

Central, exclusive diffraction in pp collisions at $\sqrt{s} = 7$ TeV observed in the ALICE experiment



Jan Figiel
for the ALICE collaboration



The Henryk Niewodniczański Institute of Nuclear Physics, Cracow

Central, exclusive diffraction in pp collisions at $\sqrt{s} = 7$ TeV observed in the ALICE experiment

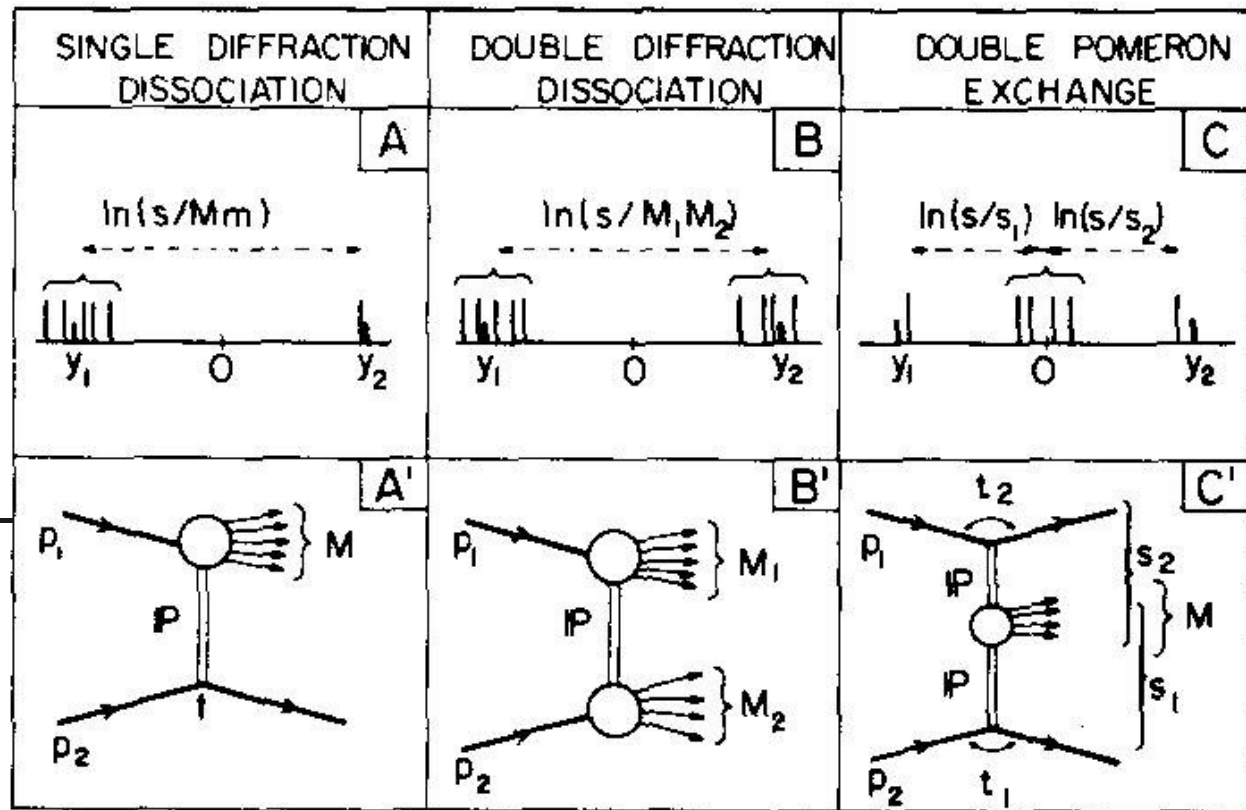
Topology of central diffraction:

- „intact” final protons (or diss.?)
- two rapidity gaps
- hadronic state X in centre

If Double Pomeron Exch. (**DPE**)

X is scalar or tensor:

$Q=0, I=0, J=0,2,\dots, G=C=P=+1$



(This figure is from ISR times...)

Central, exclusive diffraction in pp collisions at $\sqrt{s} = 7$ TeV observed in the ALICE experiment

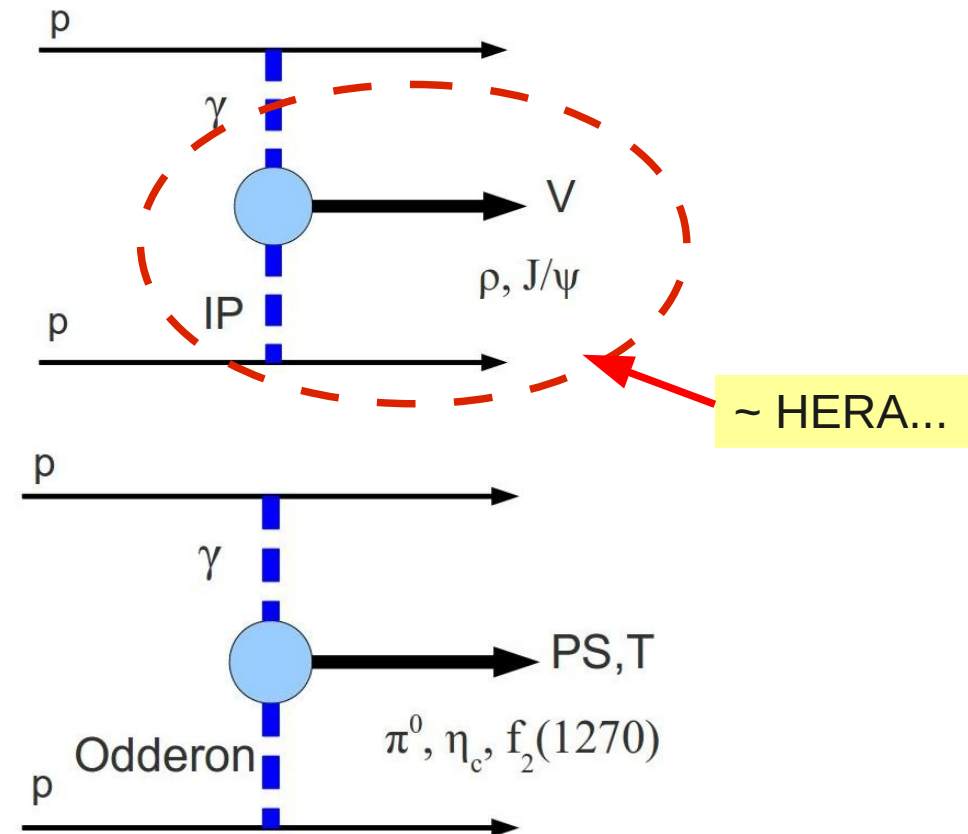
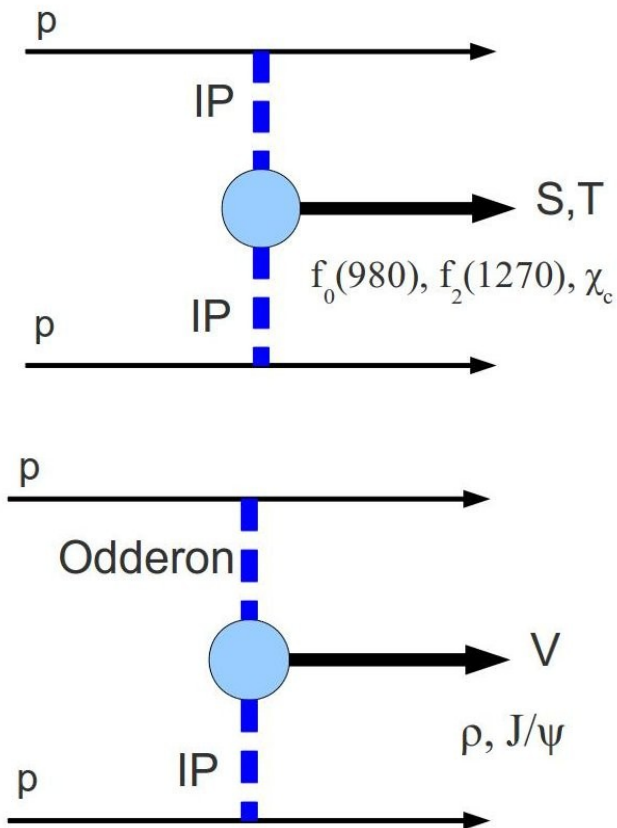
Possible exchanges:

Pomeron ($C=+1$), QCD: 2 gluons,

Odderon ($C=-1$), QCD: 3 gluons

Photon γ ($C=-1$),

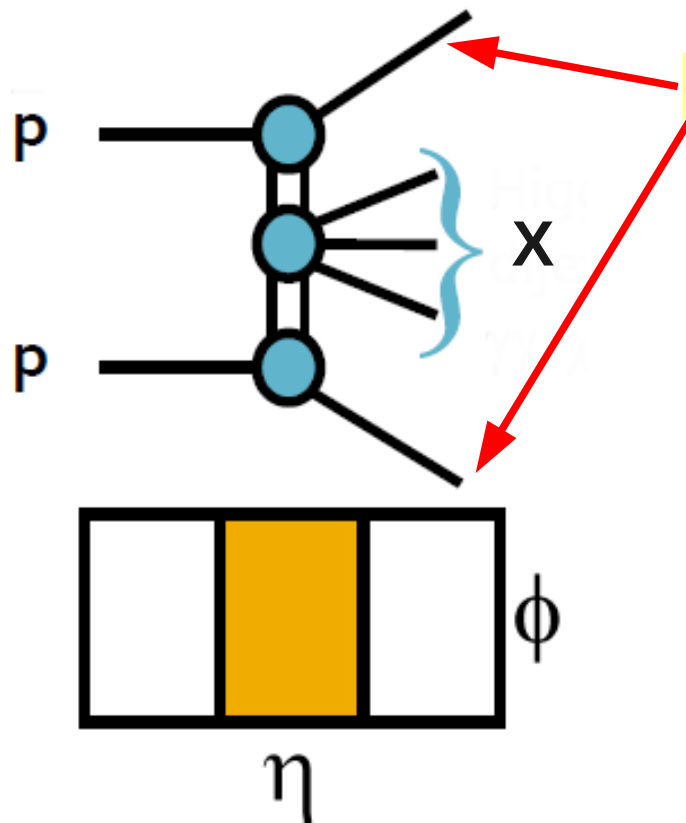
Type	Meson	I^G	J^{PC}
S	$f_0/\sigma(600)$, $f_0(980)$, χ_c	0^+	0^{++}
PS	π^0 , η_c	1^-0^+	0^+
V	ρ^0 , J/ψ	1^+0^-	1^-
T	$f_2(1270)$	0^+	2^{++}



Central, exclusive diffraction in pp collisions at $\sqrt{s} = 7$ TeV observed in the ALICE experiment



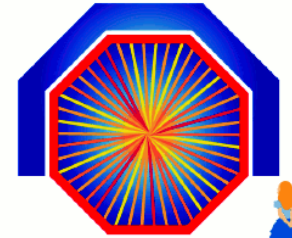
Central diffraction in ALICE ?



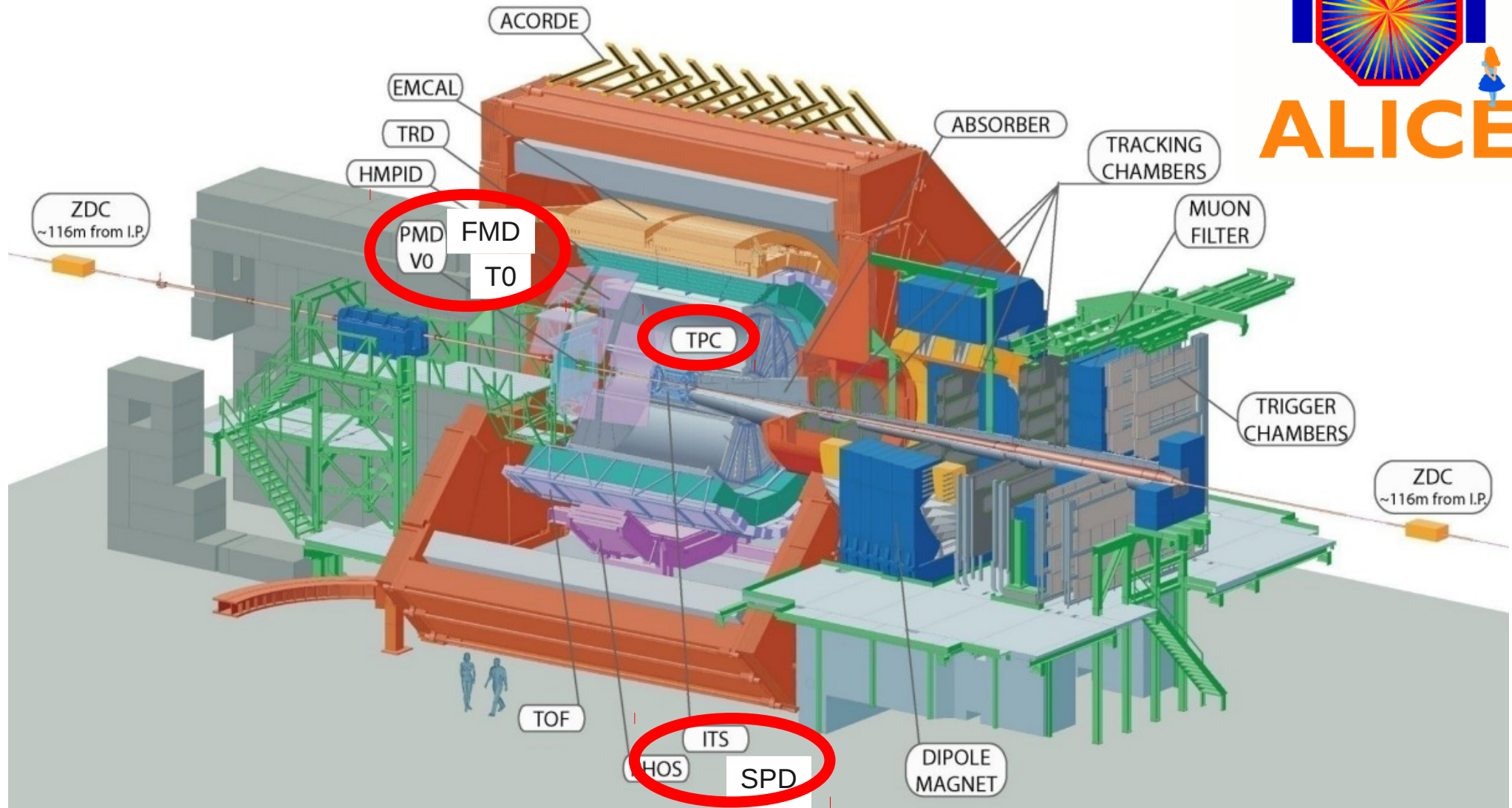
Protons „intact” or dissociate into low mass state...

- - Detector optimised for heavy-ion studies not diffraction...
- +++ excellent detection and identification of charged particles in the „centre”
- ++ good coverage of broader rapidity range
→ rapidity gaps
- ++ one should **try!**

Central, exclusive diffraction in pp collisions at $\sqrt{s} = 7$ TeV observed in the ALICE experiment



ALICE



Central, exclusive diffraction in pp collisions at $\sqrt{s} = 7$ TeV observed in the ALICE experiment

Particle detection

TPC and SPD:

$$-0.9 < \eta < 0.9$$

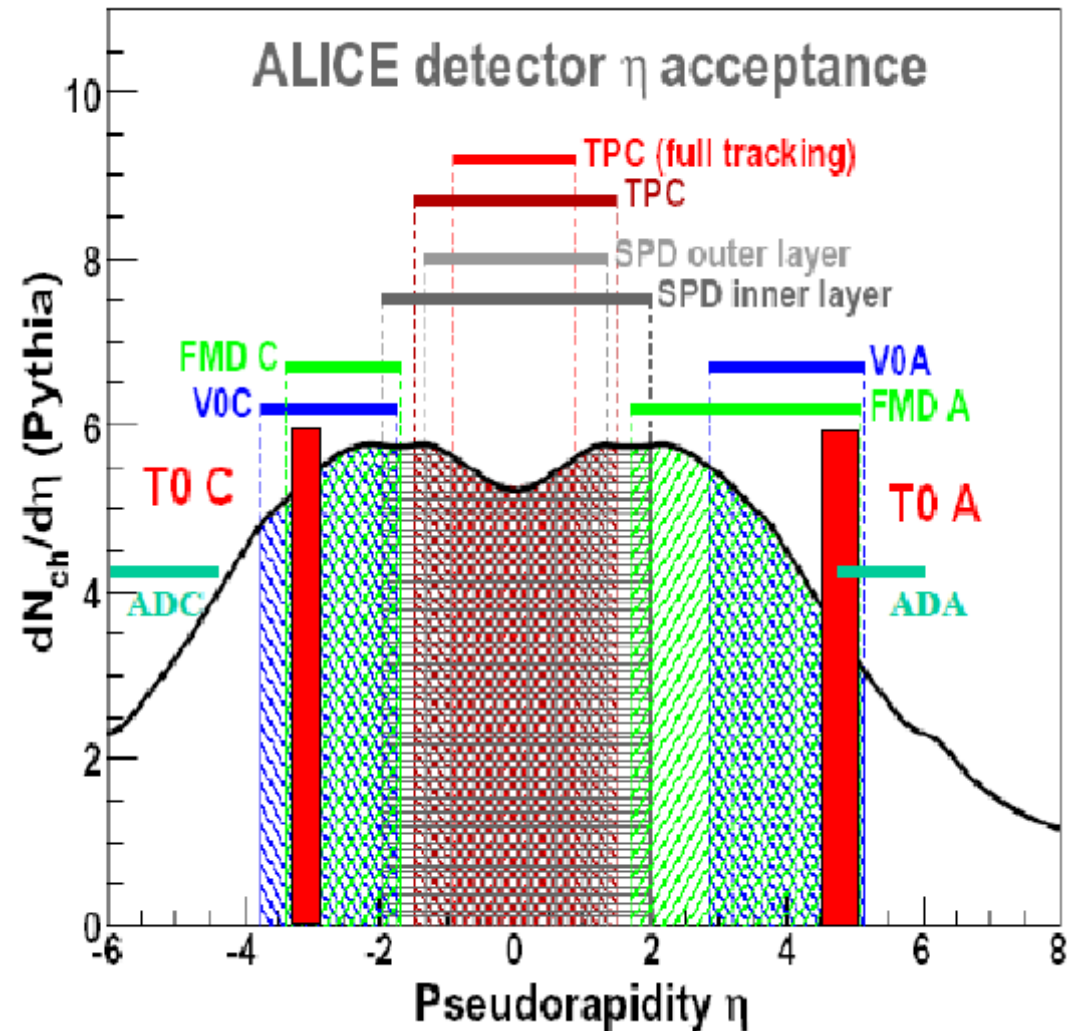
V0, FMD, SPD:

$$-3.7 < \eta < -0.9, \quad (\text{C})$$

$$0.9 < \eta < 5.1, \quad (\text{A})$$

⇒ **Double gap:**

No activity for $|\eta| > 0.9$



Charged particles: **$-3.7 < \eta < 5.1$** (~9 units of rapidity!)

Central, exclusive diffraction in pp collisions at $\sqrt{s} = 7$ TeV observed in the ALICE experiment

LHC2010: pp@7TeV, Trigger „minimum bias (MB)” (SPD, V0A, V0C)

Primary vertex and exactly 2 **TPC+ITS** tracks:

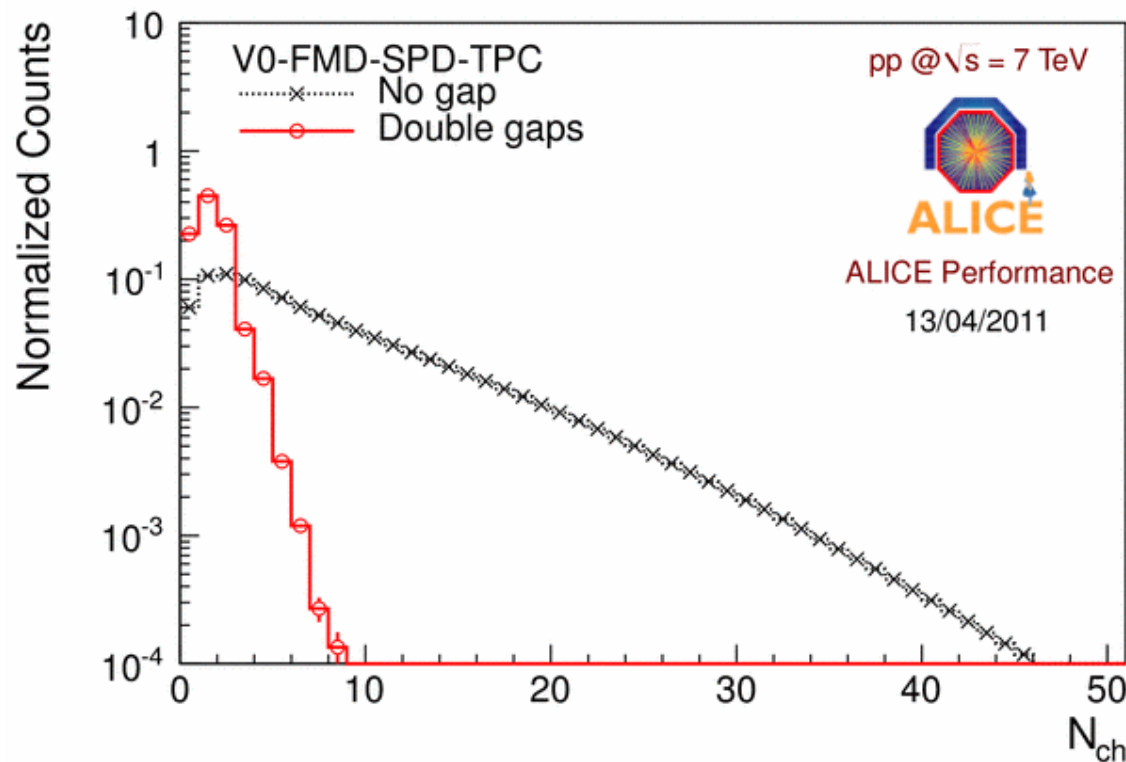
32.3 M events,

Gap A: no activity $0.9 < \eta < 5.1$ (**V0A, FMD, SPD**),

Gap C: no activity $-3.7 < \eta < -0.9$ (**V0C, FMD, SPD**)

Two rapidity gaps (gap A **and** gap C):

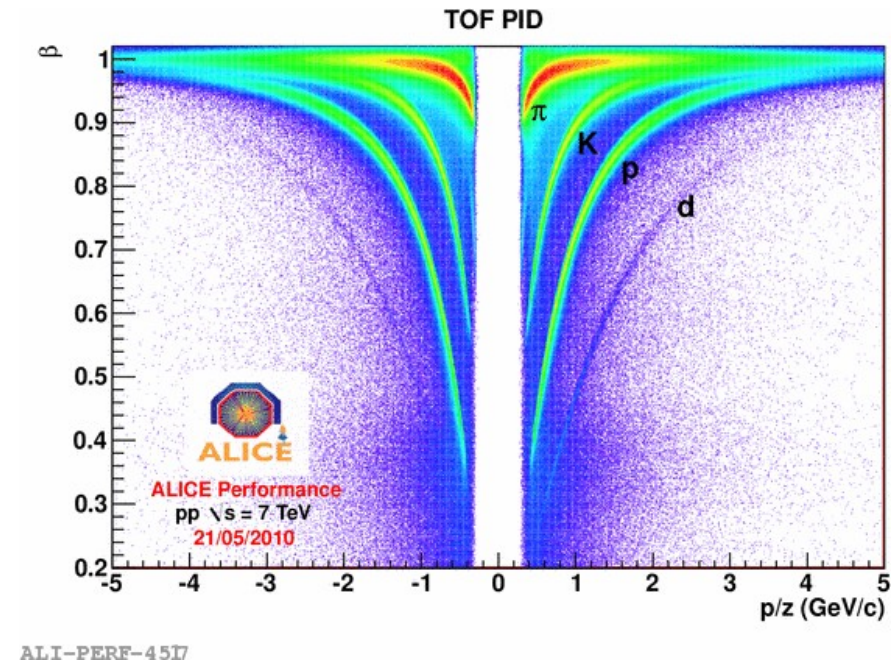
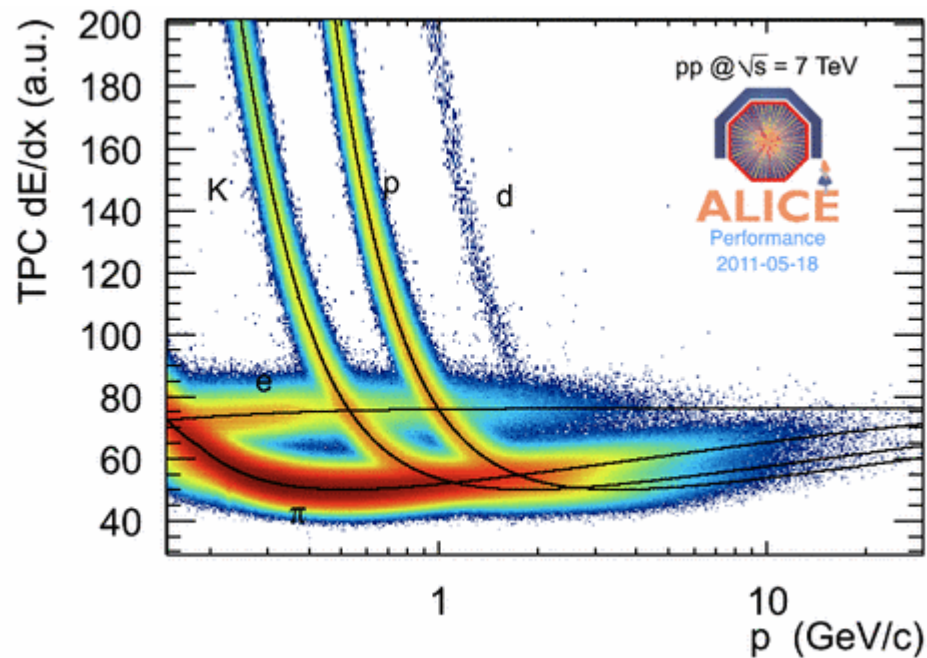
0.15 M events



ALI-PERF-4063

Central, exclusive diffraction in pp collisions at $\sqrt{s} = 7$ TeV observed in the ALICE experiment

Particle identification

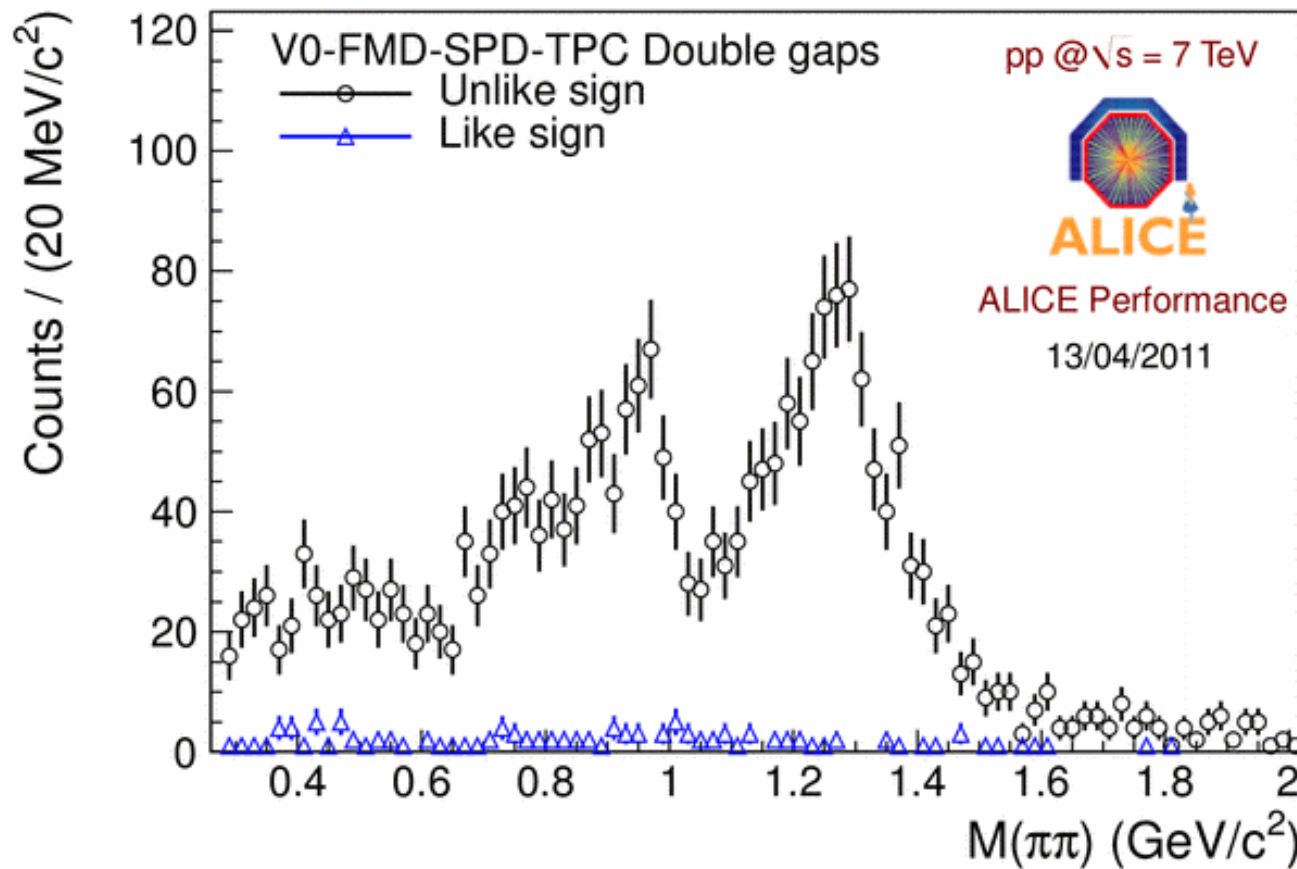


Good charged pion/kaon discrimination:

TPC – momenta < 600 MeV/c, **TOF** – momenta < 1.5 GeV/c

Central, exclusive diffraction in pp collisions at $\sqrt{s} = 7$ TeV observed in the ALICE experiment

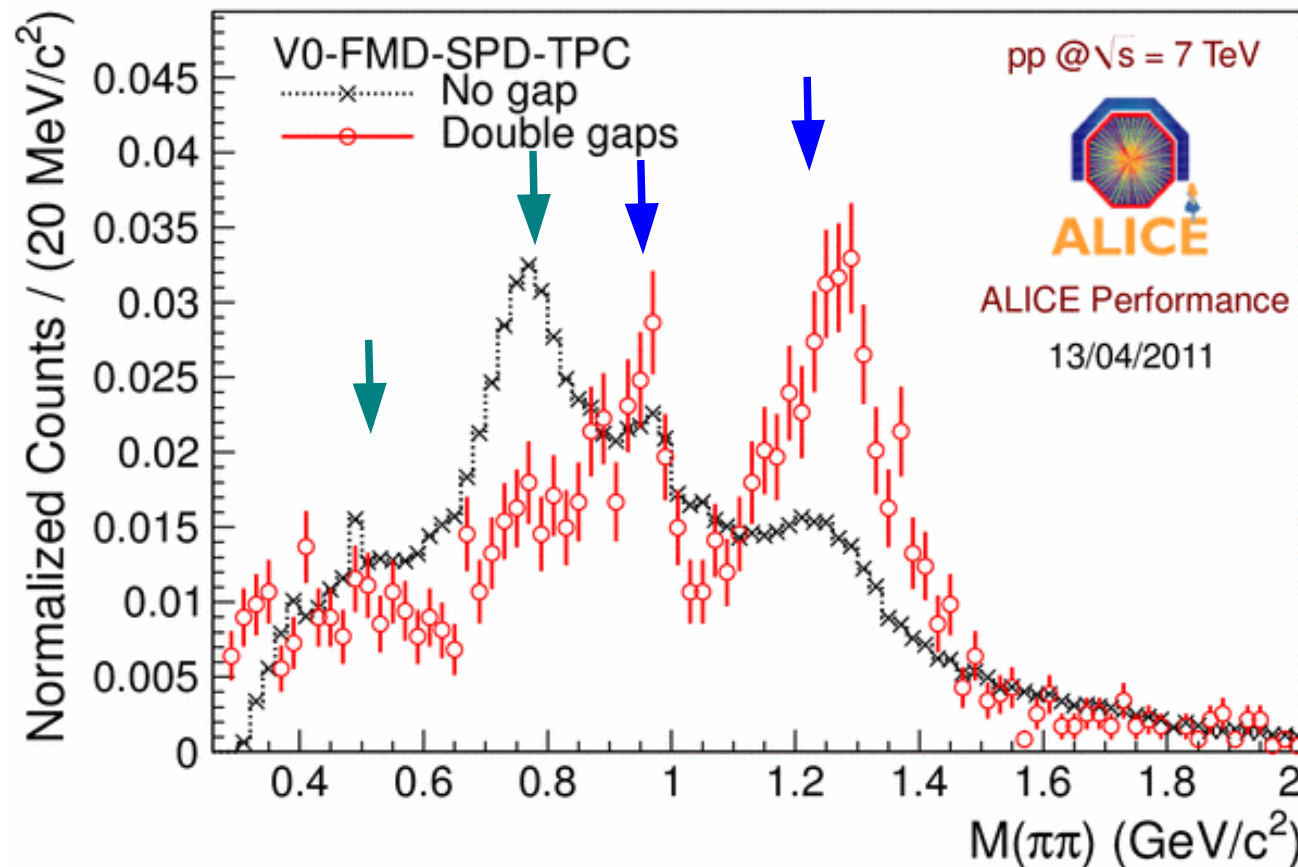
Two rap. gaps, **2** tracks in **TPC**, ($|\eta| < 0.9$) identified as pions in **TPC** or **TOF**:



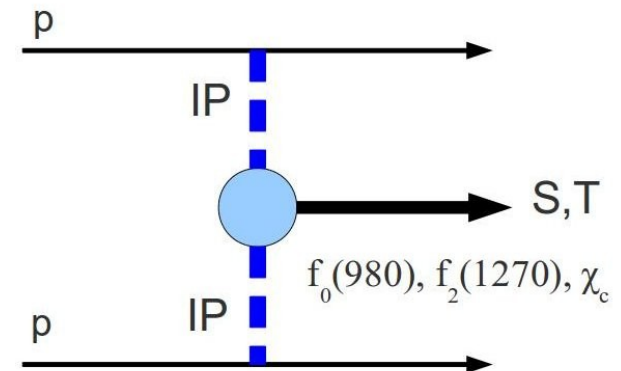
ALI-PERF-4075

Central, exclusive diffraction in pp collisions at $\sqrt{s} = 7$ TeV observed in the ALICE experiment

Comparison: „no gap” — „double gap”, **unlike** signs



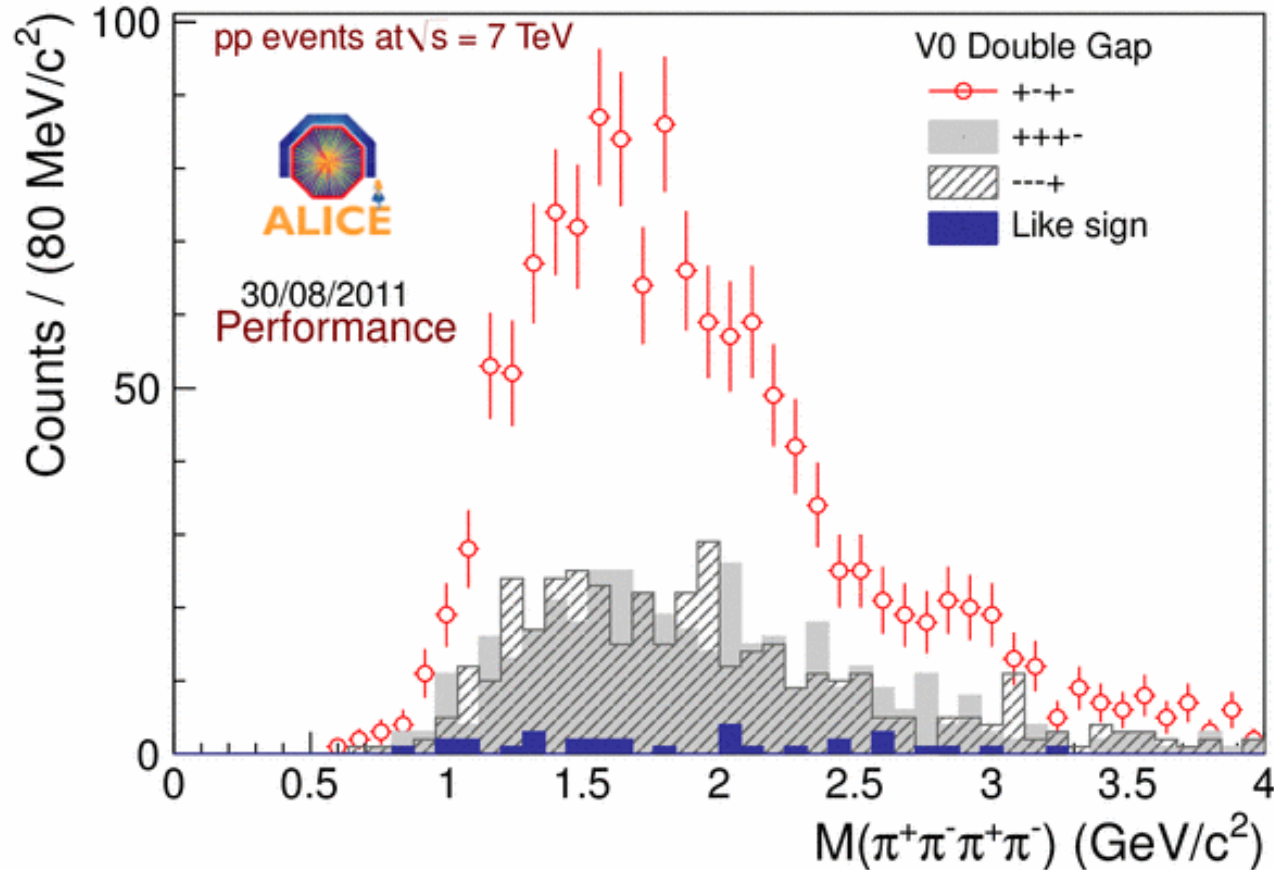
- No gap: K_s^0 , $\rho^0(770)$
- Double gap: $f_0(980)$, $f_2(1270)$



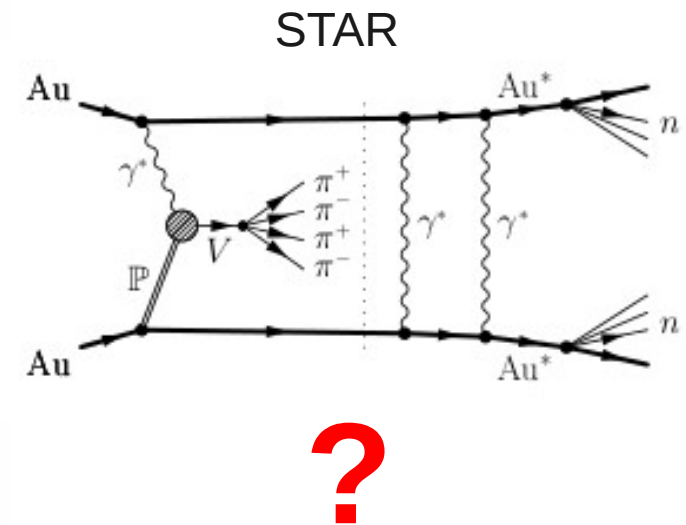
„Double gap” → Double Pomeron Exchange!

Central, exclusive diffraction in pp collisions at $\sqrt{s} = 7$ TeV observed in the ALICE experiment

„Double gap”: 4 pions



ALI-PERF-9362



Is this $\rho(1700)$, (STAR 2010, $\text{AuAu} \rightarrow \text{Au } 2\pi^+ 2\pi^- \text{ Au}$) or some exotic state?

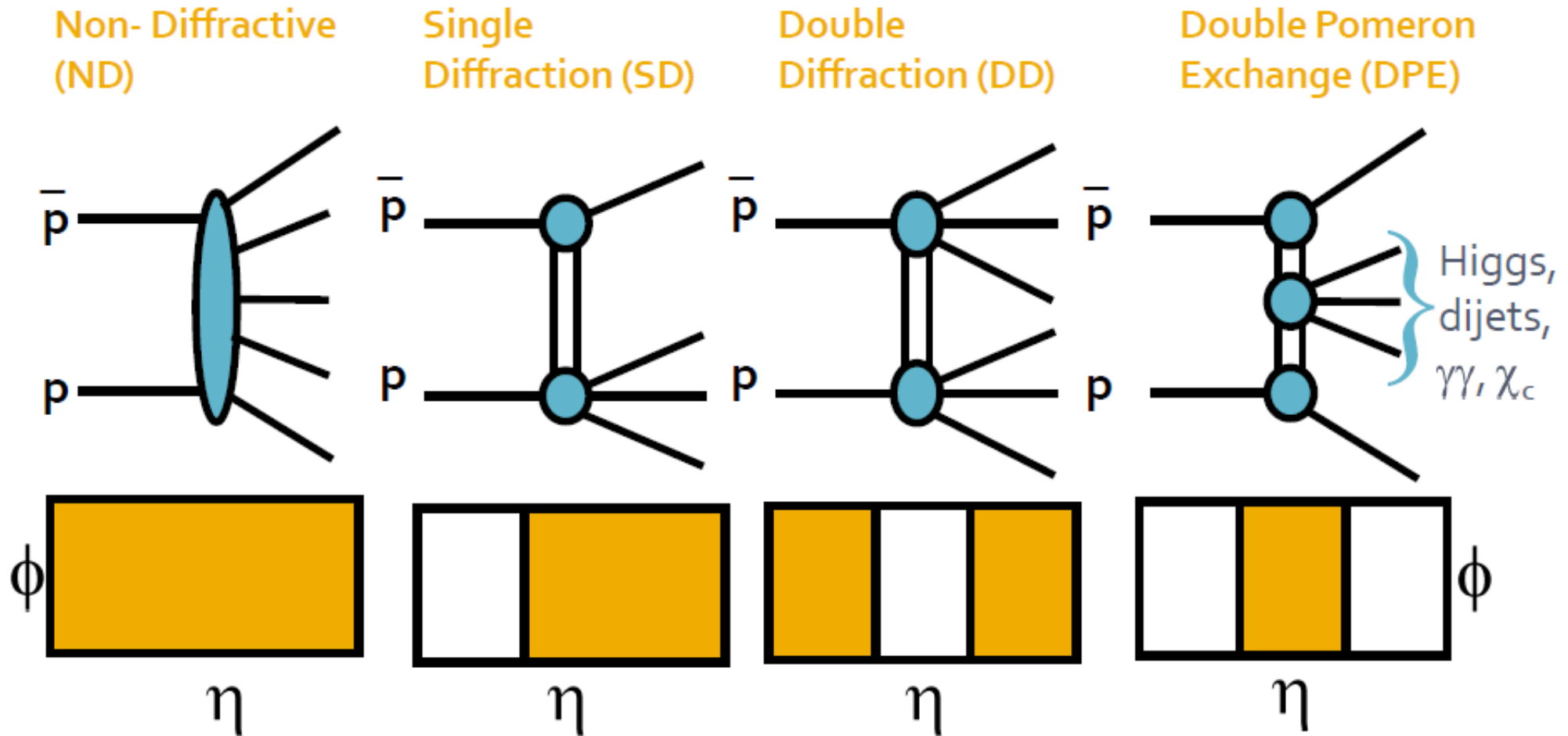
Central, exclusive diffraction in pp collisions at $\sqrt{s} = 7$ TeV observed in the ALICE experiment

Outlook

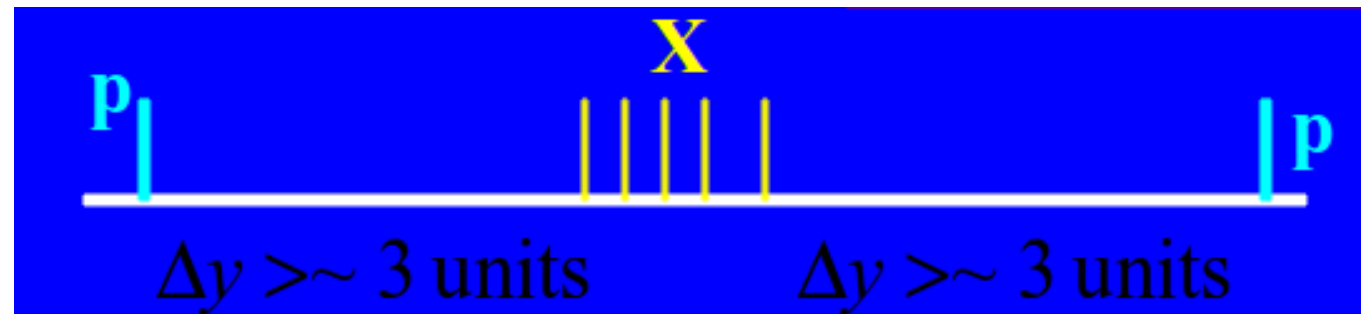
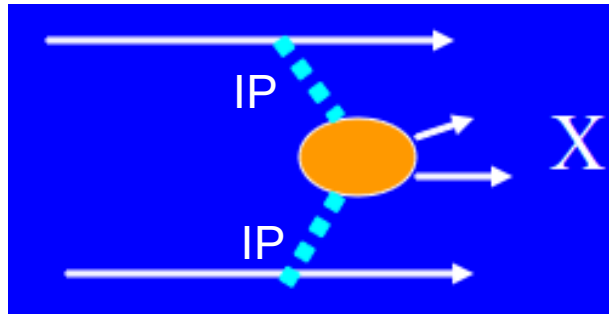
- Central, exclusive diffraction in pp collisions is observed in ALICE
- Signals of $f_0(980)$ and $f_2(1270)$ are qualitatively compatible with DPE
- A lot of work needed for quantitative results
- Chance for Odderon...?
- Ultra-peripheral Pb-Pb collisions studied as well...

Back-up slides

Central, exclusive diffraction in p-p collisions at $\sqrt{s} = 7$ TeV observed in the ALICE experiment



Central, exclusive diffraction in p-p collisions at $\sqrt{s} = 7$ TeV observed in the ALICE experiment



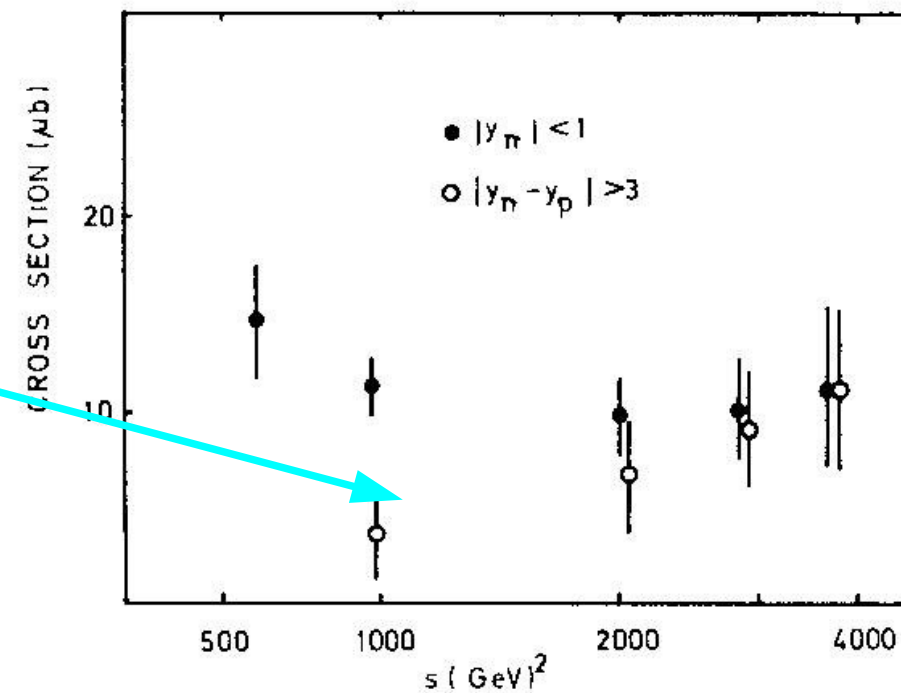
Axial Field Spectrometer (AFS: R807):

For $x_F > 0.95$ (both p)
OR for $\Delta y > 3$ (both gaps)
 $M(X) < \sim 3 \text{ GeV}/c^2$

If Double Pomeron Exchange \rightarrow

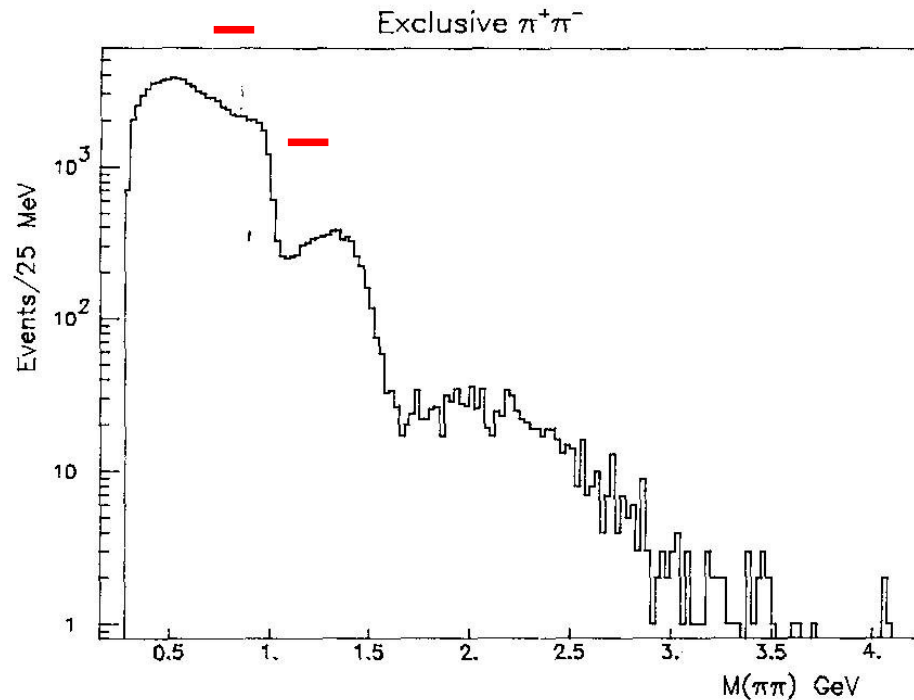
X – scalar or tensor quantum numbers:

$Q=0, I=0, J=0,2,\dots, G=C=P=+1$



Central, exclusive diffraction in p-p collisions at $\sqrt{s} = 7$ TeV observed in the ALICE experiment

AFS@ISR:



$M < \sim 3$ GeV,

$I^G(J^{PC})$

- NO $\rho(770), \quad -1^+(1^-), \quad V$
- Signals $f_0/\sigma(600), \quad f^0(980) - 0^+(0^{++}), \quad S$
- $f_0(1270) \quad - 0^+(2^{++}), \quad T$

→ this is Double Pomeron Exchange!

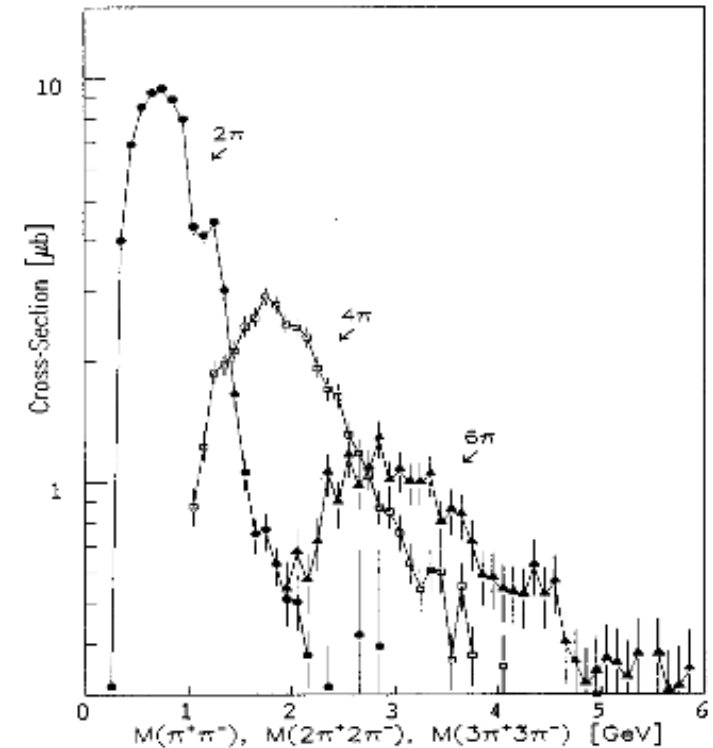


Fig. 3. Invariant mass distributions for the central $\pi^+ \pi^-$, $2\pi^+ 2\pi^-$, and $3\pi^+ 3\pi^-$ systems from reactions (1-3) respectively (in μb per 100 MeV bin). This figure, and all subsequent figures, show data which have been acceptance corrected

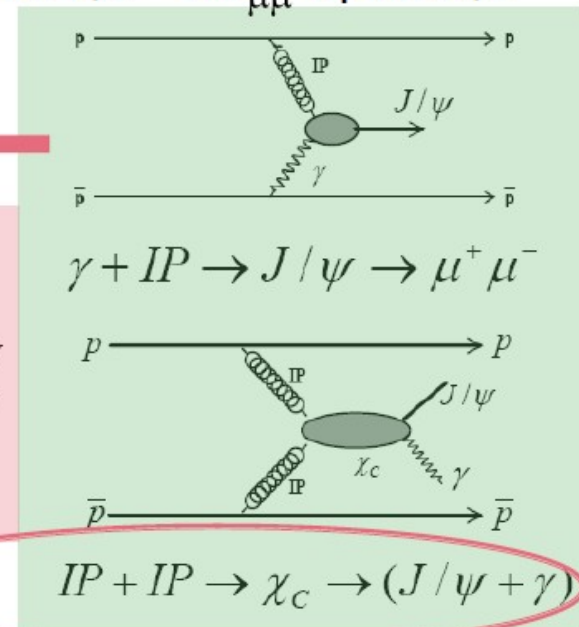
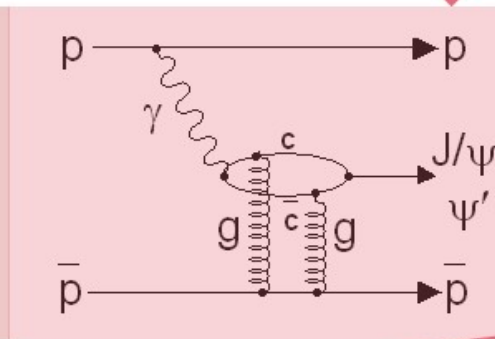
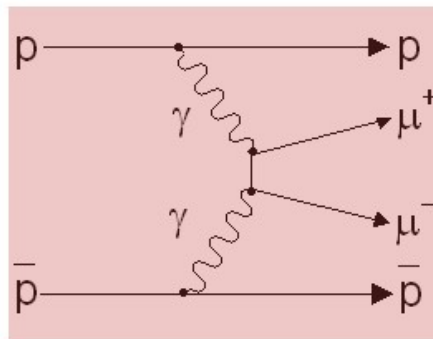
Central, exclusive diffraction in p-p collisions at $\sqrt{s} = 7$ TeV observed in the ALICE experiment



Exclusive Dimuon Production

$$\bar{p} + p \rightarrow \bar{p} + \mu^+ \mu^- + p \quad 3 \text{ GeV}/c^2 < M_{\mu\mu} < 4 \text{ GeV}/c^2$$

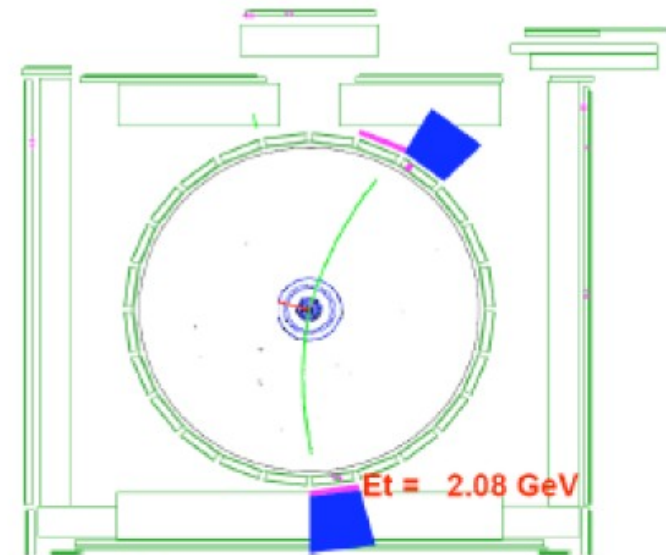
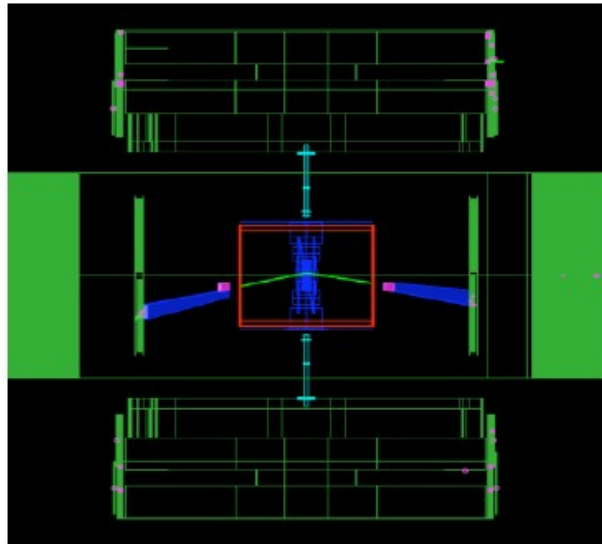
Many Physics Processes in this data:



exclusive χ_c in DPE

- Observation of exclusive χ_c PRL 102 242001 (2009)

Exclusive dimuon production



$$p + \bar{p} \rightarrow p + \mu^+ \mu^- + \bar{p}$$
$$3 \text{ GeV}/c^2 < M_{\mu\mu} < 4 \text{ GeV}/c^2$$

Trigger:

muon + track + forward rapidity gaps in BSCs

2 oppositely charged muon tracks with $p_T > 1.4 \text{ GeV}/c$, $|\eta| < 0.6$

$\epsilon_{\text{excl}} \sim 0.093 \Rightarrow L = 1.48 \text{ fb}^{-1}$ but $L_{\text{eff}} \sim 140 \text{ pb}^{-1}$

Central, exclusive diffraction in p-p collisions at $\sqrt{s} = 7$ TeV observed in the ALICE experiment



Exclusive J/ψ and $\psi(2s)$

J/ψ production

243 ± 21 events

$$d\sigma/dy|_{y=0} = 3.92 \pm 0.62 \text{ nb}$$

Theoretical Predictions

- 2.8 nb [Szczonek07,],
- 2.7 nb [Klein&Nystrand04],
- 3.0 nb [Conclaves&Machado05], and
- 3.4 nb [Motkya&Watto8].

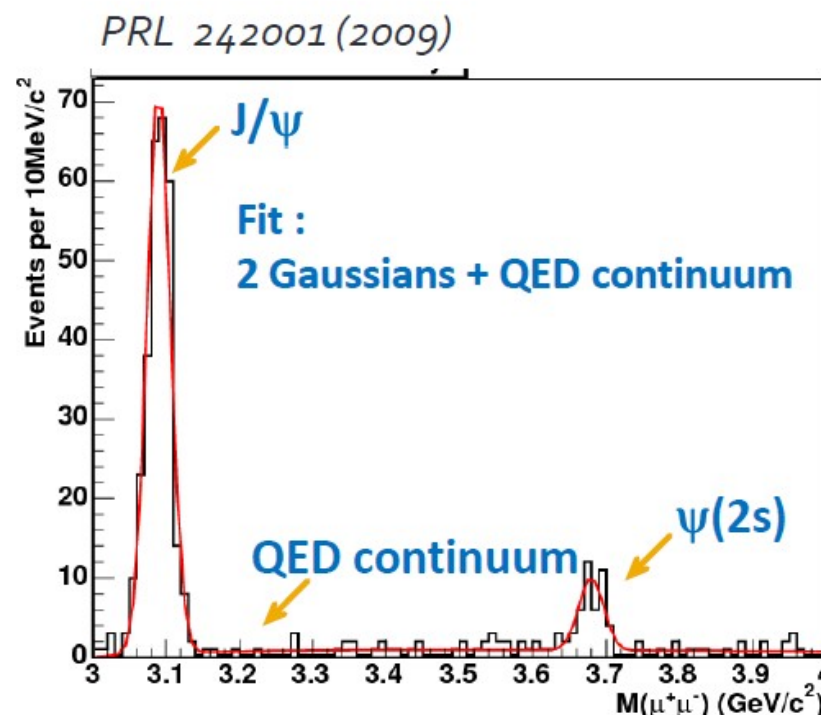
$\Psi(2s)$ production

34 ± 7 events

$$d\sigma/dy|_{y=0} = 0.54 \pm 0.15 \text{ nb}$$

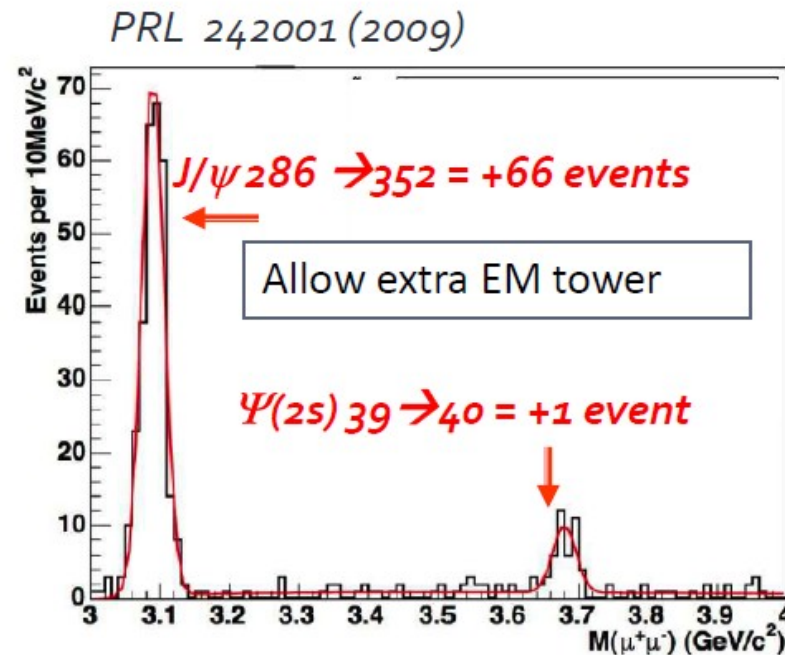
$$R = \psi(2s)/J/\psi = 0.14 \pm 0.05$$

In agreement with HERA: $R = 0.166 \pm 0.012$ in a similar kinematic region



Central, exclusive diffraction in p-p collisions at $\sqrt{s} = 7$ TeV observed in the ALICE experiment

Exclusive $\chi_c \rightarrow J/\psi (\rightarrow \mu^+ \mu^-) + \gamma$



→ Allowing EM towers ($E_T > 80$ MeV)
large increase in the J/ψ peak
minor change in the $\psi(2s)$ peak



Evidence for
 $\chi_c \rightarrow J/\psi + \gamma$ production

$d\sigma/dy|_{y=0} = 75 \pm 14$ nb,
compatible with theoretical predictions
160 nb (Yuan 01)
90 nb (KMR01)

Central, exclusive diffraction in p-p collisions at $\sqrt{s} = 7$ TeV observed in the ALICE experiment

Odderon in central diffraction at LHC

Bzdak, Motyka, Szymanowski, Cudell (2007):

$pp \rightarrow pp J/\psi$	$d\sigma/dy _{y=0}$
IP - γ	15 (2.4 – 27) nb
IP- Odderon	0.9 (0.3 – 4) nb

Odderon exchange \rightarrow bigger J/ψ p_T ...

