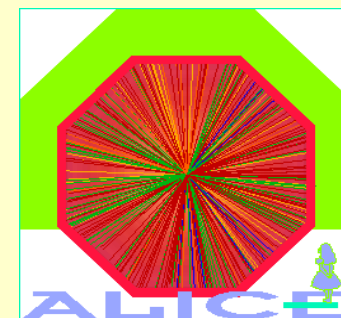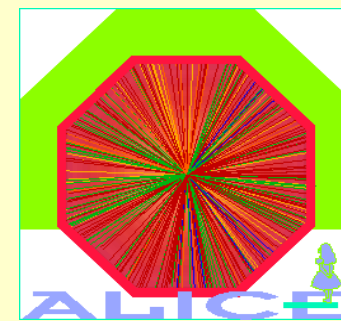# Diffractive physics in ALICE

- ALICE detector

- Diffractive gap trigger in ALICE

- Central barrel performance

- Central diffraction in ALICE

- Hunt for the odderon

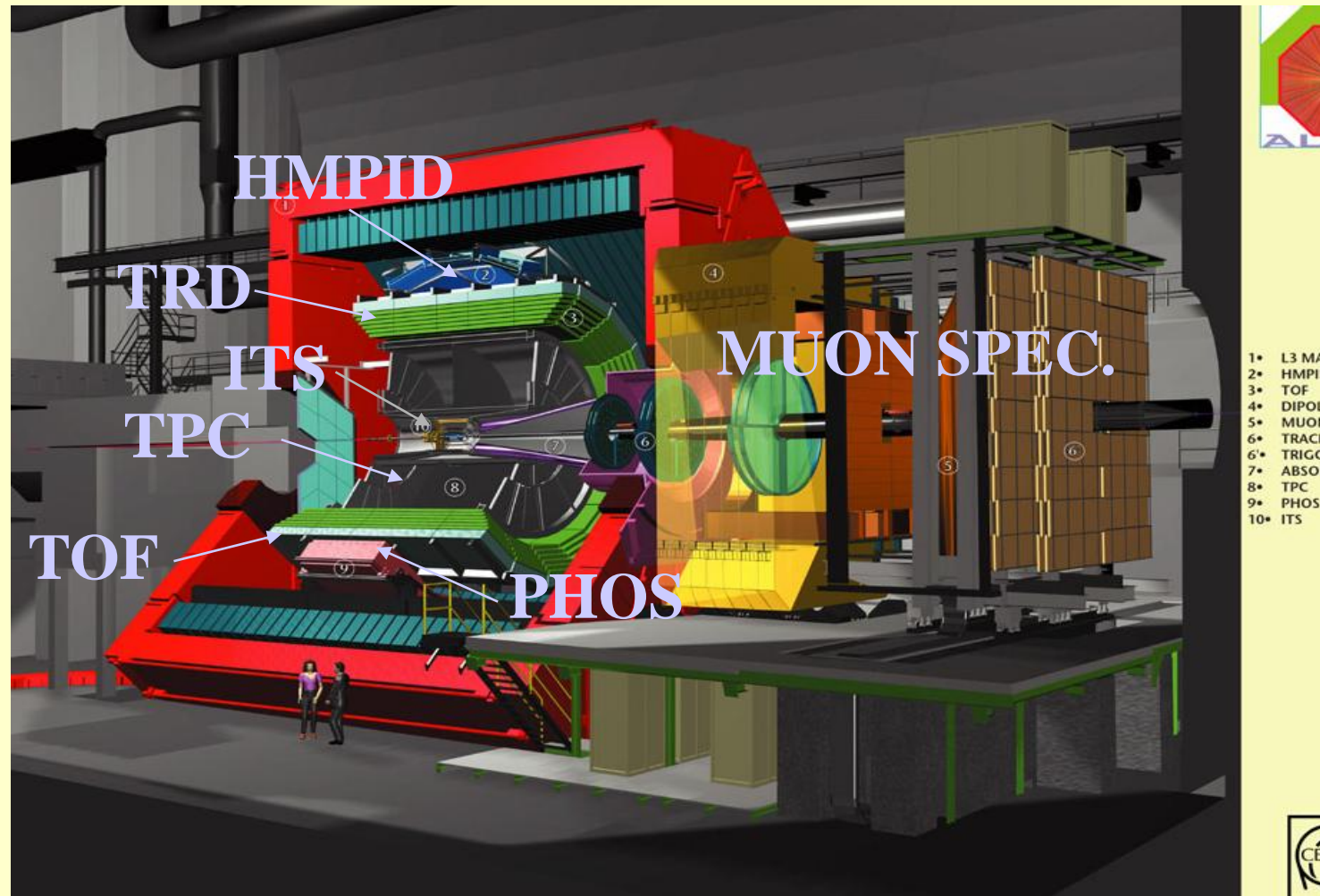- Conclusions, outlook

The ALICE experiment
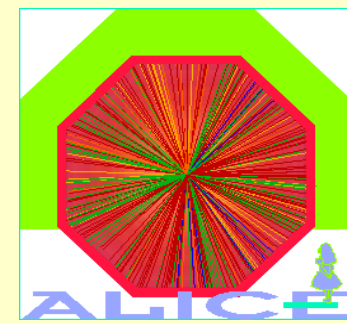

Acceptance central barrel

$-0.9 < \eta < 0.9$

Acceptance muon spectr.

$-2.5 < \eta < -4.$

ALICE diffractive gap trigger

→ *additional forward detectors*

(no particle identification)

$$1 < \eta < 5$$
$$-4 < \eta < -1$$

→ *definition of gaps η_+, η_-*

p-p luminosity L = 5x10³⁰cm⁻²s⁻¹ :

p-p luminosity L = 5×10^{30}cm^{-2}s^{-1} :

→ **one interaction/ 80 bunches**

diffractive L0 trigger (hardware):

Pixel or TOF mult (central barrel)

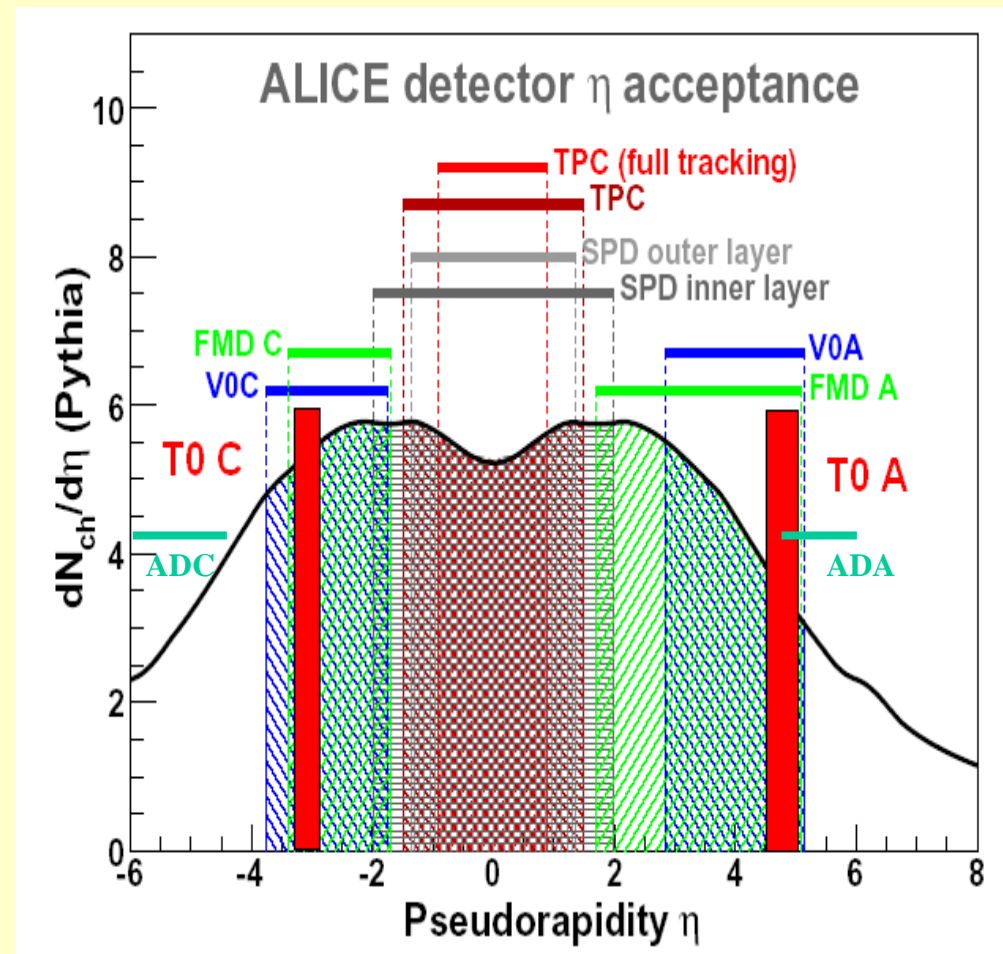*gap η_+: $3 < \eta < 5 \rightarrow \Delta\eta \sim 0.5$*
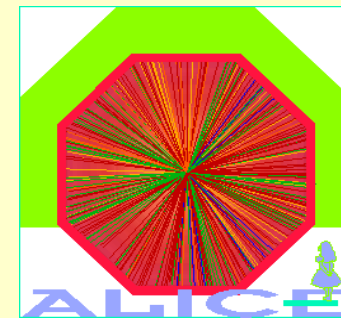*gap $\eta-$: $-2 < \eta < -4 \rightarrow \Delta\eta \sim 0.5$*

high level trigger (software):

$$-3.7 < \eta < 5$$

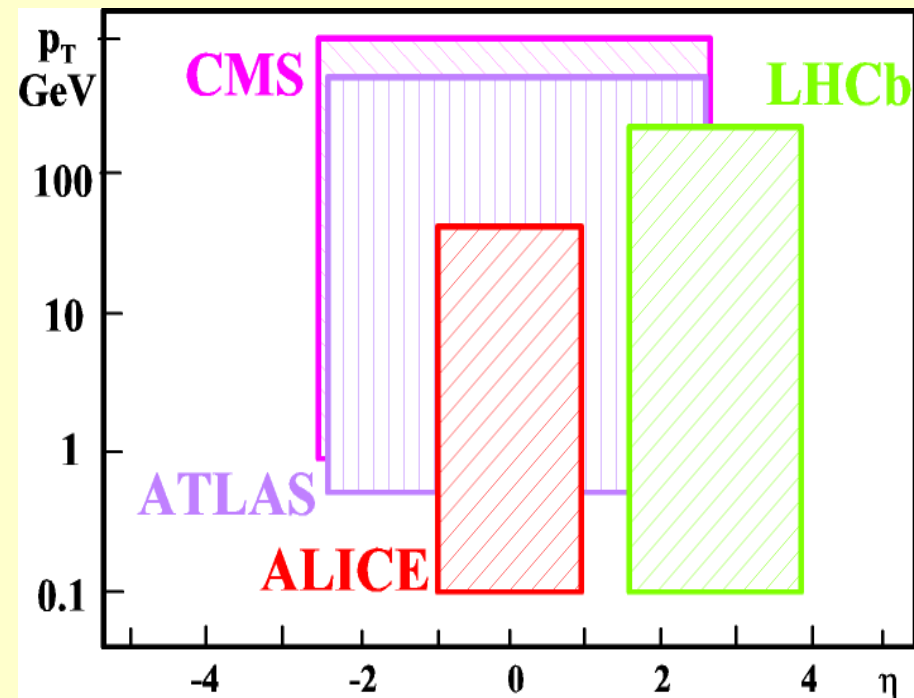→ *improved including ADA, ADD*

ALICE detector η acceptance

ALICE central barrel comparison to other LHC detectors

low magnetic field

	Magn. field (T)	P_T cutoff GeV/c	Material x/x0 (%)
ALICE	0.2-0.5	0.1-0.25	7
ATLAS	2.0	0.5 (0.08)	20
CMS	4.0	0.75 (0.2)	30
LHCb	4Tm	0.1	3.2

$\eta-pt$ acceptance

$\rightarrow$ *low p_T trigger ?*

ALICE central barrel particle identification
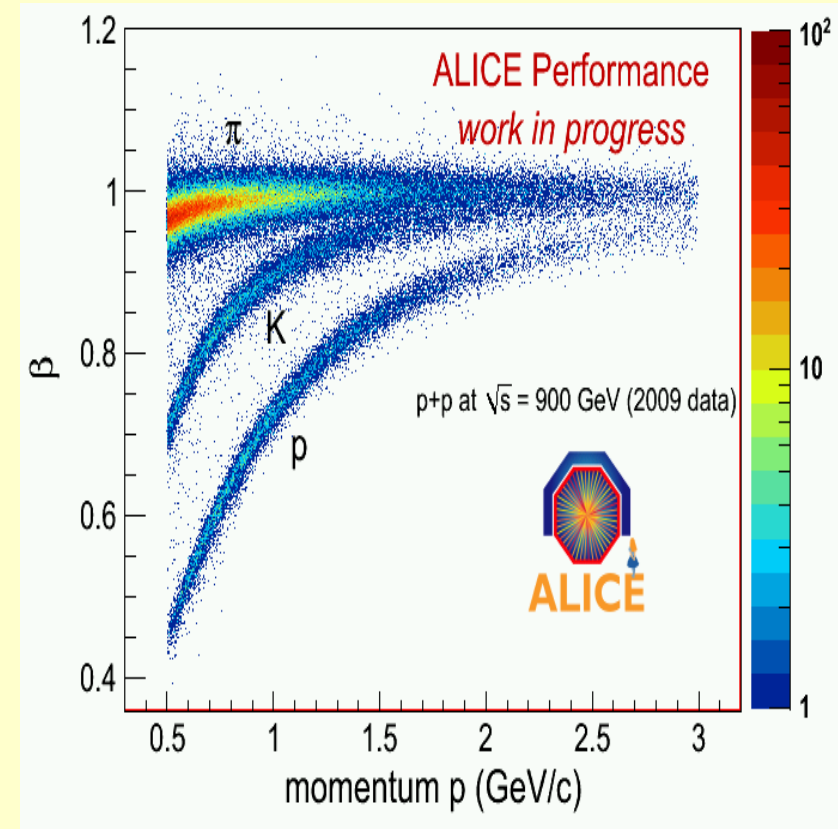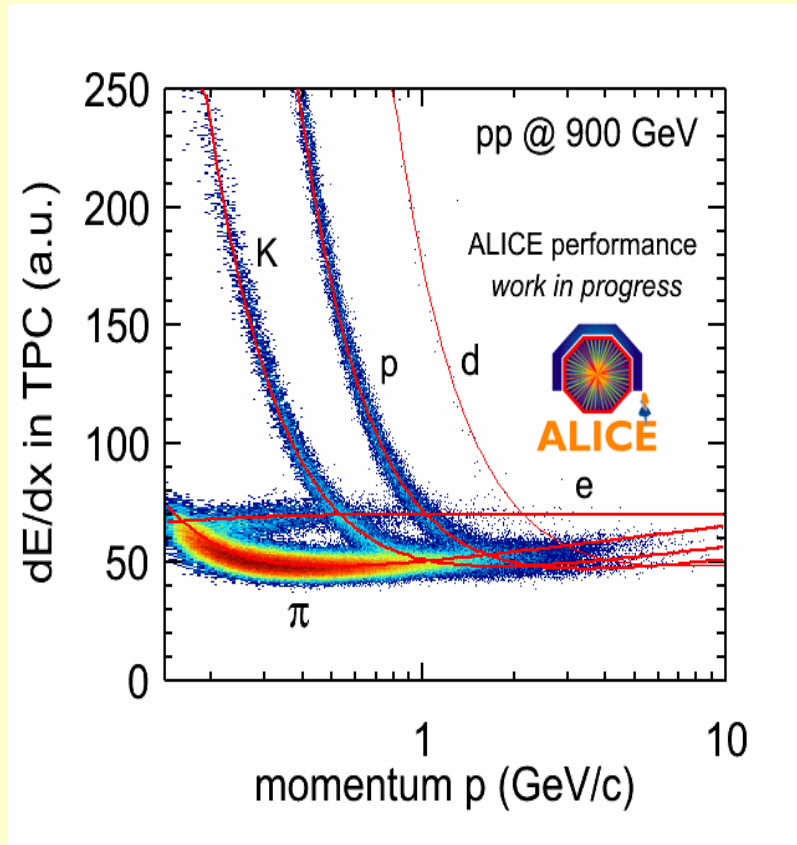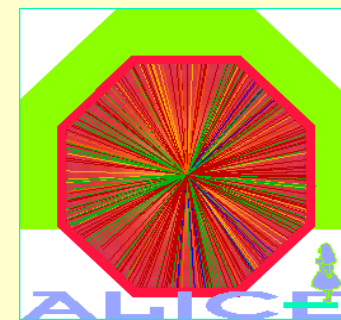
Particle identification by dE/dx in TPC as function of momentum

Particle identification by time-of-flight information for non-relativistic momenta

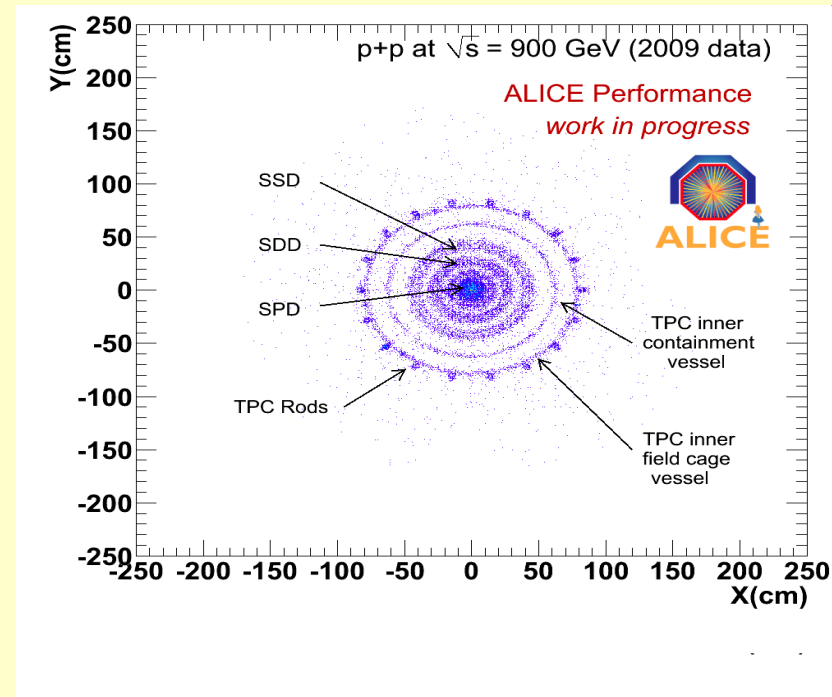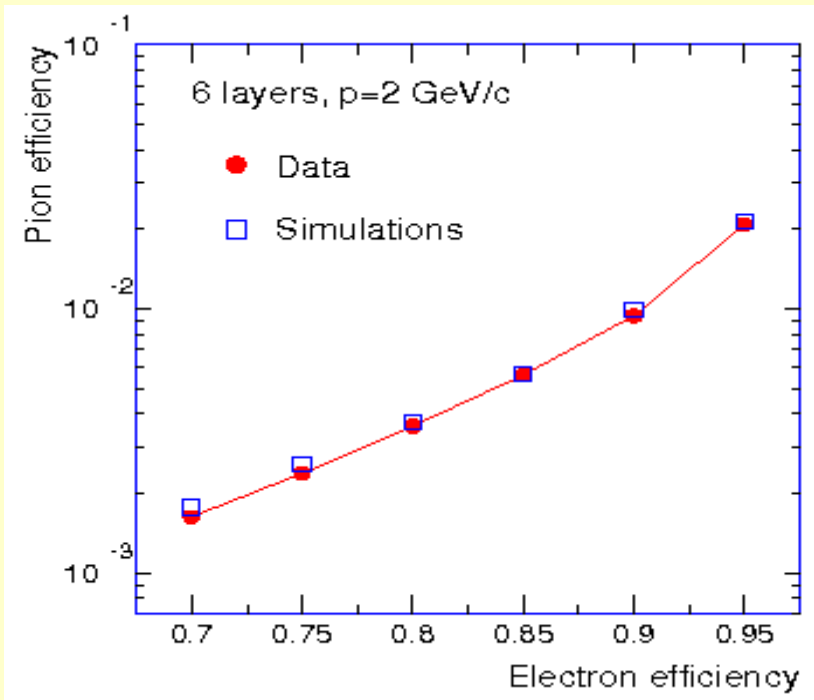# ALICE central barrel electron/photon identification
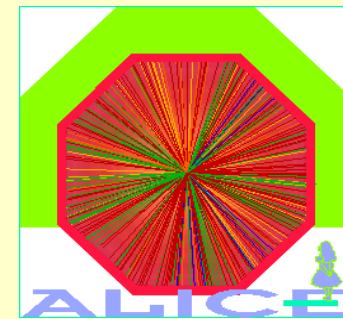
electron-pion separation in transition radiation detector at p_T= 2 GeV/c

TRD L1 trigger on electrons
→trigger on vector mesons J/Ψ, Υ by e^+e^- decay

Measure photon conversions by identifying e^+e^- in central barrel (V-topology)

→identify $π^0$, η at midrapidity

ALICE acceptance

- ALICE acceptance matched to diffractive central production:

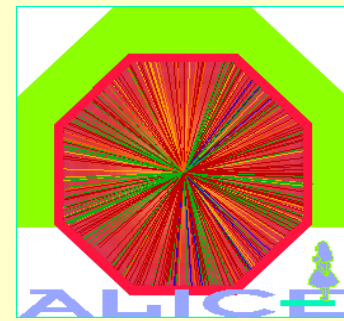   *double pomeron, (γ –pomeron, odderon-pomeron)*

central barrel

$\Delta\eta \sim 3$ $\Delta\eta \sim 4$
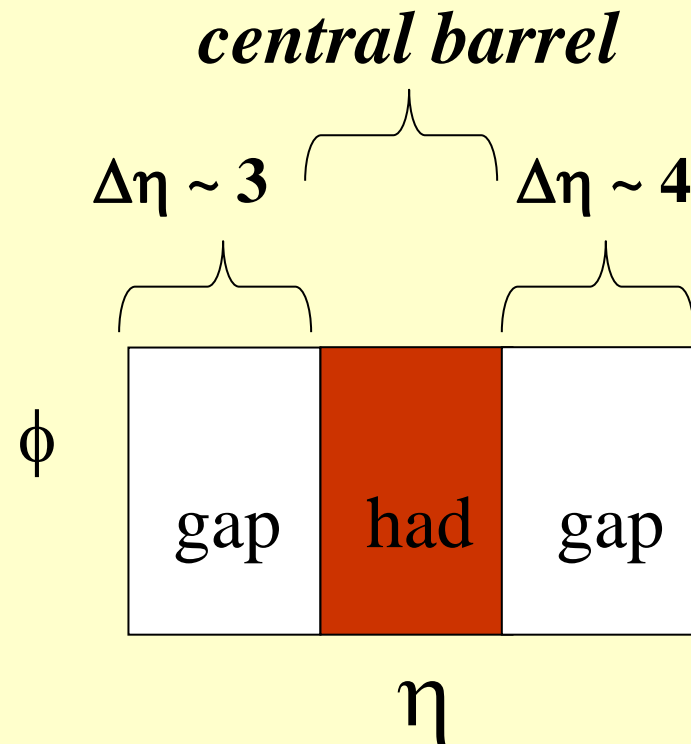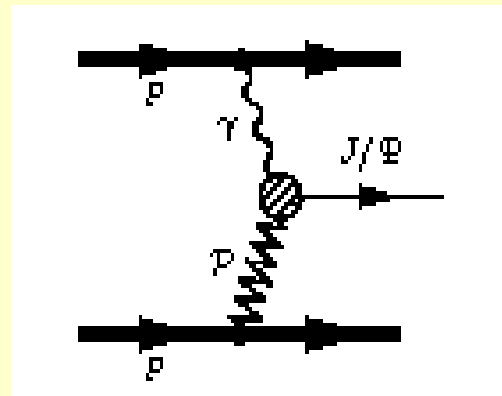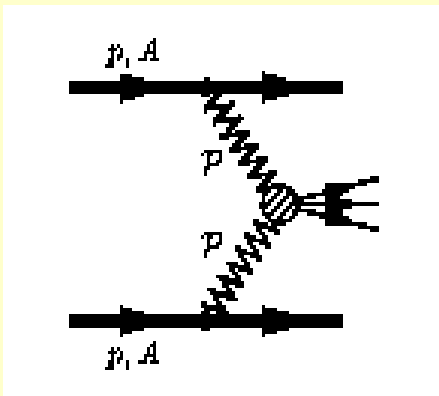
Data taking:

pp @ $L = 5 \times 10^{30}$ cm^{-2}s^{-1} $(\rightarrow \left. \dfrac{d\sigma}{dy} \right|_{y=0} \sim nb)$

pPb @ $L = 10^{29}$ cm^{-2}s^{-1}

PbPb @ $L = 10^{27}$ cm^{-2}s^{-1}

ϕ

| gap | had | gap |

η

ALICE forward calorimeter
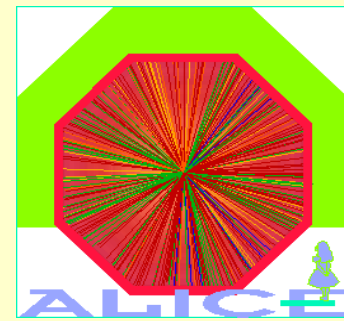
- **neutron calorimeter on each side**
  - **Placed at 116 m from interaction region**
  - **Measures neutral energy at 0°**
- **Diffractive events with and without proton breakup:**
  - **pp → ppX : no energy in zero degree calorimeters**
  - **pp → pN*X, N*N*X : energy in one or in both calorimeters**

Identify the three topologies:
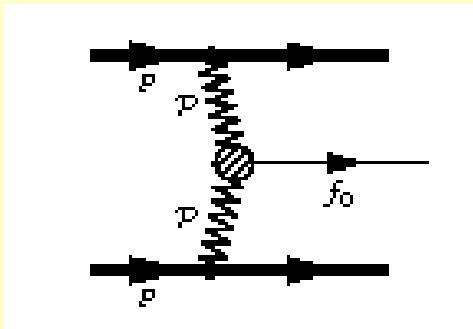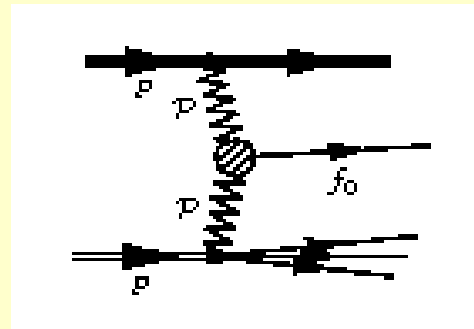
A   B   C

$$\frac{\sigma_A}{\sigma_B} \equiv f\ (x_1, x_2,..) \quad \frac{\sigma_{elast}}{\sigma_{SD}}$$

$$\frac{\sigma_B}{\sigma_C} \equiv g\ (x_1, x_2,..) \quad \frac{\sigma_{SD}}{\sigma_{DD}}$$

$$\frac{\sigma_A}{\sigma_C} \equiv h\ (x_1, x_2,..) \quad \frac{\sigma_{elast}}{\sigma_{DD}}$$

→ what are f(x_i), g(x_i), h(x_i) ?

ALICE 2010-2011: Central diffractive events

Compare double gap events to min bias inelastic events of same multiplicity

1) Enhanced production cross section of glueball states: *study resonances in central region when two rapidity gaps are required*
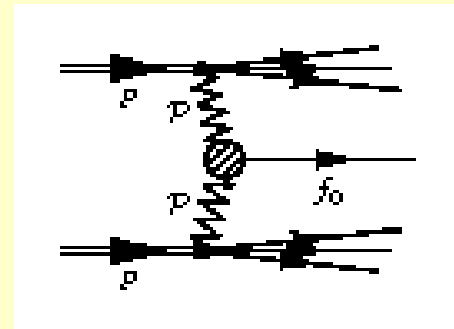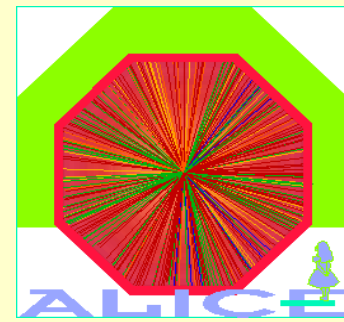
2) Slope pomeron traj. $\alpha' \sim 0.25 \text{GeV}^{-2}$ in DL fit, $\alpha' \sim 0.1 \text{GeV}^{-2}$ in vector meson production at HERA, t-slope triple pom-vertex $< 1 \text{GeV}^{-2}$

   $\rightarrow$ mean k_t in pomeron wave function $\alpha' \sim 1/k_t^2$ probably $k_t > 1$ GeV

   $\rightarrow$ *$<p_T>$ secondaries in double pomeron $>$ $<p_T>$ secondaries min bias*

3) $k_t > 1$ GeV implies large effective temperature

   $\rightarrow$ *K/π, η/π, η'/π ratios enhanced*

Central exclusive $\pi^+\pi^-$ production at $\sqrt{s} = 63$ GeV
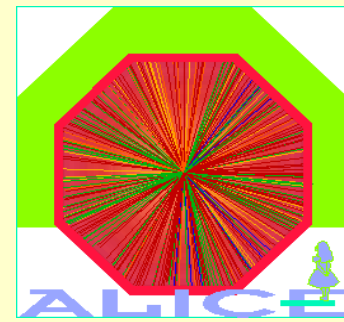
Data taken by Axial Field Spectrometer at ISR $\sqrt{s} = 63$ GeV (R807)
very forward drift chambers added for proton detection

$$p \longleftarrow \pi^+\pi^- \longrightarrow p$$
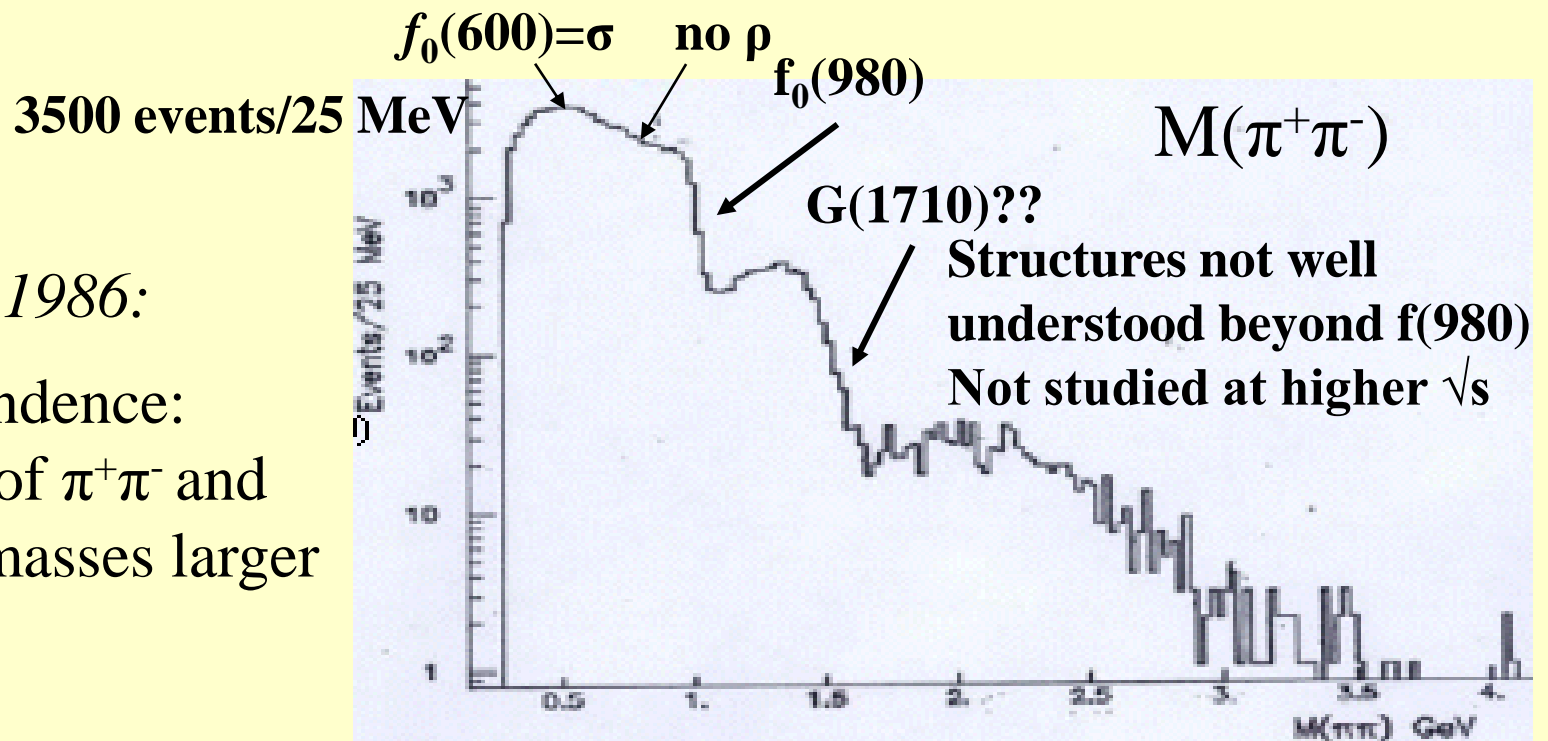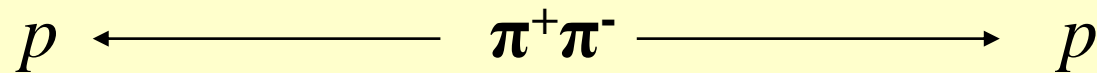
T.Akesson et al 1986:

Flavour independence:
equal numbers of $\pi^+\pi^-$ and
K^+K^- pairs for masses larger
than 1 GeV

3500 events/25 MeV

$f_0(600)=\sigma$ no ρ

$f_0(980)$

G(1710)??

$M(\pi^+\pi^-)$

**Structures not well
understood beyond f(980)
Not studied at higher $\sqrt{s}$**

χ_c as test of central exclusive production
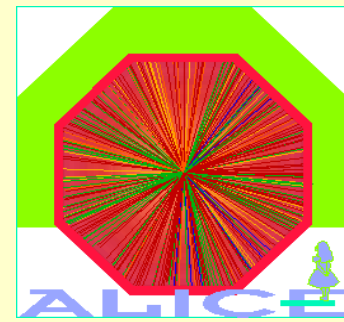
Formalism of central exclusive production predicts cross sections for $\gamma\,\gamma$, dijets, $\chi c, \chi b$
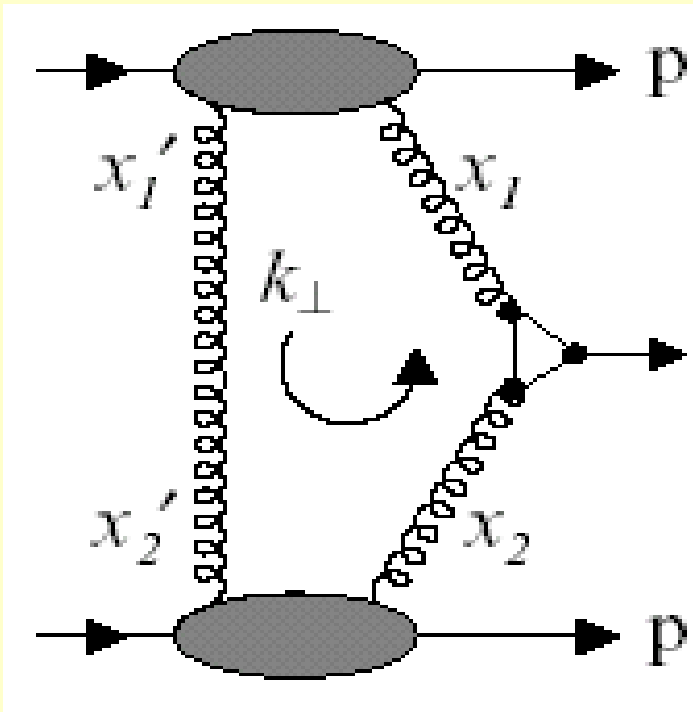
Ingredients

- *unintegrated gluon distribution*
- *cross section $gg \to X$*
- *Sudakov factor, no additional hard gluon*
- *soft rescattering, suppression factor S^2*

ALICE: measure χ_c with rapidity gap on either side

Rainer Schicker, Uni Heidelberg   *Diffraction at the LHC, may 7, 2010, CERN*

χ_c measurement

χ_c: P-wave, spin triplet:

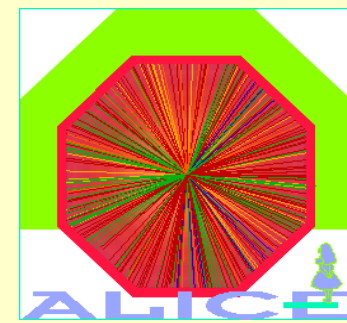|	Mass [MeV]	Width [MeV]	Br($\chi \to J/\psi\ \gamma$)
χ_{c0}	3415	10	0.01
χ_{c1}	3510	1	0.36
χ_{c2}	3556	2	0.2

|	Br($\pi\pi$)	Br(K^+K^-)	Br(pp)	Br($\Lambda\Lambda$)
χ_{c0}	7×10^{-3}	6×10^{-3}	2×10^{-4}	4×10^{-4}
χ_{c1}	-	-	7×10^{-5}	2×10^{-4}
χ_{c2}	2×10^{-3}	8×10^{-4}	7×10^{-5}	3×10^{-4}

- Harland-Lang, Khoze, Ryskin, Stirling 2010:

χ_{c0} at LHC $\sqrt{s}$ = 14 TeV:

$$\frac{d\sigma_{excl}}{dy}\bigg|_{y=0} = 45\ \text{nb} \qquad \to 4.5\times10^5\ \chi_{c0}\ \text{in}\ 10^6\text{s}$$

| decay	BR	Deacy in 4π
$\chi_{c0} \to \pi\pi$	7×10^{-3}	3.2×10^3
$\chi_{c0} \to K^+K^-$	6×10^{-3}	2.7×10^3
$\chi_{c0} \to J/\Psi\ \gamma$	1×10^{-2}	4.5×10^3
$\chi_{c0} \to p\bar{p}$	2×10^{-4}	90

- in 10^6 s there are 90 χ_{c0} proton-antiproton decays (4π)
- Preliminary estimates: P. Ladron deGuevara et al:
- estimates of efficiency reconstruction
- PID cuts, solid angle ~ 32 %
- $\to$ ~ 30 reconstructed $\chi_{c0} \to p\bar{p}$ in central barrel

$\to$ *detailed simulation studies ongoing*

The hunt for the odderon
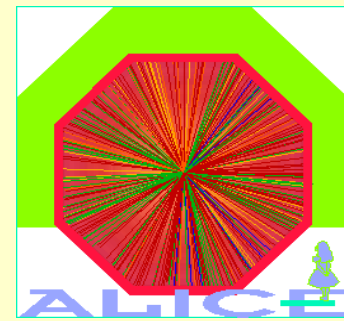
- Diffractive J/Ψ production: contributions from
  - Pomeron-photon $\qquad d\sigma/dy \big|_{y=0} \approx 15 \; nb \; (2.7 - 25 \; nb)$
  - Pomeron-odderon $\qquad d\sigma/dy \big|_{y=0} \approx 0.9 \; nb \; (0.3 - 4 \; nb)$

  $\Big\} \rightarrow$ different p_T dist. of J/Ψ

- Interference of photon-pomeron and photon-odderon amplitudes
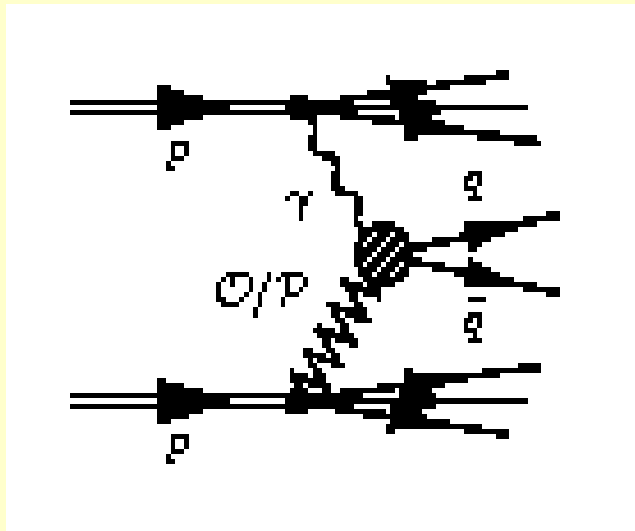
$$d\sigma \sim A\gamma(A_P + A_O)^2 d^N q$$
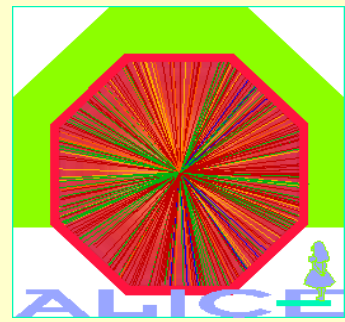
$$\sim (A_P^2 + 2Re(A_P A_O^*) + A_O^2) d^N q$$

interference of C-even and C-odd amplitudes results in asymmetries of $\pi^+\pi^-$ or K^+K^- pairs :

$\rightarrow$ charge asymmetry relative to polar angle of $\pi+$ (K+) in dipion (dikaon) rest frame

$\rightarrow$ asymmetries in HERA kinematics estimated 10% - 15%

$\rightarrow$ *how much are such asymmetries in pp @ LHC ?*

Conclusions, outlook

- ALICE has unique opportunity to do soft diffractive physics @LHC

- Diffractive trigger defined by two rapidity gaps

- Neutral energy measurement at 0^0

- Tests of central exclusive formalism at low masses

- Phenomenology of Pomeron/Odderon

- Photon-Photon physics