikael Mieskolainen

MULTIPLE GAPS IN RAPIDITY?





'hot spots' – vacuum fluctuations of the 'wee' partons in the gluon cloud of protons?

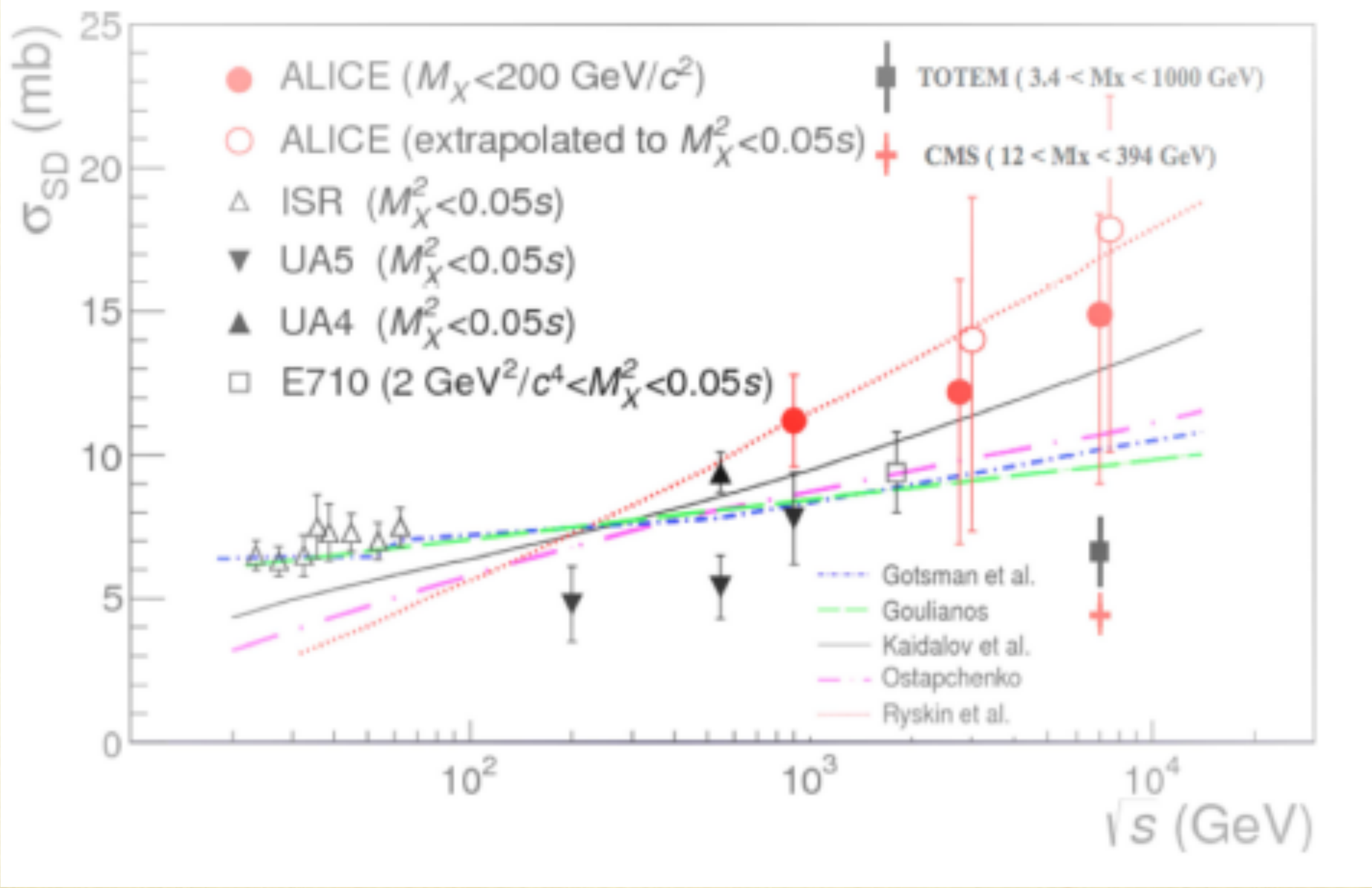
SINGLE DIFFRACTION - SUMMARY

Experiment	Energy TeV	Mass GeV	σ (sd) mb
ALICE	2.76	0-200	$12.2^{+3.9}_{-5.3}$
ALICE	7	0-200	$14.9^{+3.4}_{-5.9}$
CMS	7	12-394	$4.27 \pm 0.04^{+0.65}_{-0.58}$
TOTEM	7	3.4-1100	6.5 ± 1.3
TOTEM	8	3.4-1100	

LOW MASS SINGLE DIFFRACTION - TOTEM

M_{Diff} GeV	<3.4	3.4-1100	3.4-7	7-350	350-1100
TOTEM	2.62±2.17	6.5±1.3	≈1.8	≈3.3	≈1

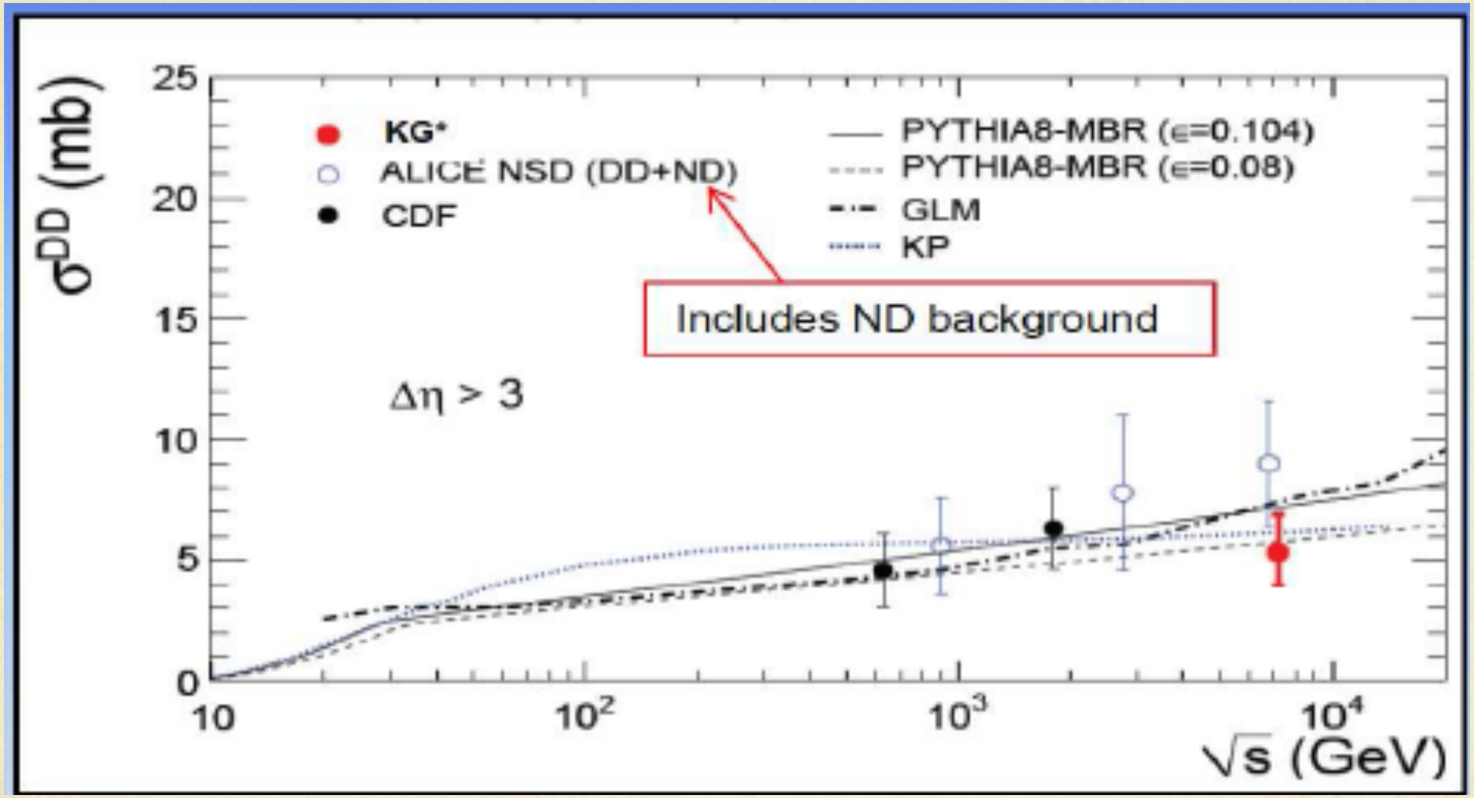
SINGLE DIFFRACTION - SUMMARY



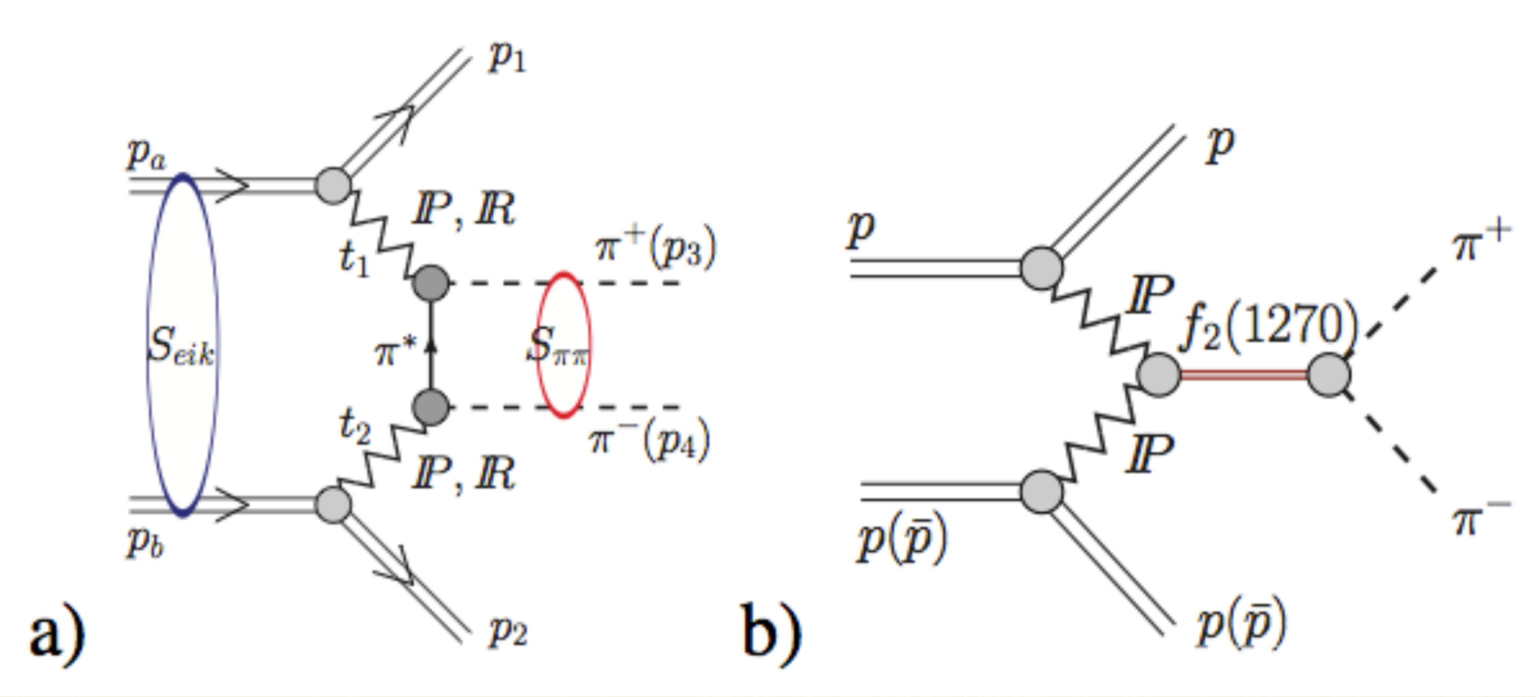
DOUBLE DIFFRACTION - SUMMARY

Experiment	Mass GeV	σ_{dd} mb
ALICE	0-200	9.0 ± 2.6
CMS	$M_{X,Y}>10;\Delta\eta>3$	$0.93 \pm 0.01^{+0.26}_{-0.22}$
TOTEM	$3.4<M_{Diff}<8$	0.116 ± 0.025
PYTHIA 8		0.159
PHOJET		0.101

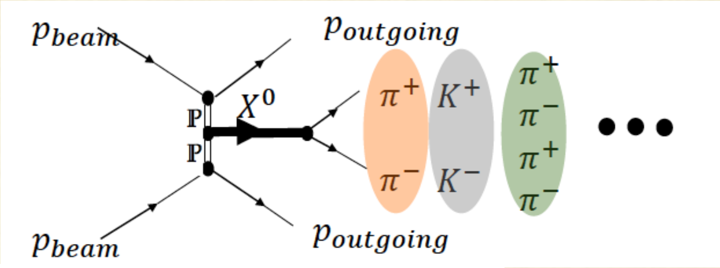
DOUBLE DIFFRACTION - SUMMARY

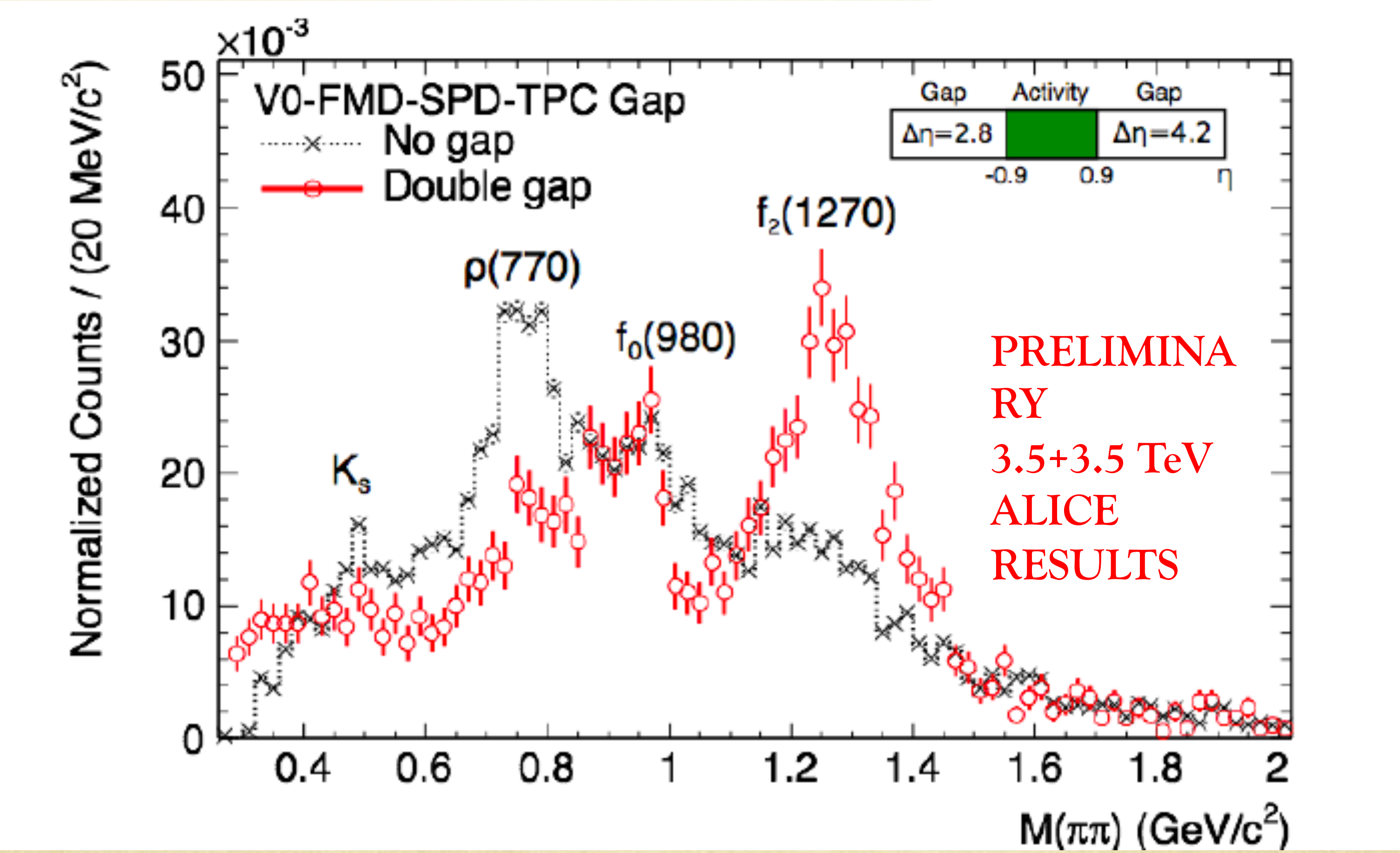


SOFT CENTRAL DIFFRACTION



CENTRAL ππ MASS: EXCLUSIVE vs. INCLUSIVE

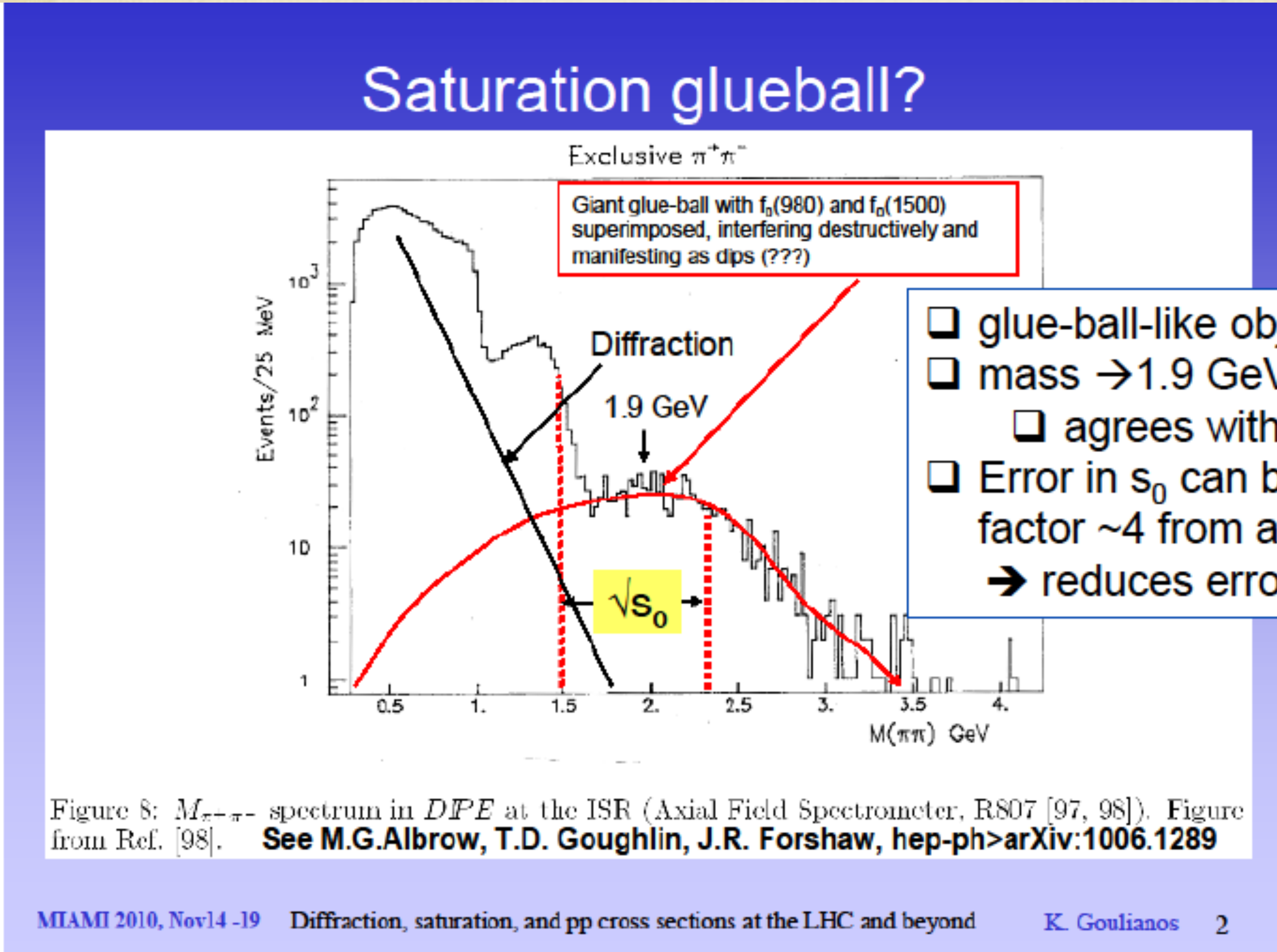




PRELIMINARY
3.5+3.5 TeV
ALICE
RESULTS

see the poster by Sofia Patomäki

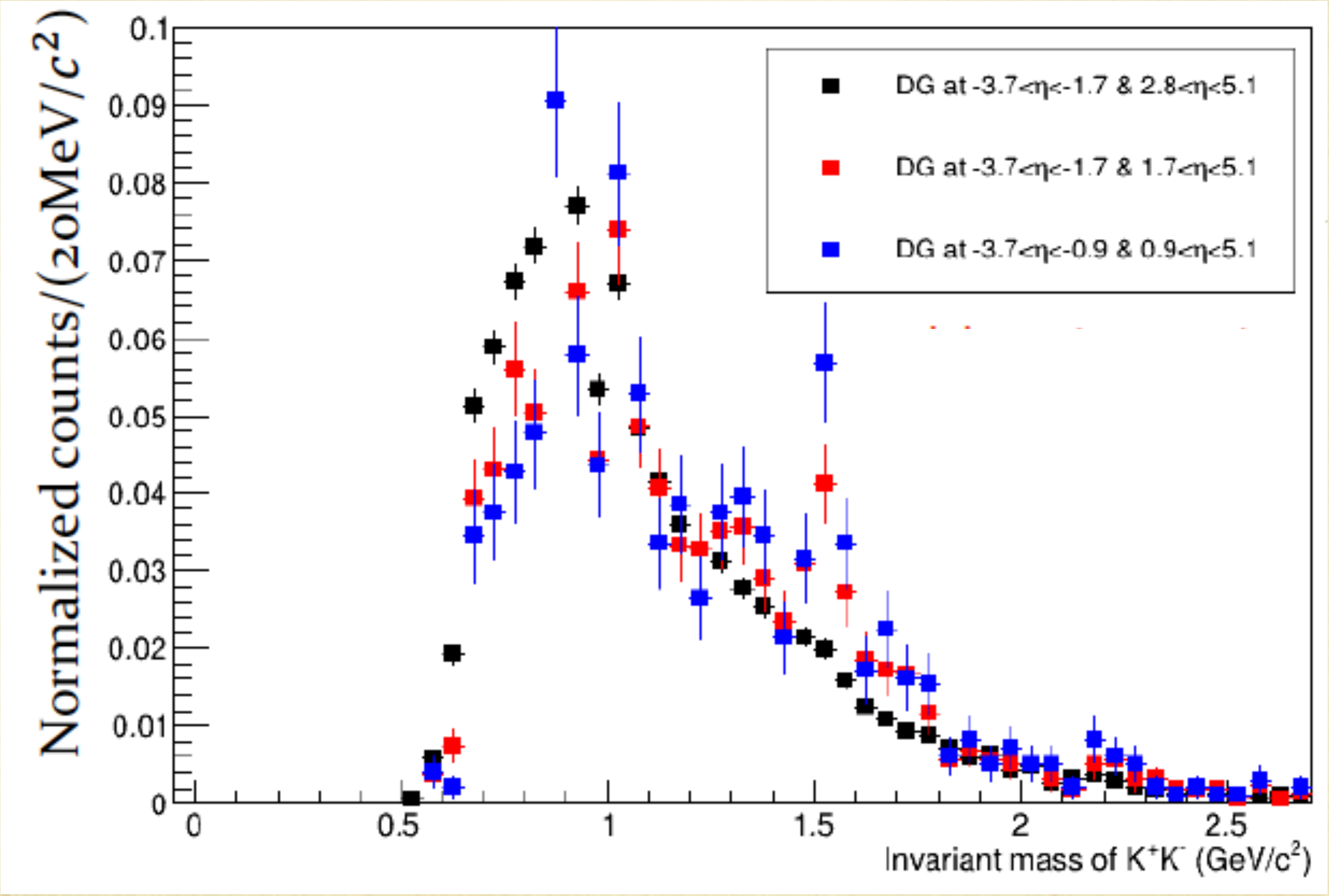
DINO's GLUEBALL?



- ❑ glue-ball-like object ➔ "superball"
- ❑ mass →1.9 GeV ➔ m_s^2= 3.7 GeV
  - ❑ agrees with RENORM s_o=3.7
- ❑ Error in s_0 can be reduced by factor ~4 from a fit to these data!
  ➔ reduces error in σ_t.

WE-Heraeus-15 - R. Orava - Aug'15

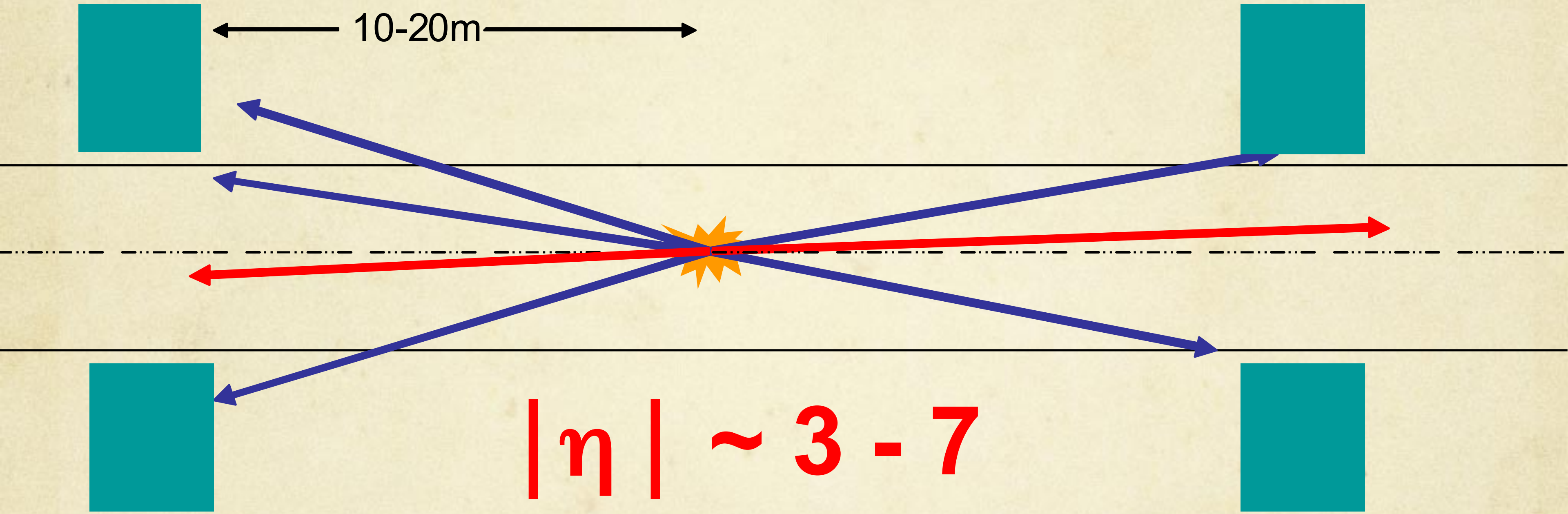
CENTRAL K^+K^- MASS vs. RAP GAP SELECTION - PRELIMINARY!



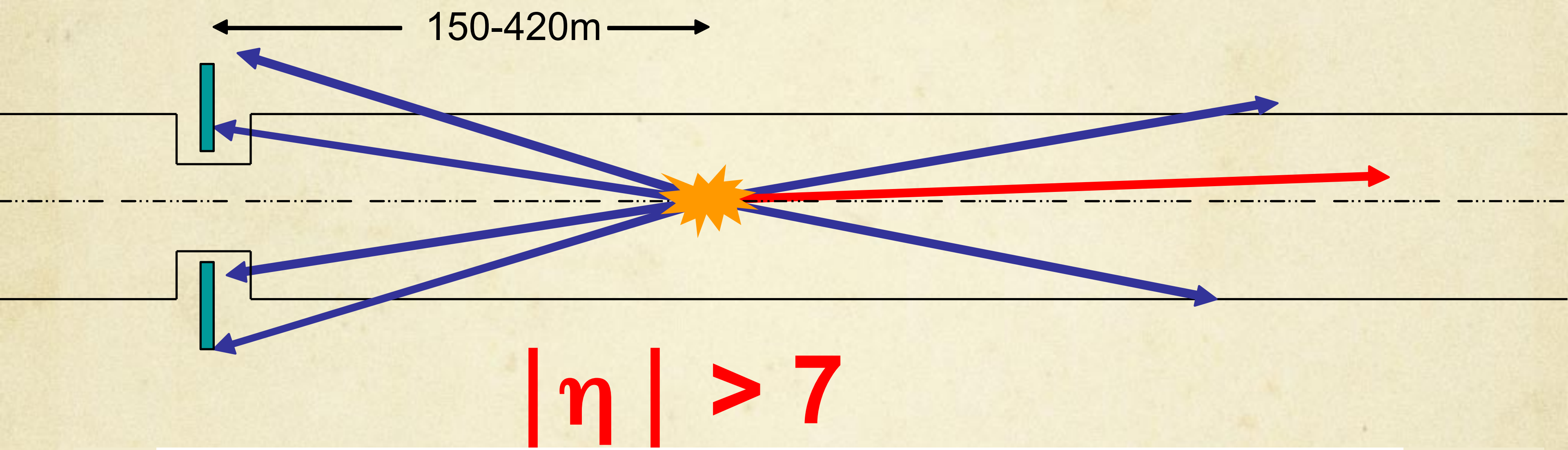
PID is the key! see the poster by Marc Härkönen

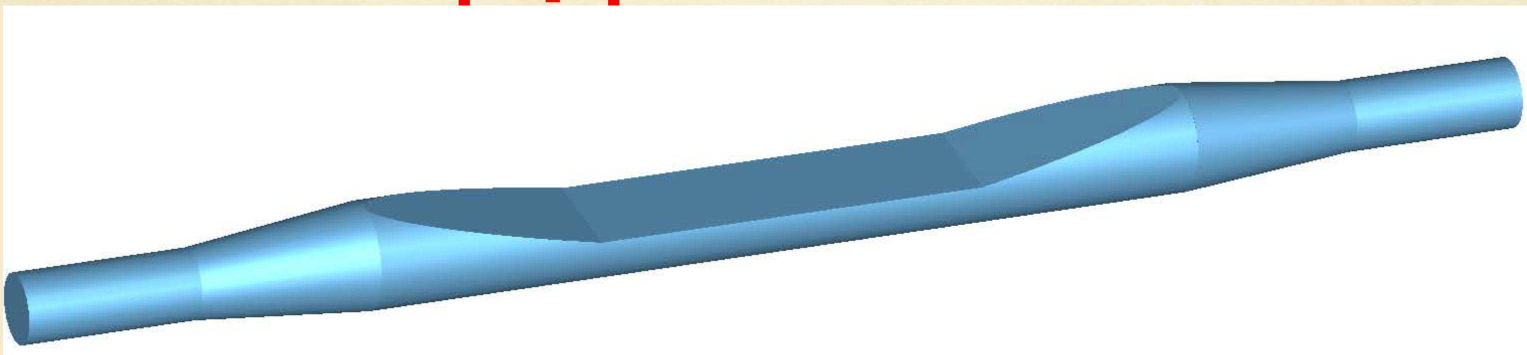
Forward Particle Detection at the LHC (1): Surround the Beam Pipe

CALORIMETRY
TRACKING

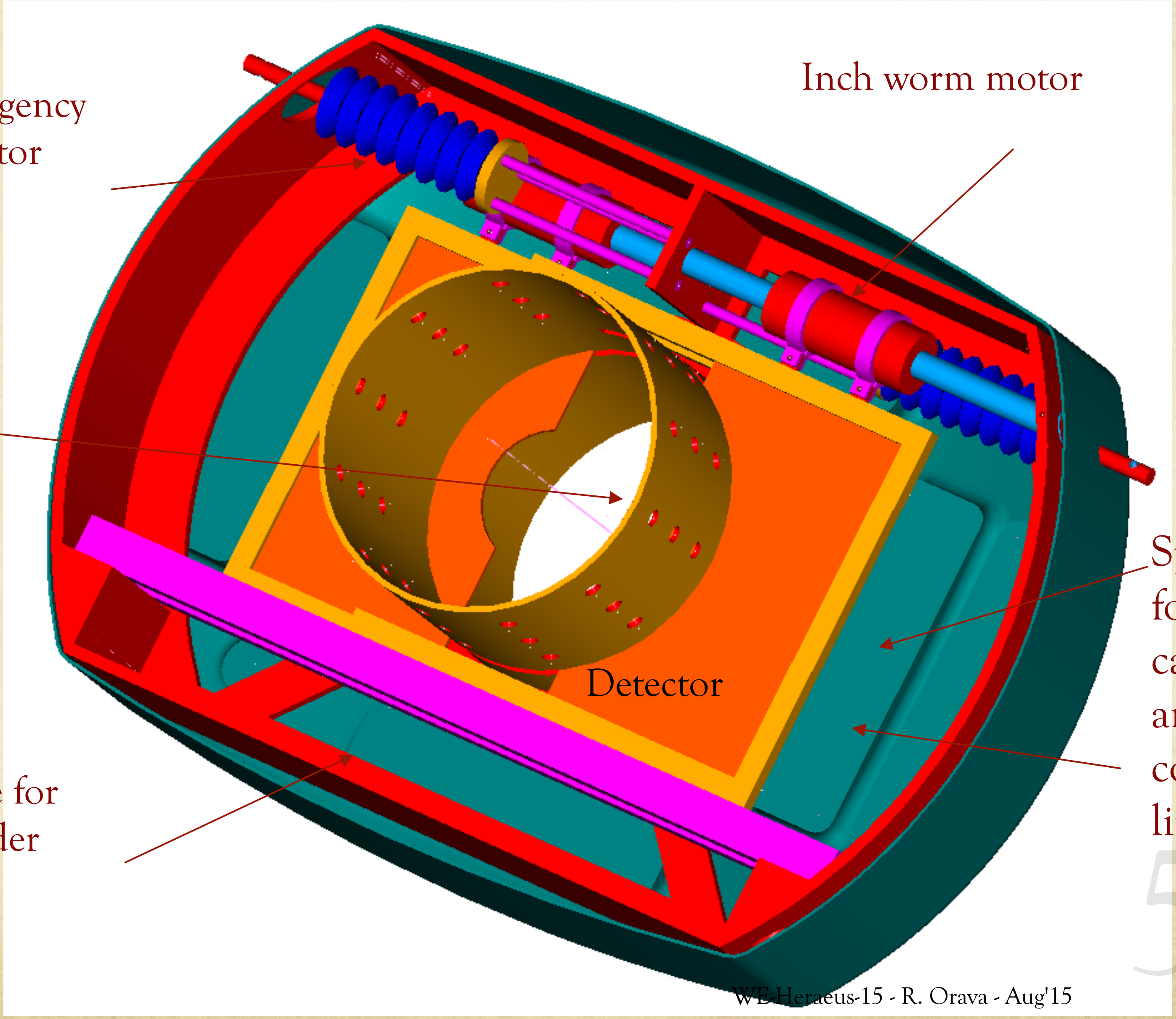


Forward – Very Forward – Particle Detection at the LHC (2): Go into the Beam Pipe (or Move It!)





μStation - the ultimate fwd particle detector



SMALL MASS REGION DOMINATED BY N* RESONANCES

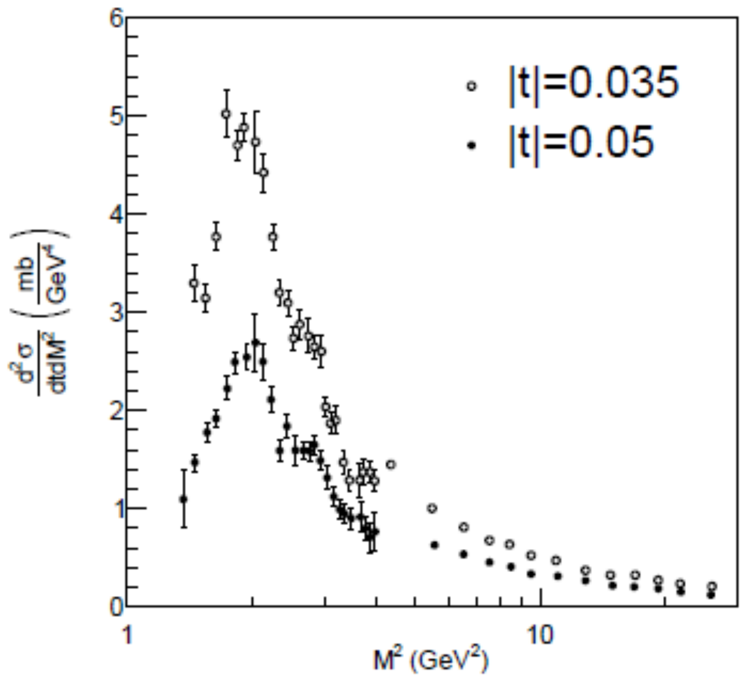
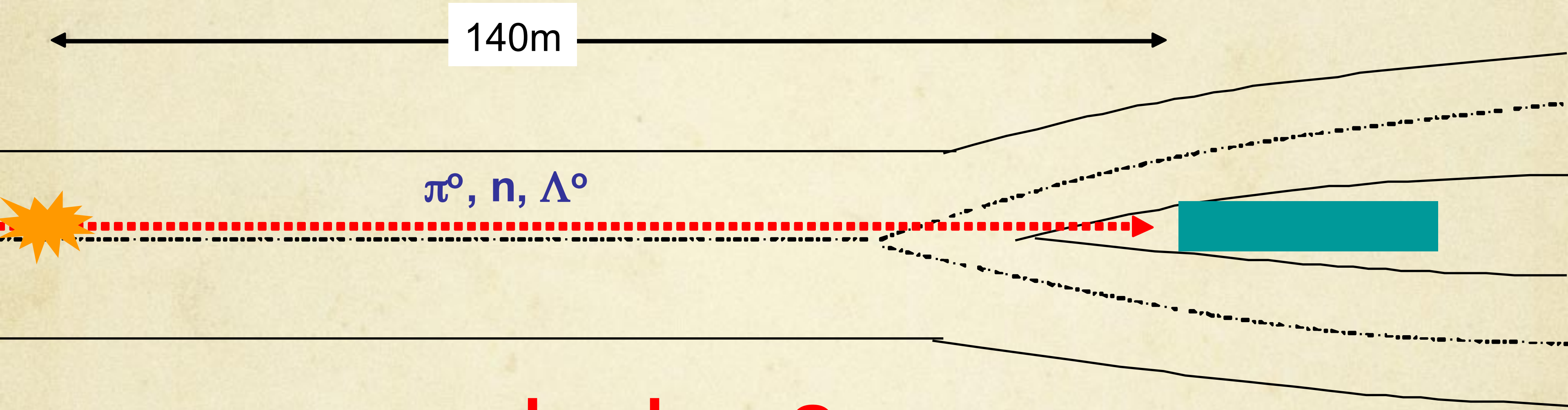


Fig. 1 Compilation of low-mass SD data form Fermilab experiments $p + d \to X + d$, $P_{lab} = 275\,\mathrm{GeV/c}$, see [2]. The first peak has the mean value of $M_{X,1} = 1400\,\mathrm{MeV}$ and the second bump has $M_{X,1} = 1688\,\mathrm{MeV}$, wich correspond to the masses of N^* resonances, see Sec. 4.2

N*(1680MeV)

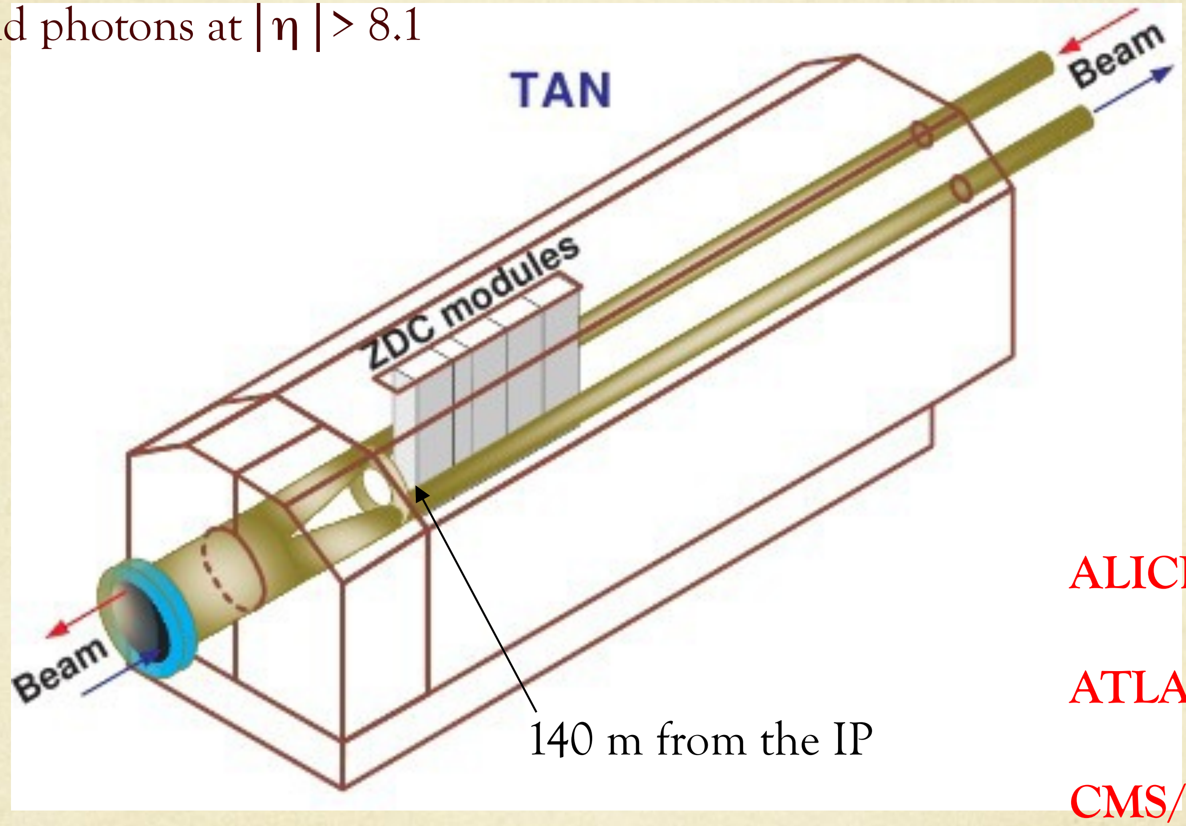
Forward – Very Forward – Particle Detection at the LHC (3): Use the beam split region (ZDC's)



$|\eta| \geq 8$

Zero Degree Calorimeter - ZDC

Quartz fiber Tungsten sampling calorimeter
for neutrons and photons at $|\eta| > 8.1$



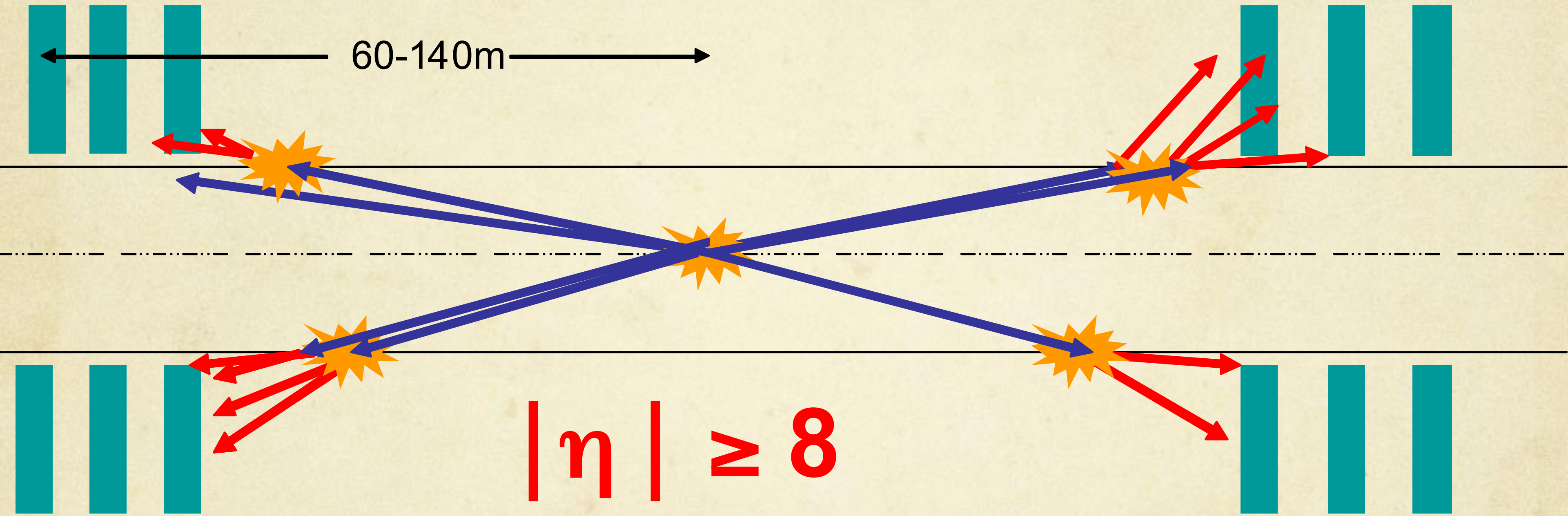
ALICE

ATLAS/LHCf

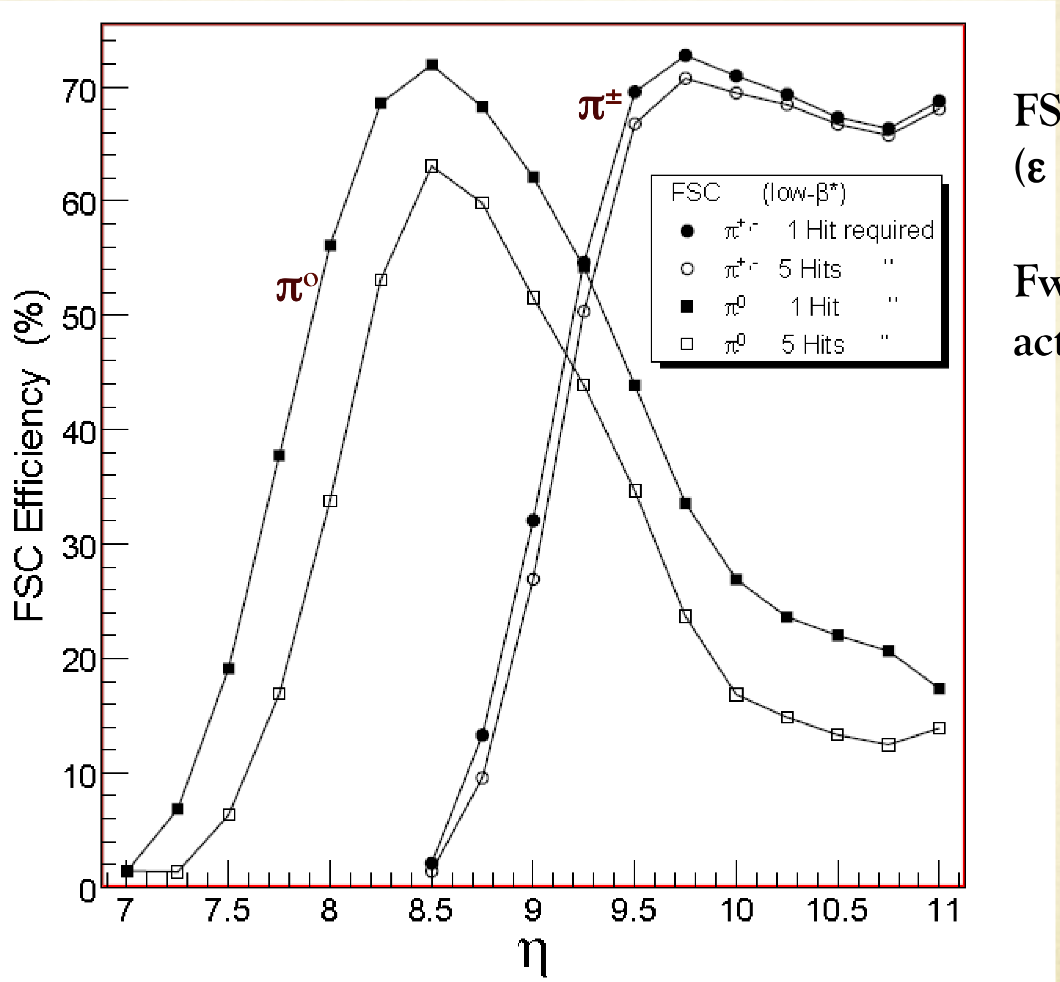
CMS/TOTEM

Reconstruction of π^0, η, η', Δ, Σ, Λ

Forward – Very Forward – Particle Detection at the LHC (4): Detect the showers (FSCs)



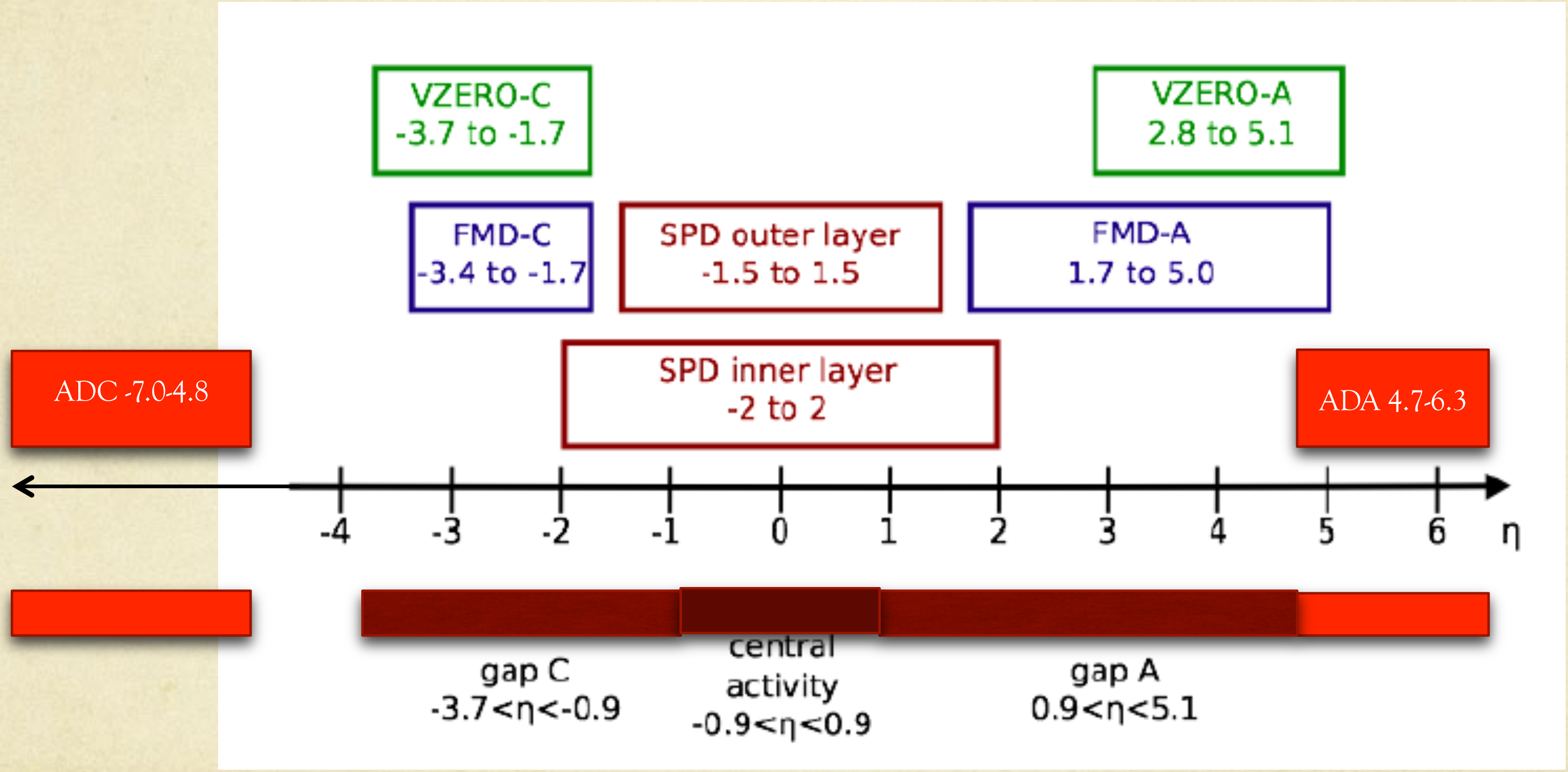
FORWARD DETECTION EFFICIENCIES ARE IMPROVED



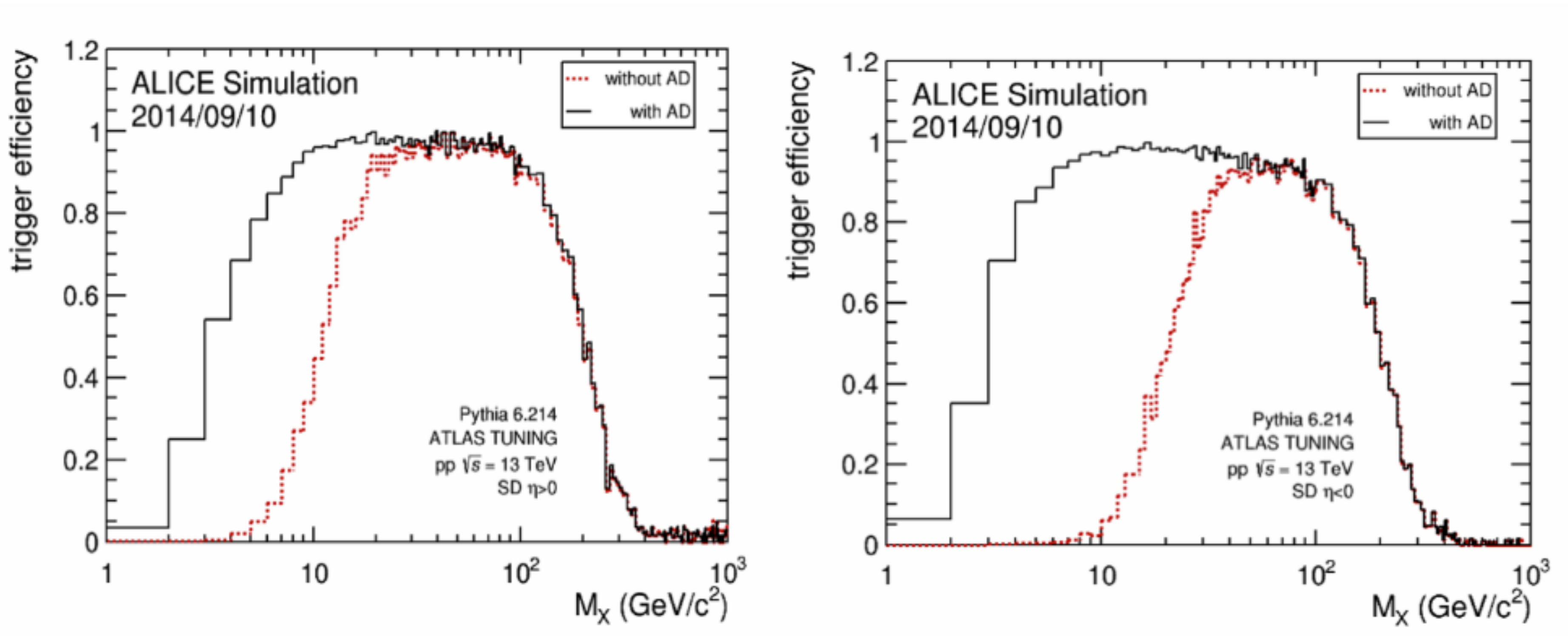
FSCs see forward particles (ε =50%) with rapidities $|\eta| > 8$

Fwd particles detected via inter-actions in the beam pipe

ALICE FORWARD DETECTORS – ADA/ADC COMPLETE THE COVERAGE



ADC FORWARD TRIGGER EFFICIENCY

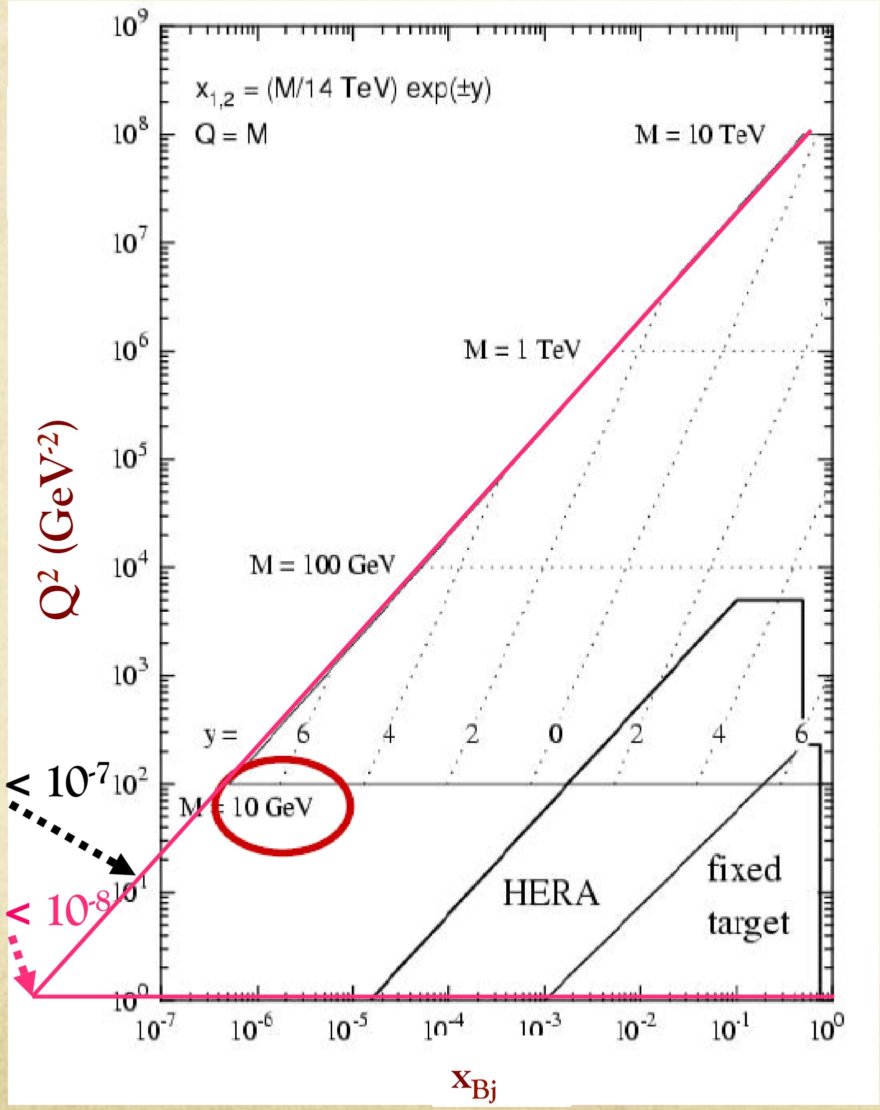


50% acceptance at 3 GeV

by Ernesto Calvo

efficiency down to lowest
N* masses

ACCEPTANCE in x_{Bj}-Q^2



With the current forward detectors ALICE reaches forward masses of ≈ 3 GeV

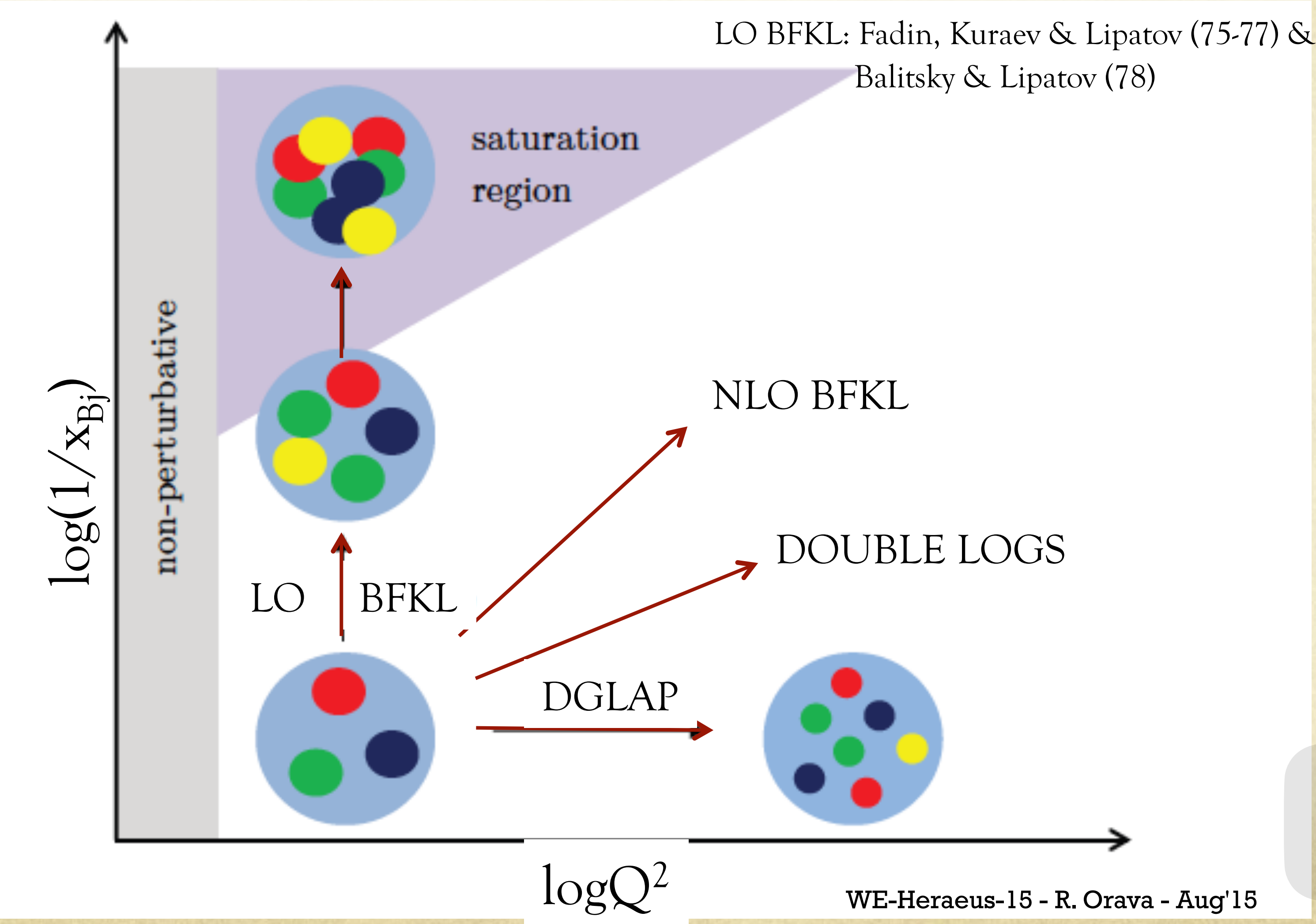
⇒ $x \leq 10^{-7}$

With a reduced efficiency reach ≈ 1.1 GeV forward masses

⇒ $x \leq 10^{-8}$

CMS and LHCb experiments are been upgrading their forward detector systems.

DIFFERENT PARTON CONFIGURATIONS ARE RESOLVED DEPENDING ON x_{Bj} and Q^2



DIFFRACTIVE SCATTERING MAPS OUT CONFIGURATIONS OF PARTONS (QUARKS AND GLUONS) CONFINED WITHIN HADRONS

• DESCRIBED EITHER IN PRODUCTION (s-CHANNEL) OR IN EXCHANGE (t-channel) PROCESS – OPTICAL ANALOGY

• DIFFRACTION IS CHARACTERIZED BY PHERIPHERAL VACUUM FLUCTUATIONS – NUMBER FLUCTUATIONS OF 'WEE' PARTONS DOMINATE WITH INCREASING ENERGIES

• DIFFRACTIVE PROCESSES WITH A HARD SCALE CALCULABLE IN pQCD – BFKL, CEP,..

• CENTRAL EXCLUSIVE PROCESS AS A GLUON FACTORY, J^{PC} QUANTUM NUMBER FILTER, DISCOVERY MACHINE..

• CLASSIFICATION OF DIFFRACTIVE SCATTERING ENTERS NEW ERA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