Diffractive and ultraperipheral physics with ALICE

- ALICE detector
- Diffractive gap trigger in ALICE
- Signatures of Pomeron/Odderon in pp
- Central diffractive production of χ_c in pp
- Exclusive vector meson production in PbPb
- Conclusions, outlook

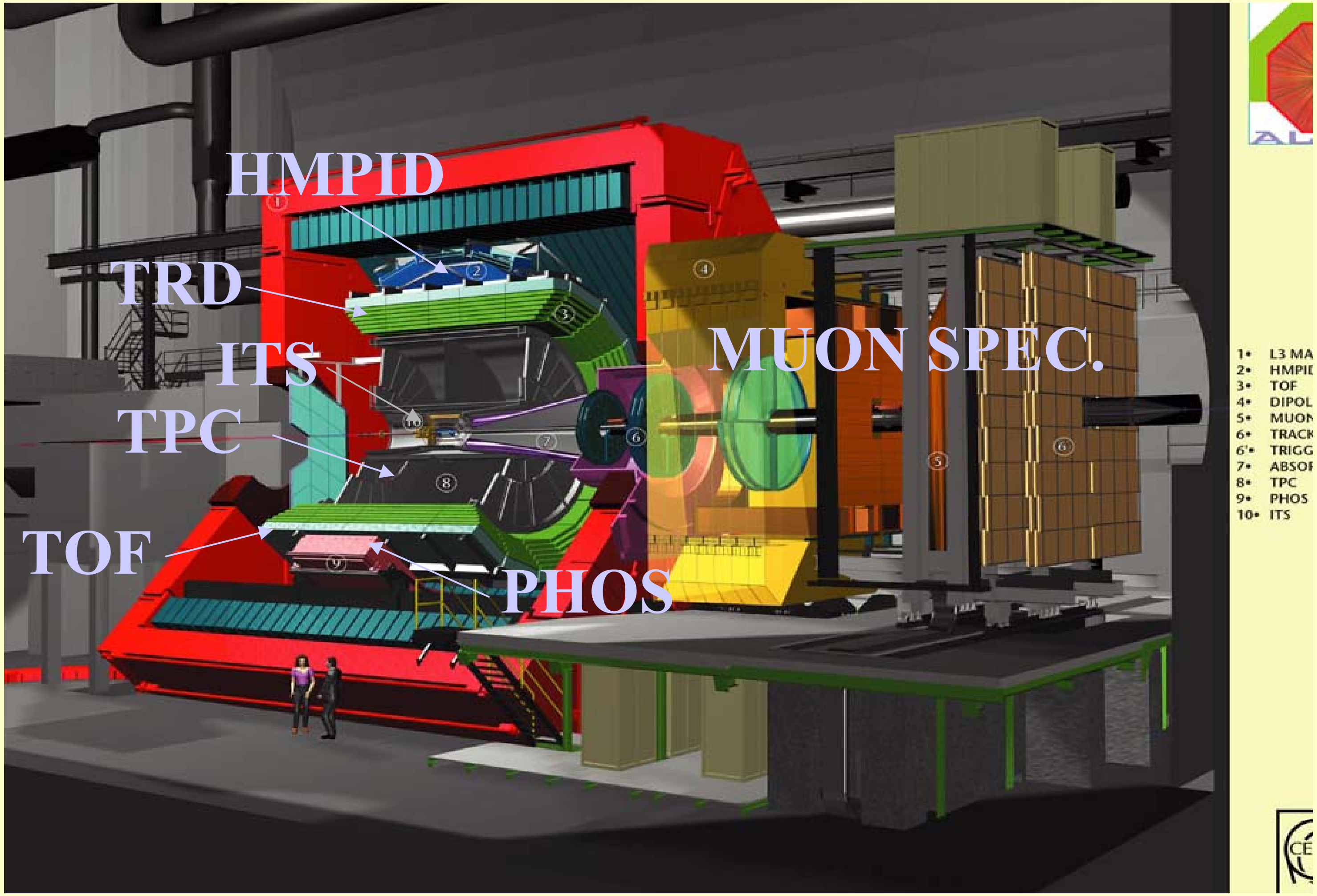
The ALICE experiment

Acceptance central barrel

-0.9 < η < 0.9

Acceptance muon spectr.

2.5 < η < 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 = 5x10^{30}cm^{-2}s^{-1} :

→ **one interaction/ 80 bunches**

diffractive L0 trigger (hardware):

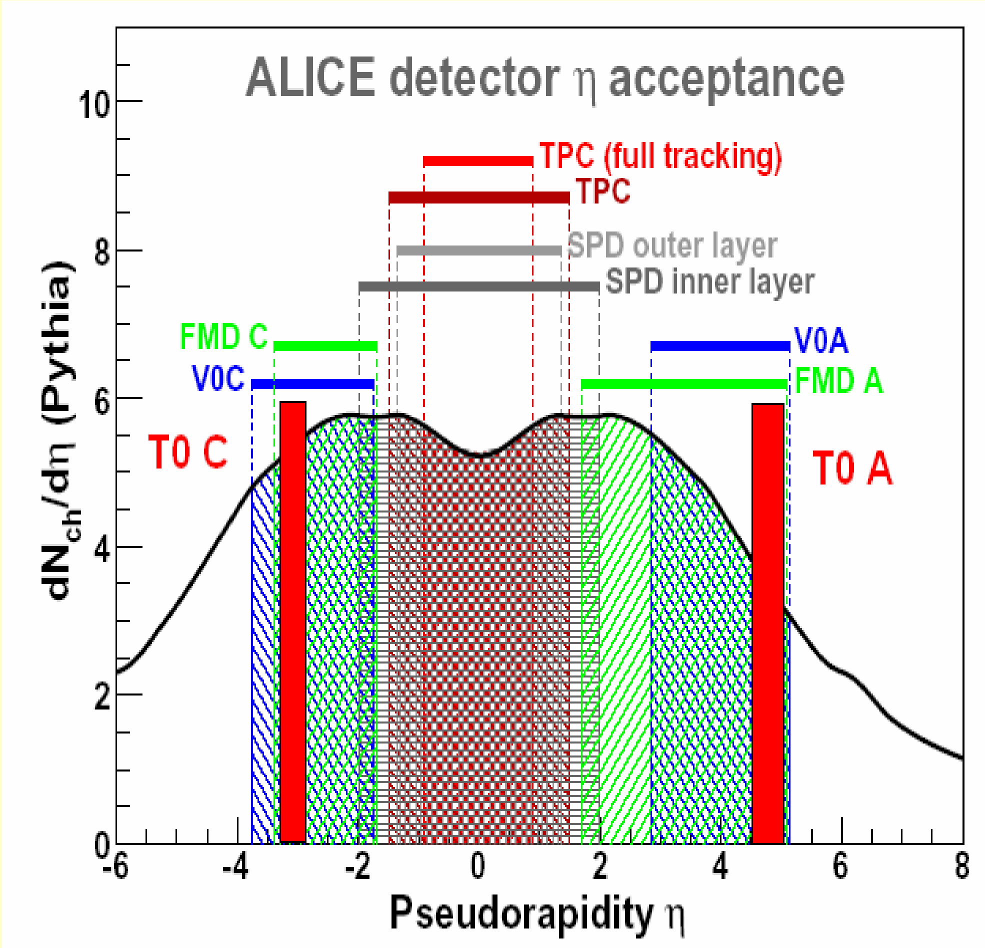
Pixel or TOF mult

gap η_+: $3 < \eta < 5$ → $\Delta\eta \sim 0.5$

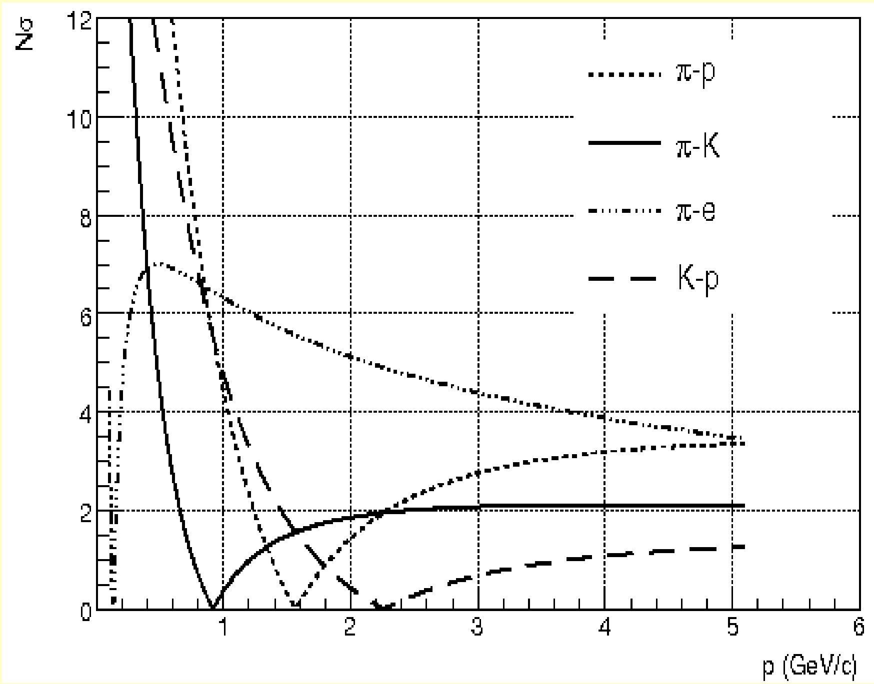
gap η_-: $-2 < \eta < -4$ → $\Delta\eta \sim 0.5$

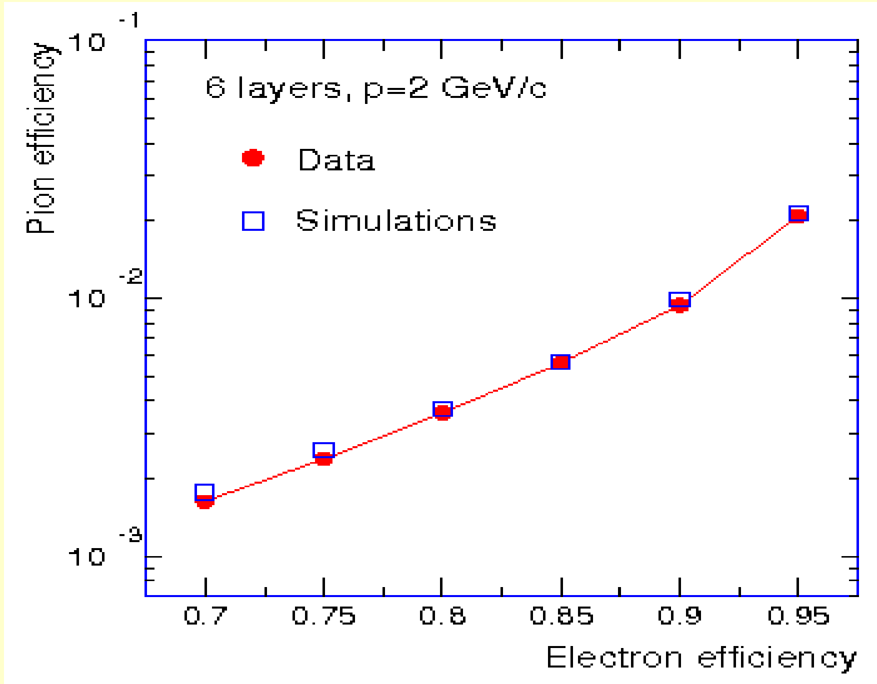
high level trigger (software):

$-3.7 < \eta < 5$



ALICE central barrel particle identification





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

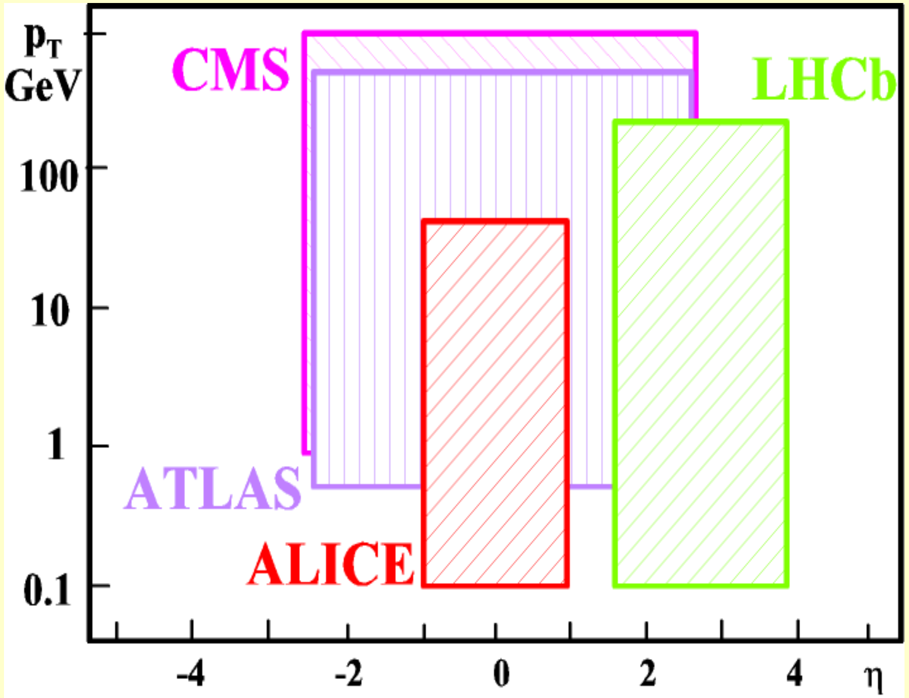
Electron-pion separation in TRD as function of momentum

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

η–pt acceptance



→ low p_T trigger ?

→good ALICE acceptance for ϕ, J/Psi, Ψ' by electron decays (p_T > 0 MeV/c)

ALICE forward calorimeter

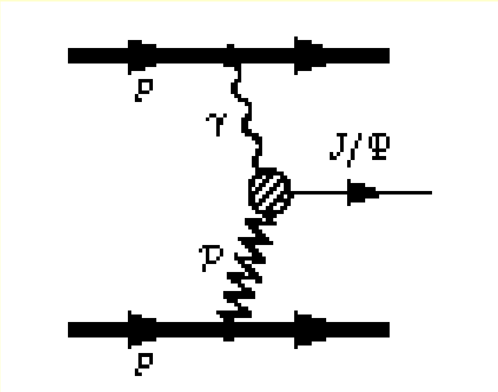
- neutron calorimeter on each side
  - Placed at 116 m from interaction region
  - Measures neutral energy at 0^{o}
- Diffractive events:
  - pp → ppX : no energy in zero degree calorimeter
  - pp → pN*X : energy in one calorimeter
  - pp → N*N*X : energy in both calorimeters

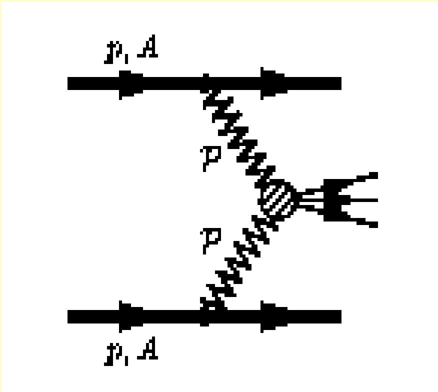
(no Roman pots for proton tagging)

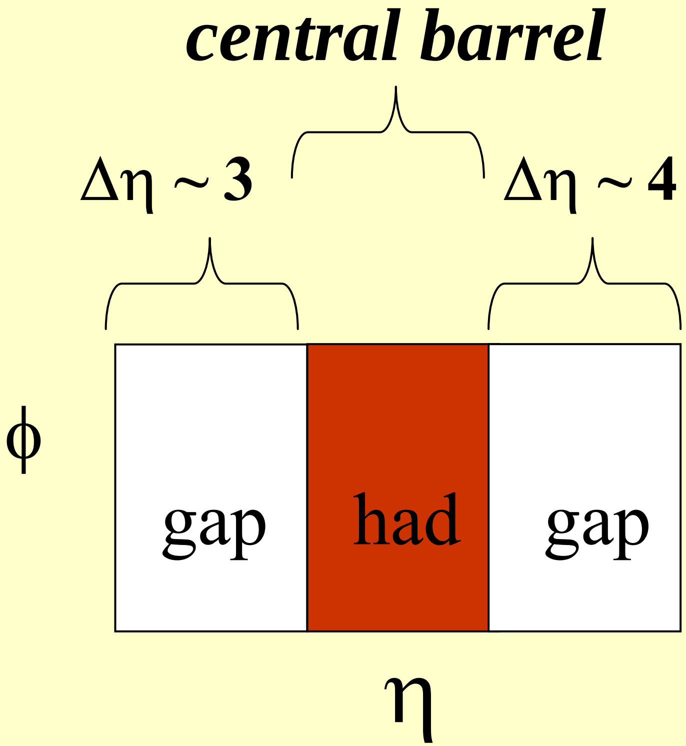
ALICE diffractive physics

- ALICE acceptance matched to diffractive central production:

  γ-pomeron, double pomeron, odderon-pomeron







Data taking:
pp @ L = $5x10^{30}$ $cm^{-2}s^{-1}$
pPb @ L = 10^{29} $cm^{-2}s^{-1}$
PbPb @ L = 10^{27} $cm^{-2}s^{-1}$

Pomeron signatures

Compare pomeron-pomeron fusion events to min bias inelastic events

1) Enhanced production cross section of glueballs states: *study resonances in central region when two rapidity gaps are required*

2) Slope pomeron traj. $\alpha' \sim 0.25 GeV^{-2}$ in DL fit, $\alpha' \sim 0.1 GeV^{-2}$ in vector meson production at HERA, t-slope triple pom-vertex $< 1 GeV^{-2}$

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

→ *$\langle p_T \rangle$ secondaries in pomeron-pomeron > $\langle p_T \rangle$ secondaries min bias*

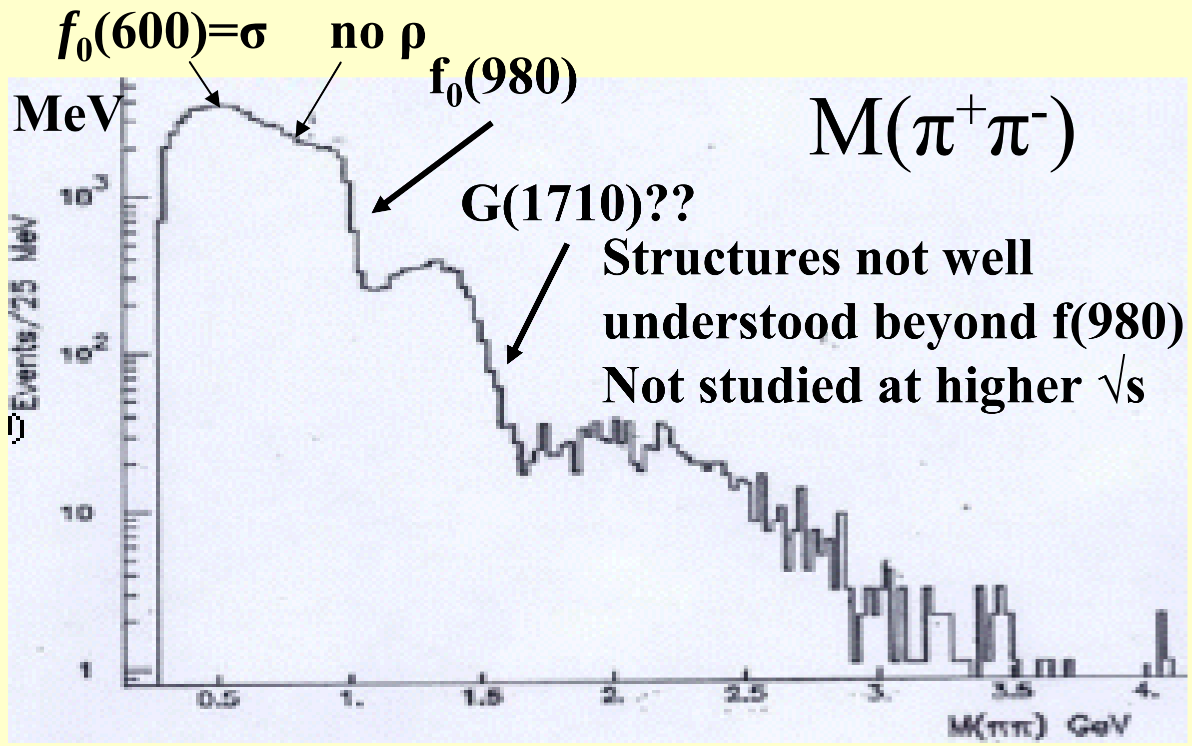
3) $k_t > 1$ GeV implies large effective temperature

→ *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

$p \longleftarrow \boldsymbol{\pi^+\pi^-} \longrightarrow p$



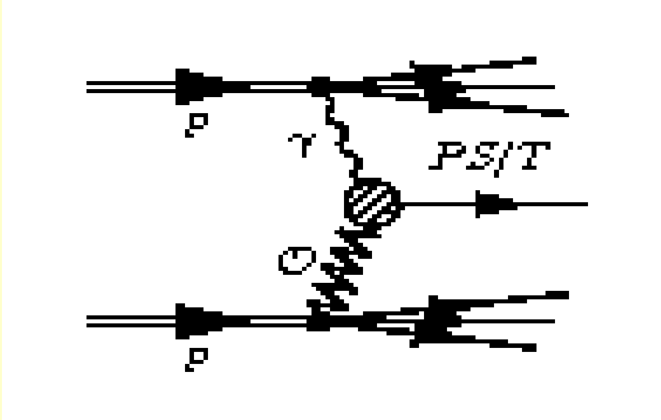
T.Akesson et al 1986:

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

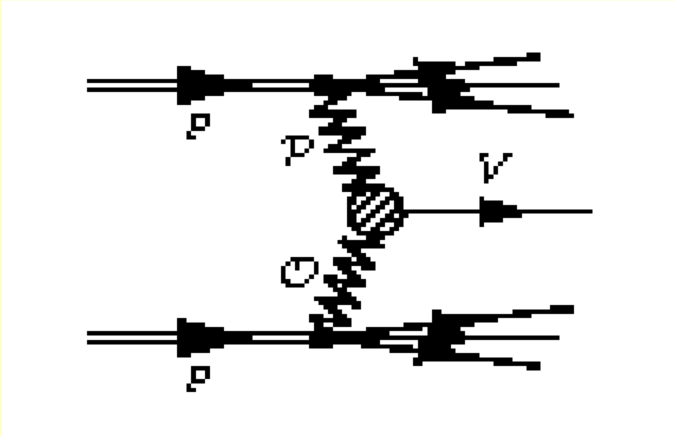
Signature Odderon cross section

Look at exclusive processes with rapidity gaps

Examples:



diffractive pseudo scalar and tensor meson production: C = +1 states



diffractive vector meson production: C = -1 states

→ *measure cross sections*

The hunt for the Odderon

- Production cross sections in pp at LHC energies
  - diffractive production: $\pi^0, \eta, \eta_c (J^{PC} = 0^{-+})$, $f0(0^{++})$, $a2(2^{++})$

    → contributions from Photon-Photon, Photon-Odderon, Odderon-Odderon
  - Look for diffractive J/Ψ production: $J^{PC} = 1^{--}$

    → Photon-Pomeron, Odderon-Pomeron contributions

→ such an experimental effort is a continuation of physics programs carried out at LEP (γγ) and HERA (γ-Odderon)

Diffractive J/Ψ production in pp at LHC

- First estimates by Schäfer, Mankiewicz, Nachtmann 1991
- pQCD estimate by Bzdak, Motyka, Szymanowski, Cudell
  - Photon: t-integrated $\left.\frac{d\sigma}{dy}\right|_{y=0} \sim$ 15 nb (2.4 - 27 nb)
  - Odderon: t-integrated $\left.\frac{d\sigma}{dy}\right|_{y=0} \sim$ 0.9 nb (0.3 - 4 nb)

At $L = 5 \times 10^{30}\ cm^{-2}s^{-1}$:

→ ***0.15 J/Ψ in ALICE central barrel in 1 s, 150k in 10^6 s***

→ ***9000 in e^+e^- channel in 10^6 s***

→ identify Photon and Odderon contribution by analysing p_T distribution (Odderon harder p_T spectrum)

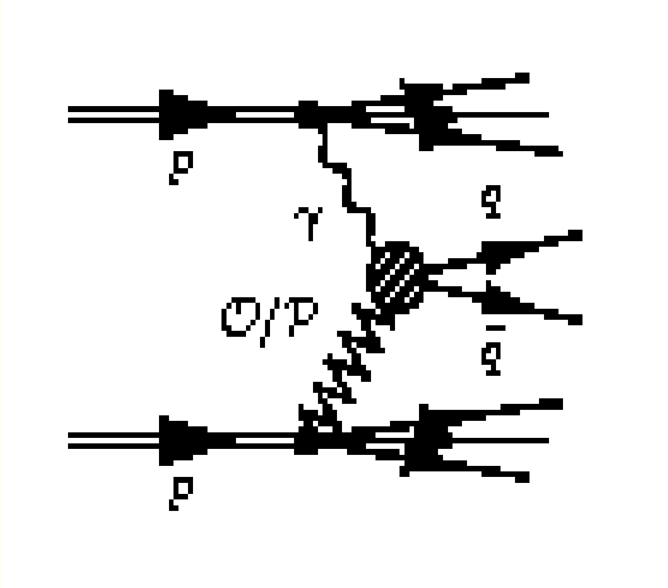
Signature Odderon interference

- Cross sections contain squared Odderon amplitudes

  → ***Odderon-Pomeron interference !***

$$d\sigma \sim |A\gamma(A_P + A_O)|^2 \, d^N q$$

$$\sim |A_P|^2 + 2\mathrm{Re}(A_P A_O^*) + |A_O|^2$$



→ ***look at final states which can be produced by Odderon or Pomeron exchange***

→ ***find signatures for interference of C-odd and C-even amplitude***

Interference signal

- Interference effects (relative contribution C = − 1)
  - Asymmetries in $\pi^+\pi^-$ and K^+K^- pairs (C = ± 1) in continuum

→ charge asymmetry relative to polar angle of π^+ in dipion rest frame

→ fractional energy asymmetry in open charm diffractive photoproduction

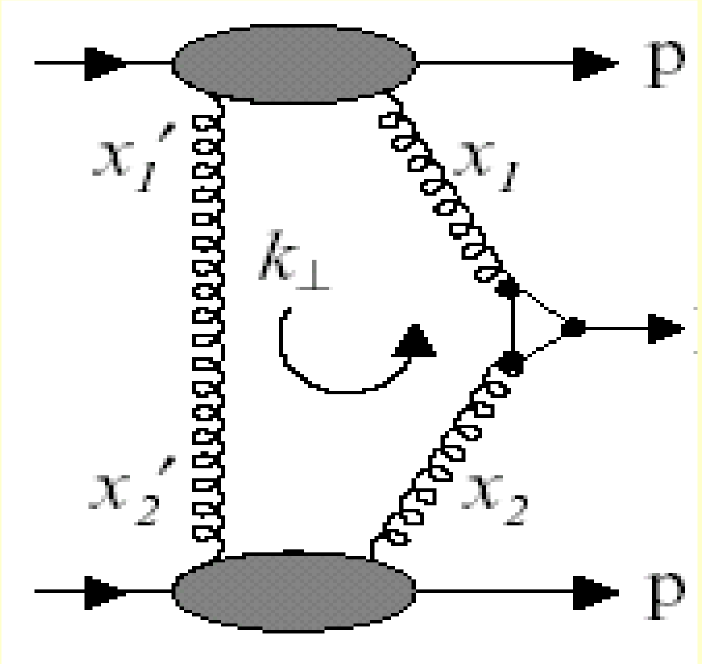
asymmetries in HERA kinematics estimated 10% - 15 %

χ_c production

Diffractive Higgs production has small cross section with large uncertainties (gap survival factor, Sudakov factor)
Same formalism can be used to predict $\gamma\gamma$, dijet and χ_c,χ_b

→ *see talk by A. Martin*

→check uncertainties by measuring systems with larger cross section (smaller mass)



χ_c rates

- Khoze, Martin, Ryskin, Stirling 2004:

χ_c at LHC $\sqrt{s}$ = 14 TeV: $\left.\frac{d\sigma_{excl}}{dy}\right|_{y=0} = 340$ nb → 3.5 10^6 χ_c in 10^6 s

decay mode	BR	signal	backgnd
$\chi_c \rightarrow p\bar{p}$	$2\text{x}10^{-4}$	700	??
$\chi_c \rightarrow \pi\pi$	$7\text{x}10^{-3}$	$2.4\text{x}10^{4}$	??
$\chi_c \rightarrow K^+K^-$	$6\text{x}10^{-3}$	$2.1\text{x}10^{4}$	??
$\chi_c \rightarrow J/\psi\ \gamma$	$1\text{x}10^{-2}$	$3.5\text{x}10^{4}$	??

} *χ_c measurement seems feasible*

feasibility study $\chi_c \rightarrow J/\psi\ \gamma$, BR $J/\psi \rightarrow e^+e^-$, acceptance γ, reconstruction eff, signal ~35

Exclusive vector meson production in PbPb

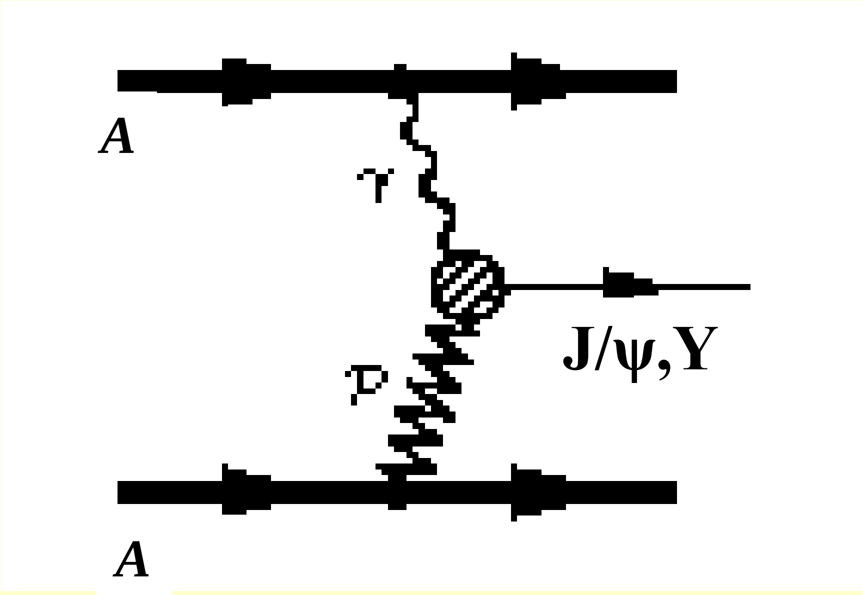
- γ-pomeron interaction in PbPb
- Calculate equivalent photon flux $n(\omega)$

$$\sigma(A+A\rightarrow A+A+V) = 2\int n(\omega)\sigma_{\gamma A\rightarrow VA}(\omega)d\omega$$

For heavy states J/ψ,Y, the cross section $\sigma_{\gamma A\rightarrow VA}$ is given by

$$\frac{d\sigma}{dt}\Big|_{t=0} = \frac{\alpha_s^2\Gamma_{ee}}{3\alpha M_V^5}16\pi^3[xg(x,\frac{M_V^2}{4})]^2$$

→ *This cross section probes the nuclear gluon distribution $g(x,Q^2)$*



Exclusive vector meson cross sections

Many calculations use different approaches, including gluon shadowing, a full Glauber model for the absorption, the color dipole model etc.

[KN] S. Klein and J. Nystrand, Phys. Rev. C 60 (1999) 014903.
[GM] V. P. Goncalves and M. V. T. Machado, J. Phys. G 32 (2006) 295.
[IKS] Yu. P. Ivanov, B. Z. Kopeliovich and I. Schmidt, arXiv:0706.1532 [hep-ph].
[FSZ] M. Strikman, M. Tverskoy and M. Zhalov, Phys. Lett. B 626 (2005) 72;
L. Frankfurt, M. Strikman, M. Zhalov, Phys. Lett. B 540 (2002) 220; Phys. Lett. B 537 (2002) 51.

Pb+Pb → Pb+Pb+V at the LHC

Model	ρ^0 [b]	J/Ψ [mb]
KN	5.2	32
GM	10.1	41.5
IKS	4.0, 4.4	26.7, 26.3
FSZ	9.5	14, 85

Conclusions, outlook

- ALICE has unique opportunity to do diffractive physics
- Diffractive trigger defined by two rapidity gaps
- Neutron tagging at zero degree
- Phenomenology of Pomeron/Odderon
- Measurement of exclusive χ_c feasible
- Photon-Photon physics