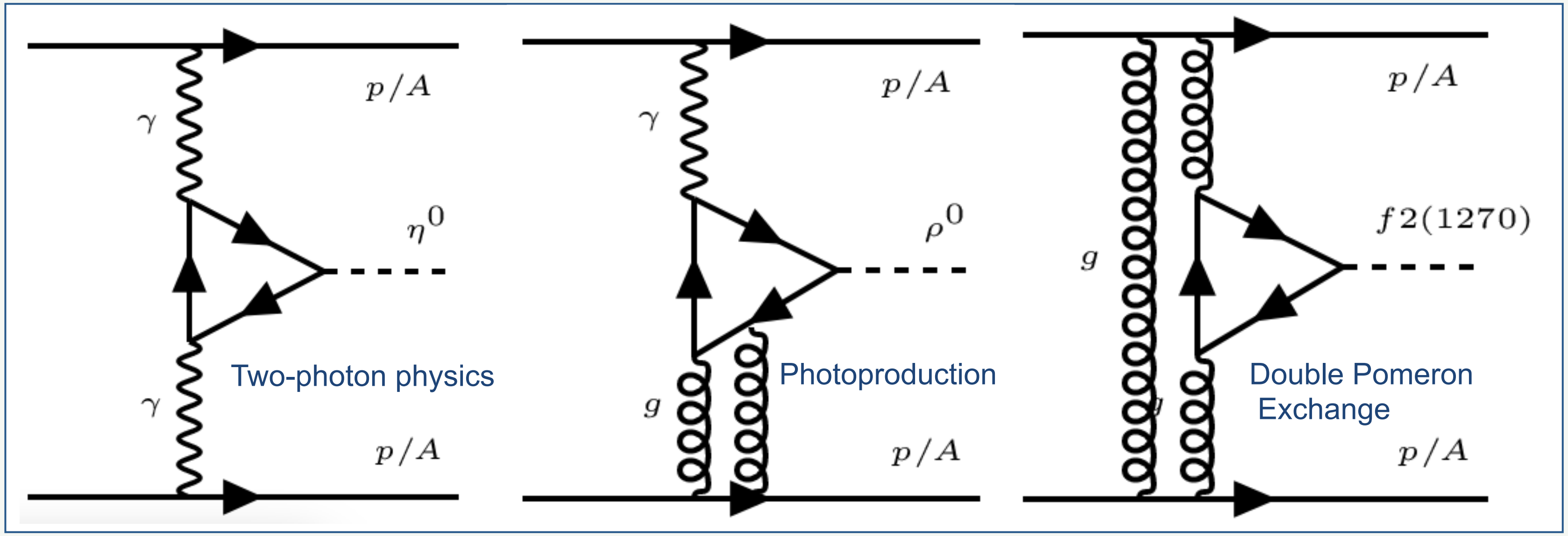
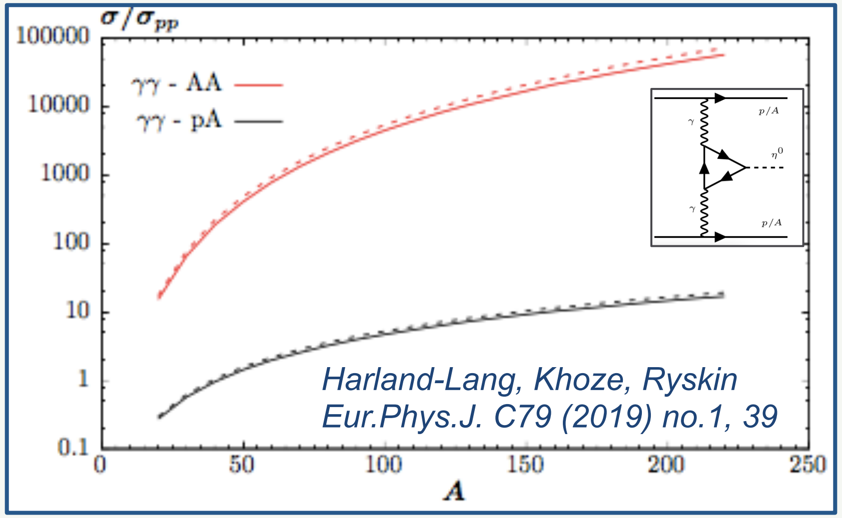
Light Quark Exotica in Central Exclusive Production (CEP) at LHC

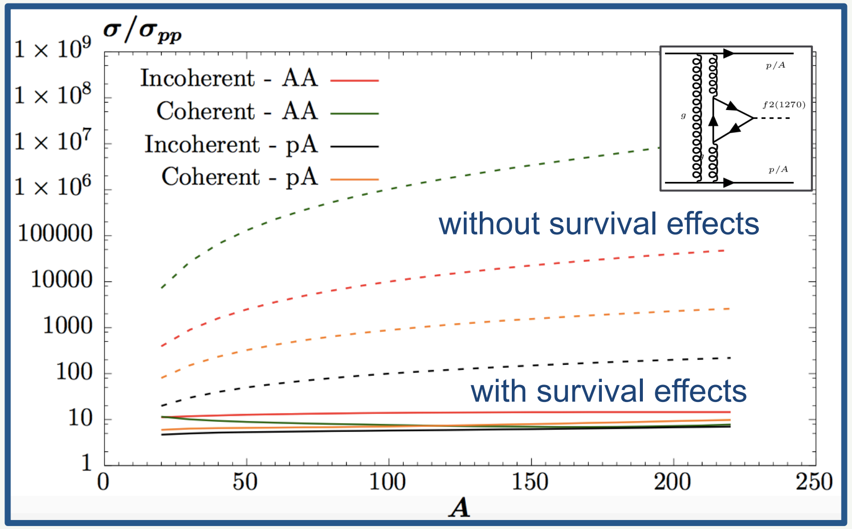


Ronan McNulty
University College Dublin

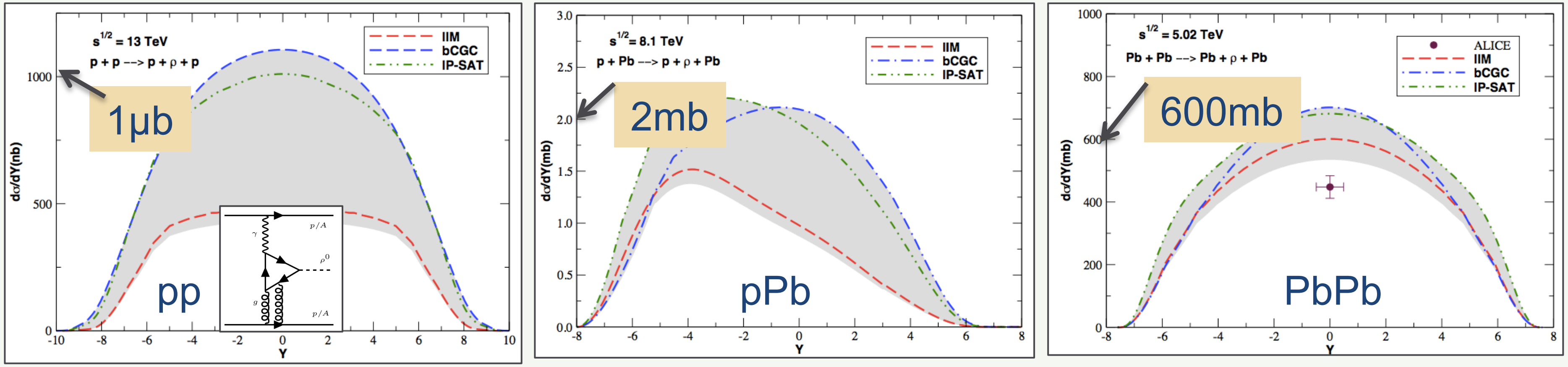
SnowMass Workshop. 30th Sep. 2020

Complementarity of collisions

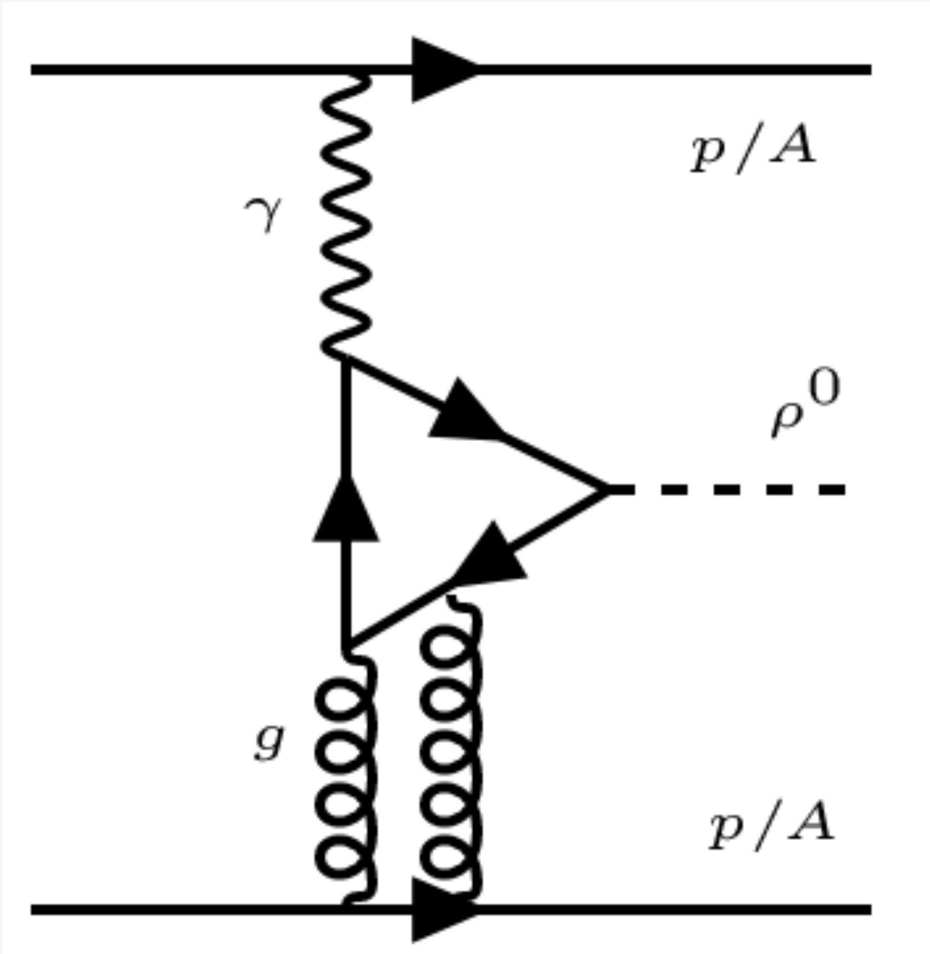




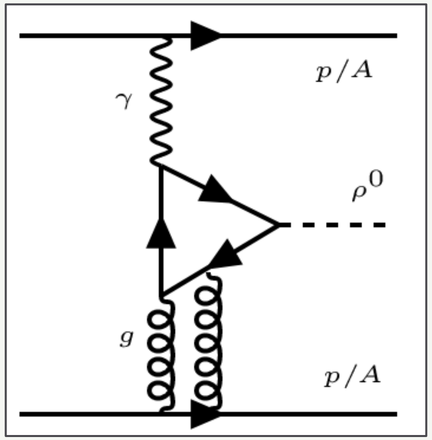
Goncalves et al. Nucl.Phys. A976 (2018) 33-45



Photoproduction



$\sigma_{\gamma p}^{pp\text{-}tot} \sim 100\mu b$



Photoproduction

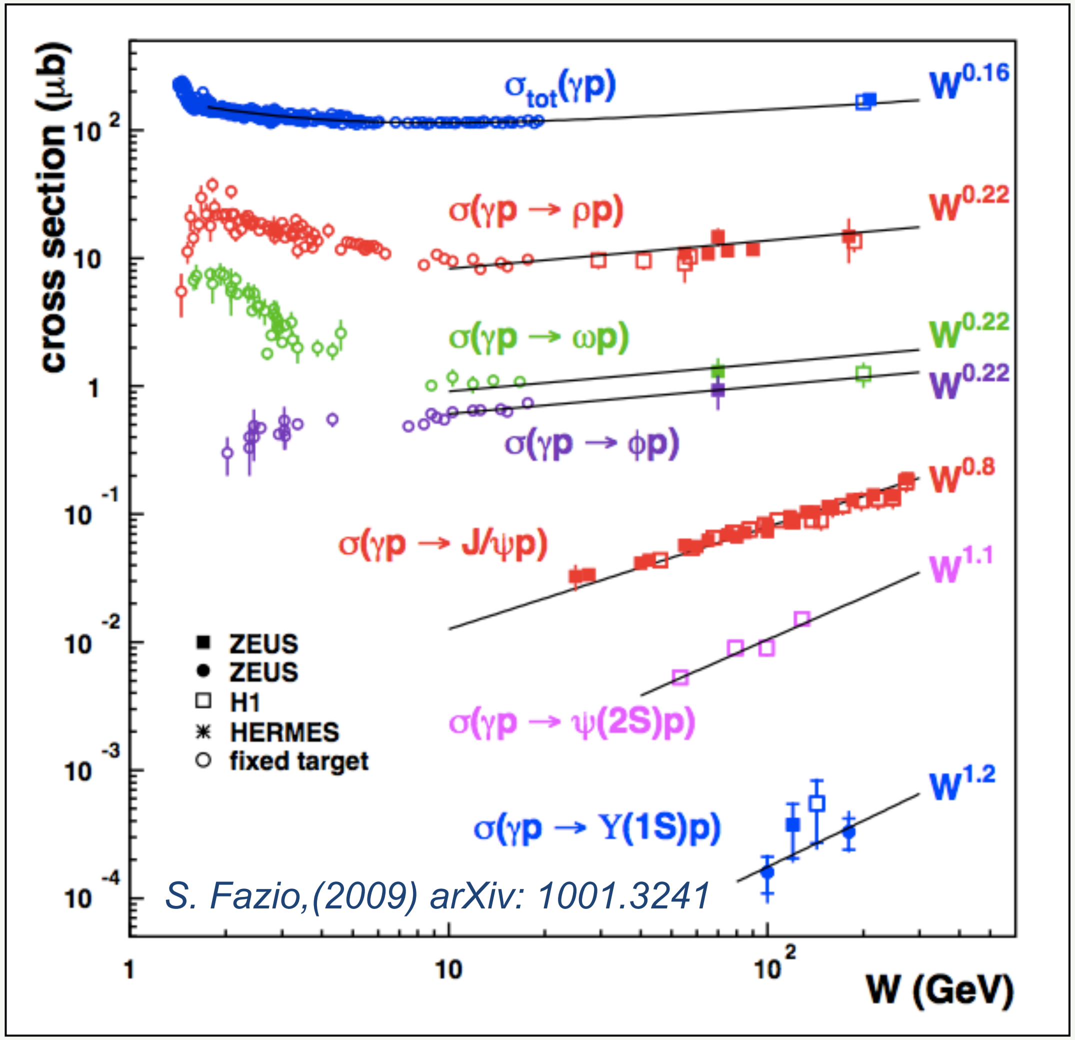
Understand standard physics in order to search for exotica

Rise in σ related to Pomeron intercept

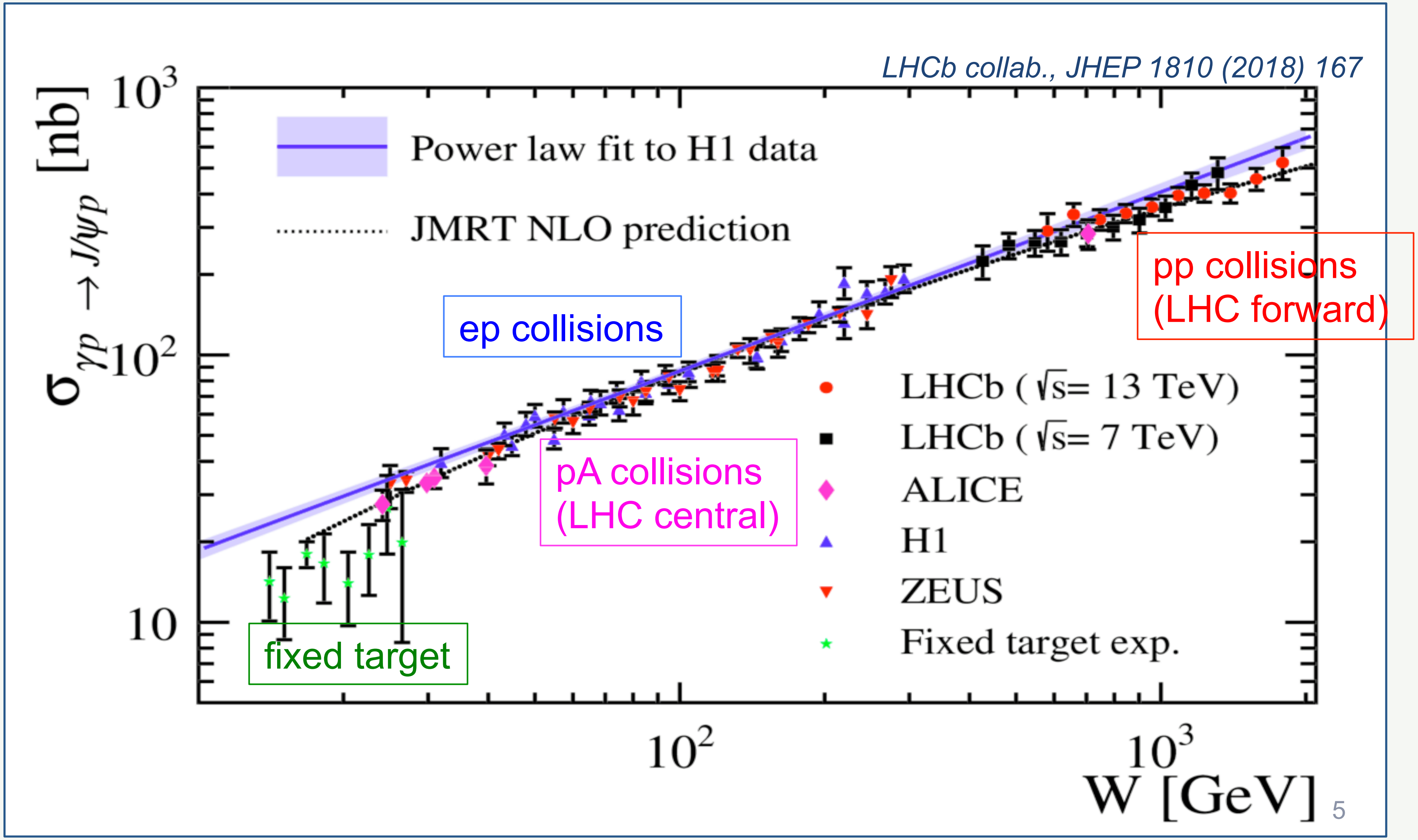
$$\sigma \sim W^{4(\alpha P(t)-1)}$$

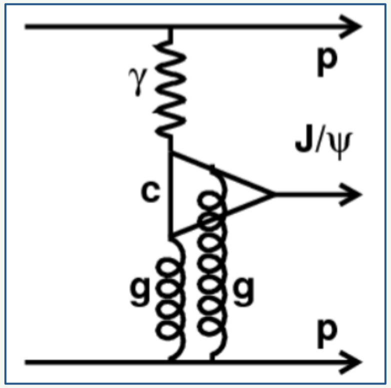
Flat W/rapidity dependence for light mesons.

Consistency between HERA and LHC



J/ψ production (muons are easier)





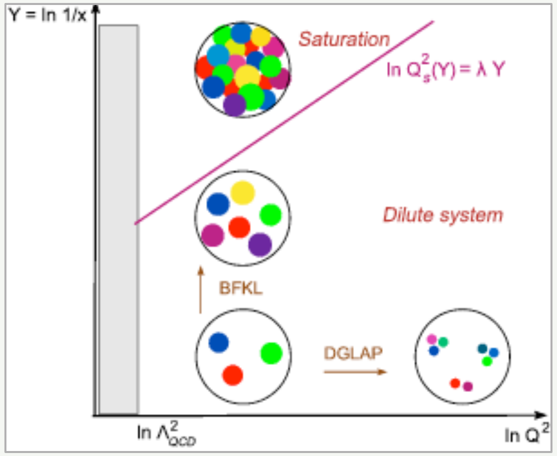
Gluon PDF and saturation

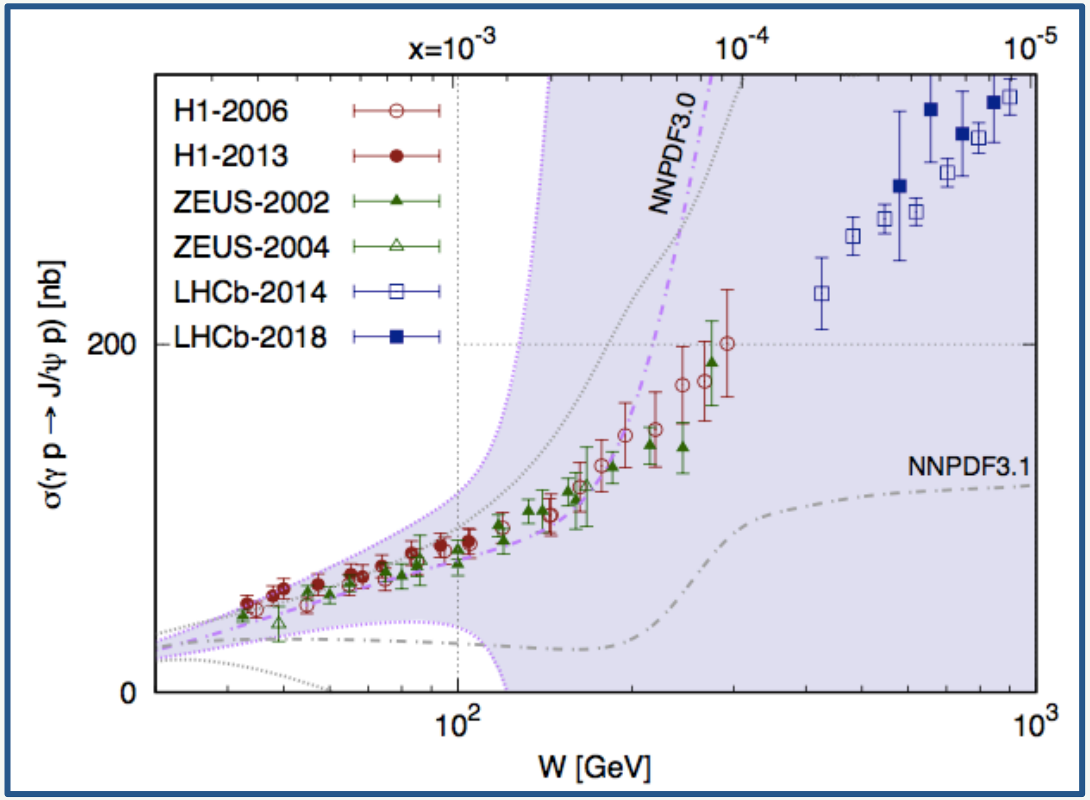
$$\frac{d\sigma}{dt}(\gamma^* p \to J/\psi\, p)\Big|_{t=0} = \frac{\Gamma_{ee} M^3_{J/\psi}\pi^3}{48\alpha}\left[\frac{\alpha_s(\bar{Q}^2)}{\bar{Q}^4} xg(x,\bar{Q}^2)\right]^2\left(1+\frac{Q^2}{M^2_{J/\psi}}\right)$$

In LHC kinematics:

J/ψ probes $x \to 2.10^{-6}$

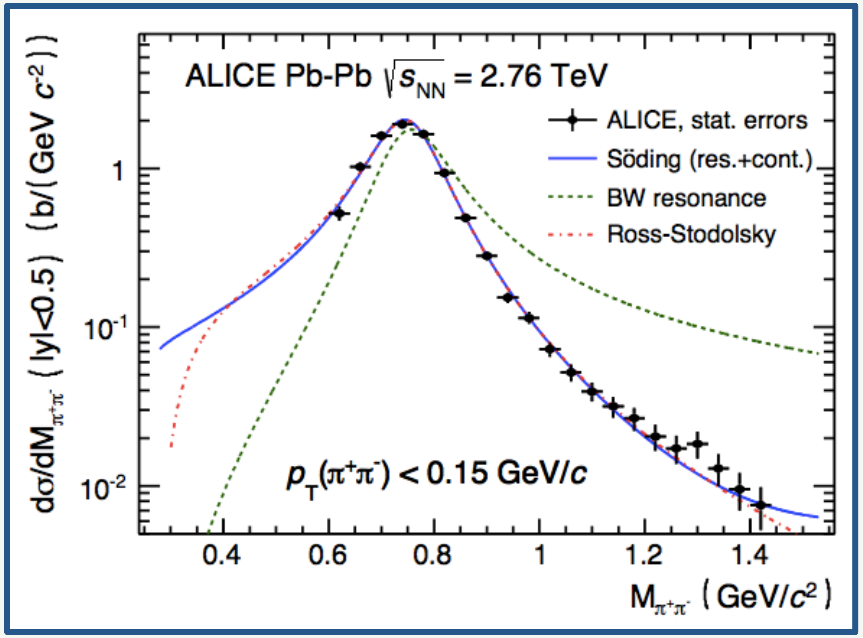
ρ probes $x \to 3.10^{-7}$



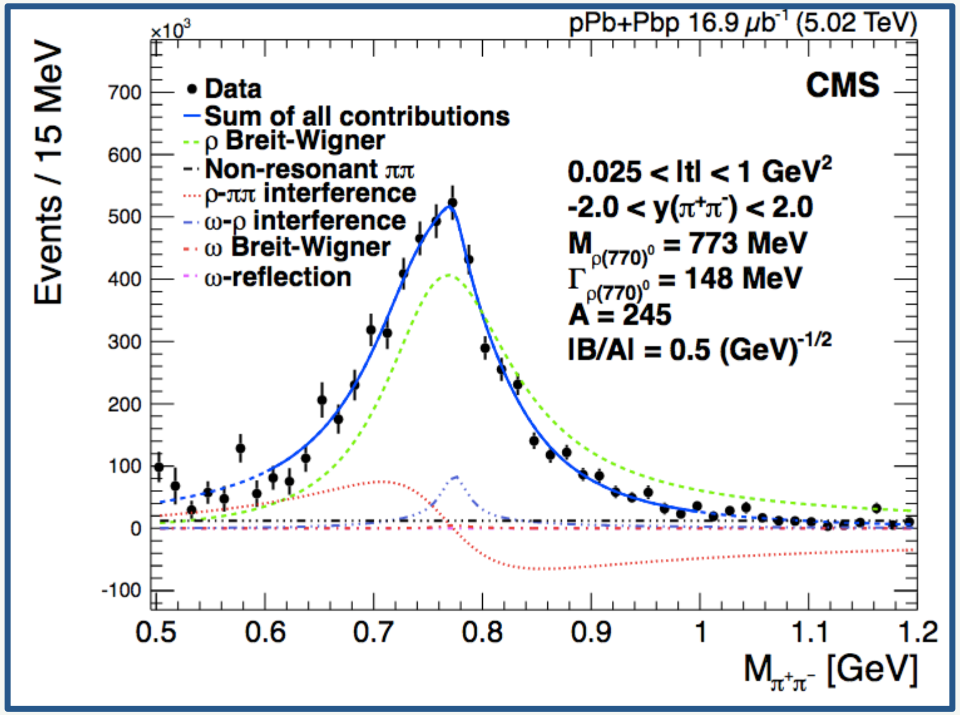


Flett, Jones, Martin, Ryskin, Teubner. Phys.Rev.D 101 (2020) 9, 094011

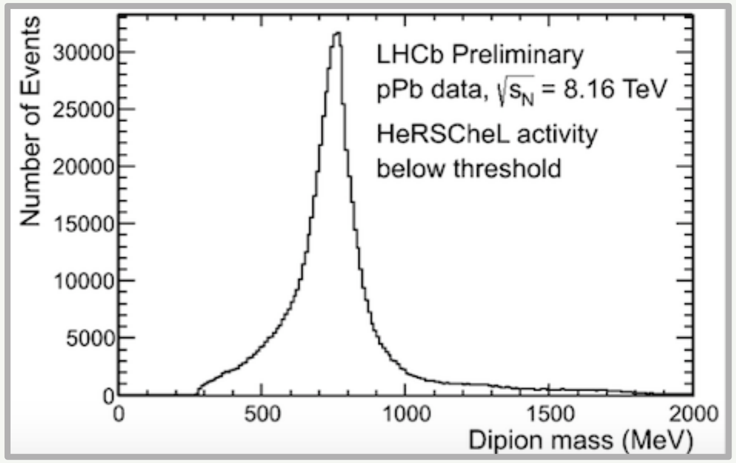
ρ photoproduction



Alice collab., JHEP 1509 (2015) 095

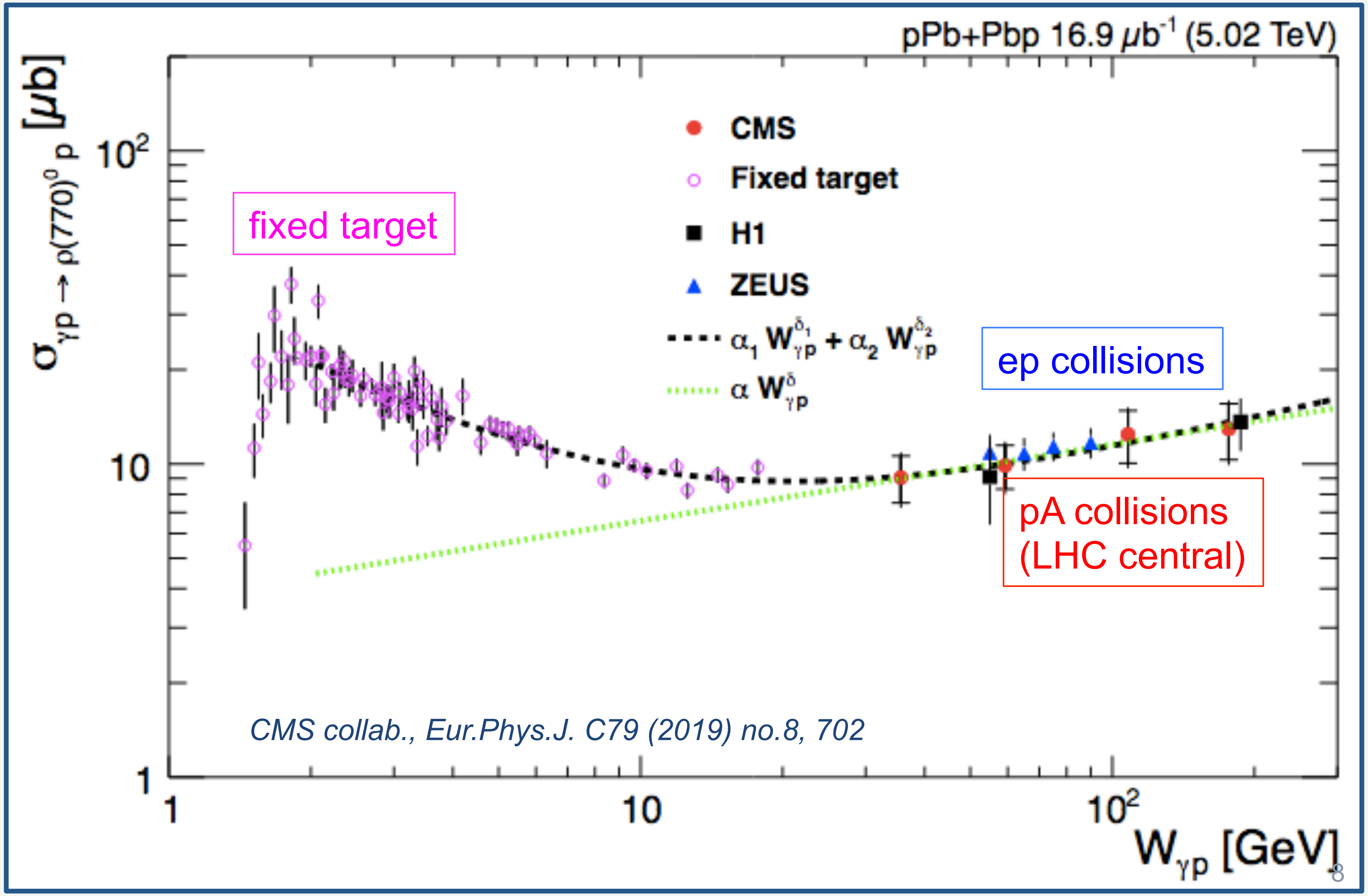


CMS collab., Eur.Phys.J. C79 (2019) no.8, 70

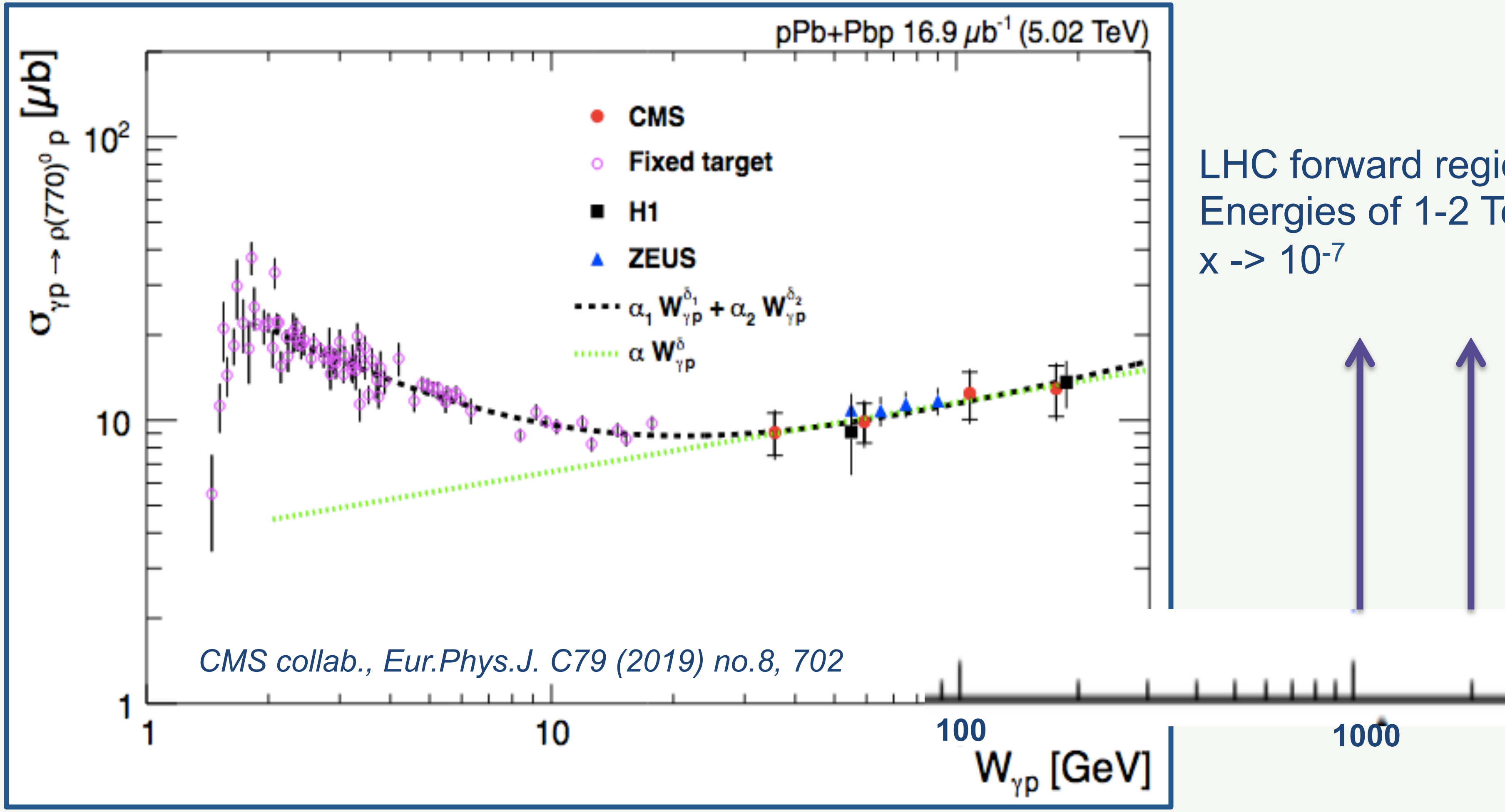


arXiv:1608.08103

ρ photoproduction



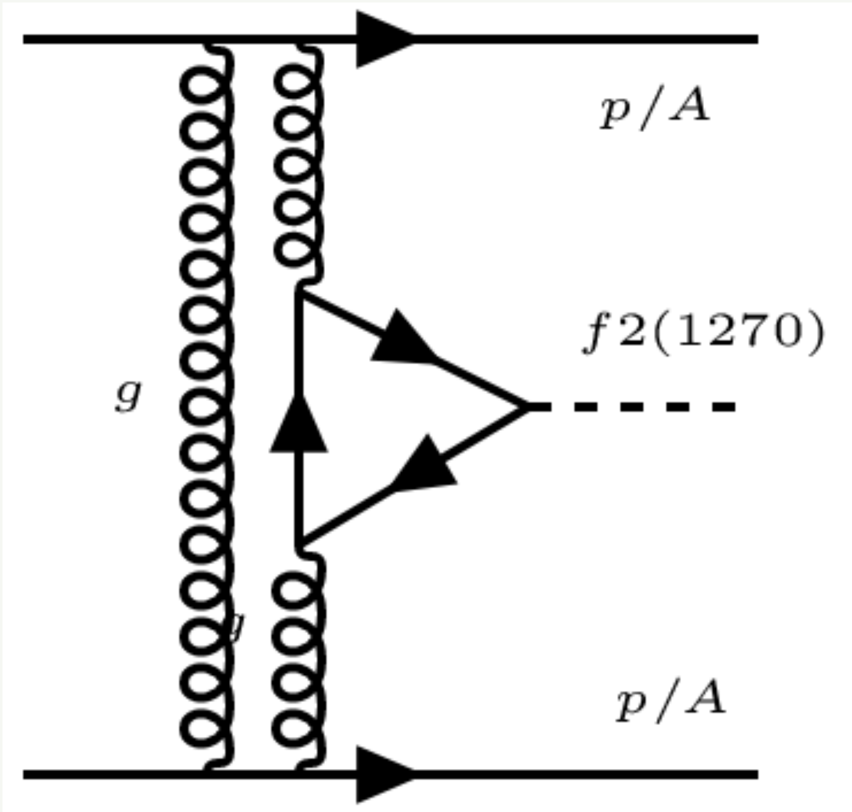
ρ photoproduction



CMS collab., Eur.Phys.J. C79 (2019) no.8, 702

LHC forward region
Energies of 1-2 TeV
x -> 10^{-7}

Double Pomeron Exchange

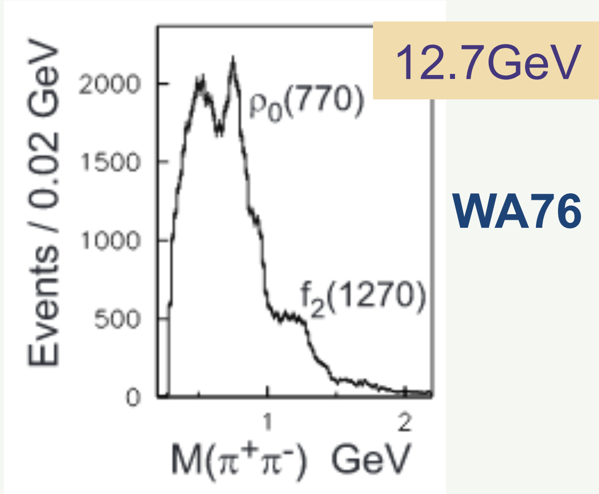


LHC: colourless gluon-gluon collider.
Excellent place to search for glueballs.

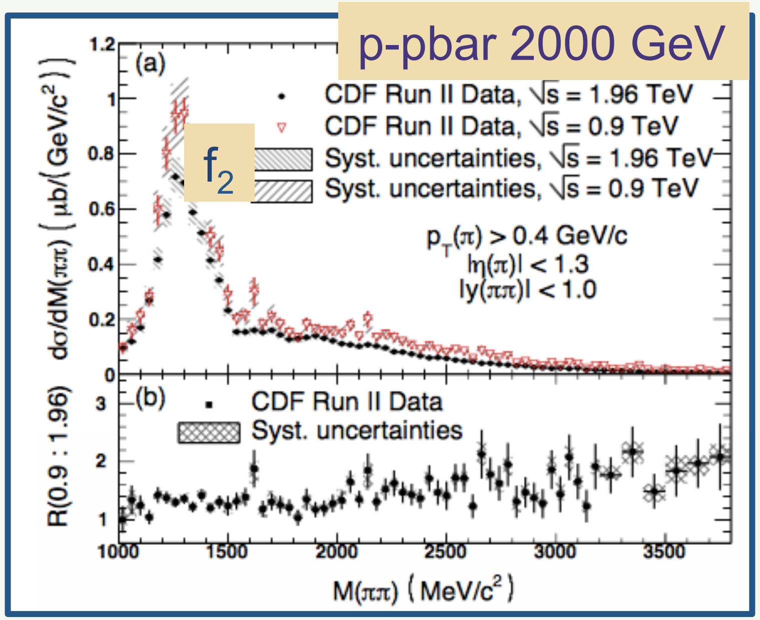
$\sigma_{DPE}^{pp\text{-}tot} \sim 100\mu b$

$\pi^+\pi^-$ final state

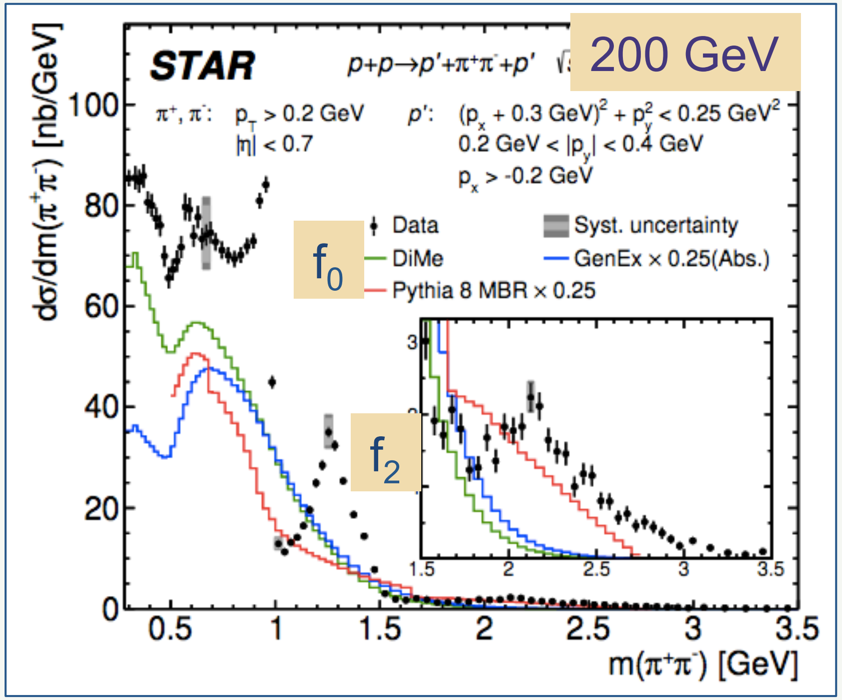
Simple final state...
.... but complicated structure



T. A. Armstrong et al., Z. Phys. C 51, 351 (1991)
A.Kirk, Int.J.Mod.Phys.A 29 (2014) 28, 1446001



CDF collab., Phys.Rev. D91 (2015) no.9, 091101



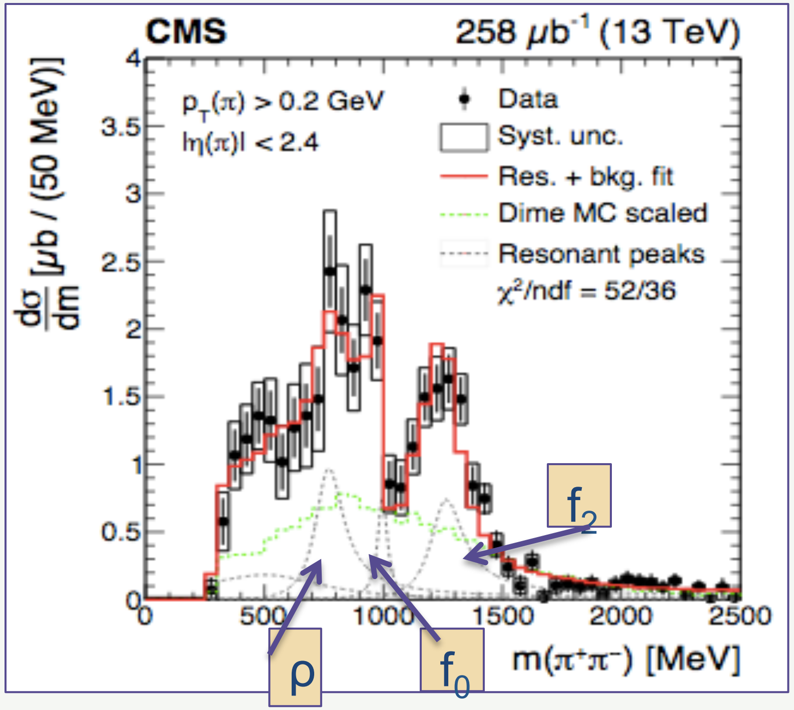
Observed structure depends critically on acceptance and efficiency.

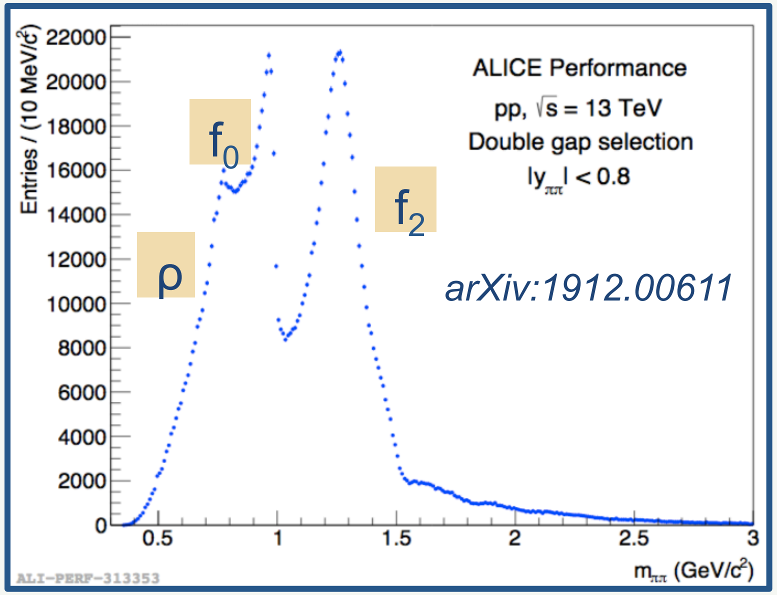
Difficult to extrapolate from fiducial region when intermediate resonances poorly understood.

STAR collab., JHEP 07 (2020) 07, 178

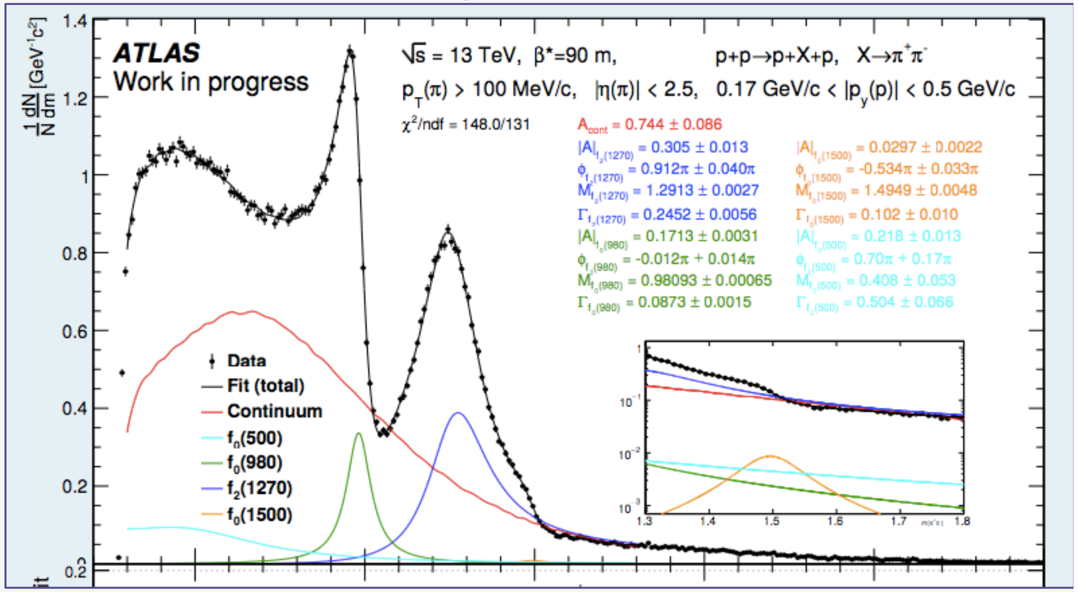
LHC: ππ final state

CMS collab., Eur.Phys.J.C 80 (2020) 8, 718





Poster: ICFA School https://indico.cern.ch/event/630418/

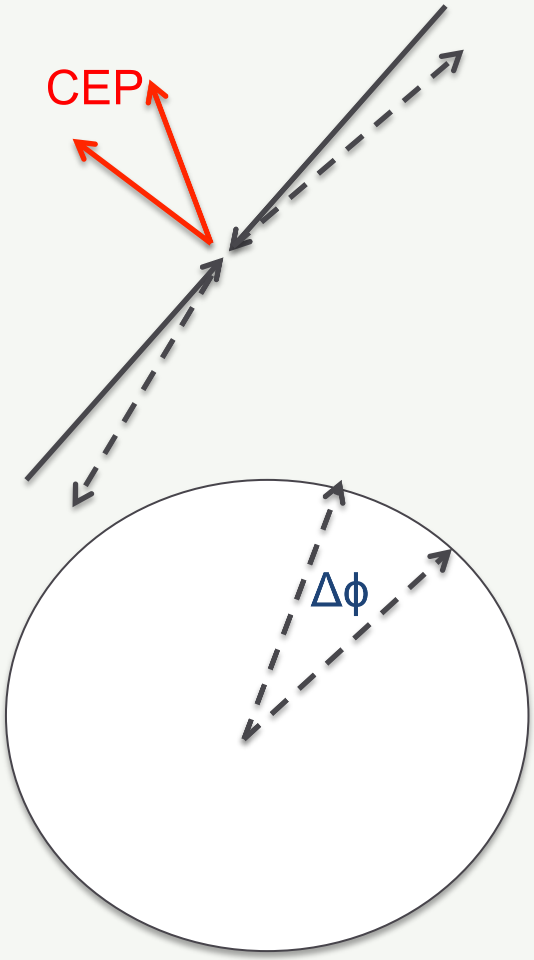


LHC sees similar structures. Very sensitive to kinematic requirements.
ATLAS results with proton-taggers eagerly anticipated.

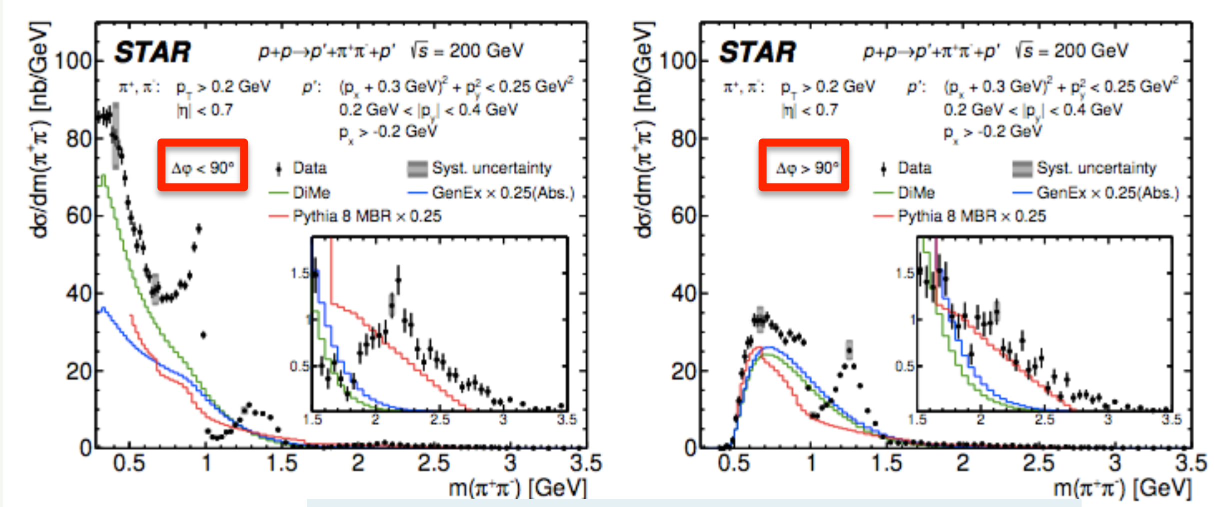
Glueball filter?

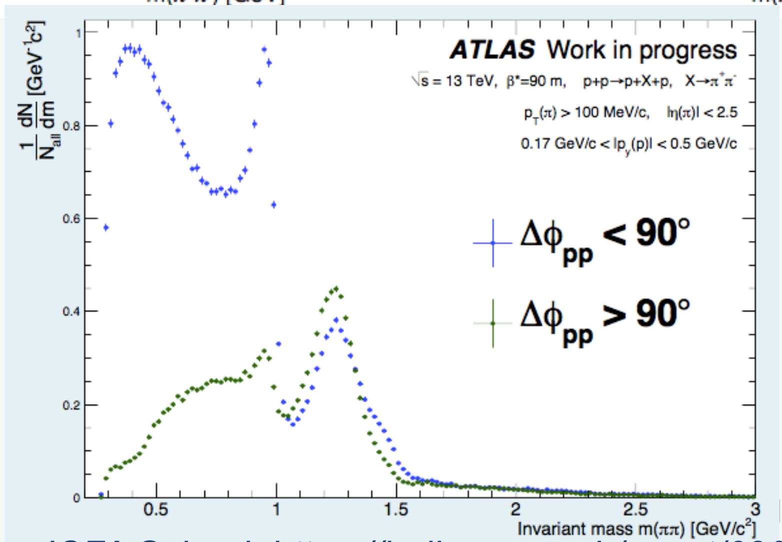
F. Close, A. Kirk, Phys.Lett.B397:333-338,1997

We shall suggest that it is driven primarily by the variable $dP_T \equiv |\vec{p'_T} - \vec{q'_T}|$ and that gg configurations are enhanced in kinematic configurations where the gluons can flow "directly" into the final state with only small momentum transfer, in particular when $dP_T \to 0$.



STAR collab., JHEP 07 (2020) 07, 178

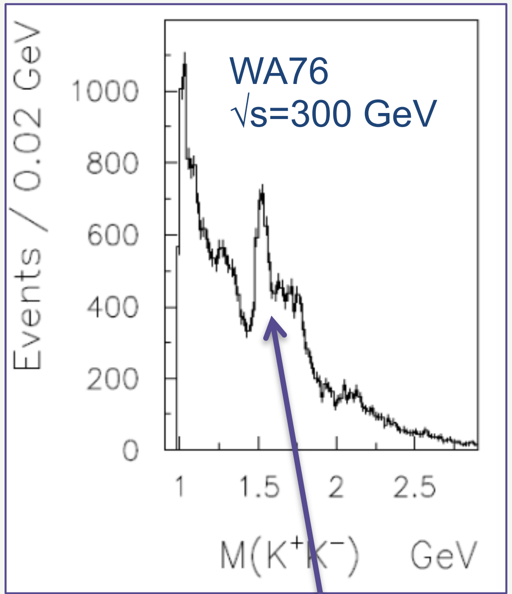




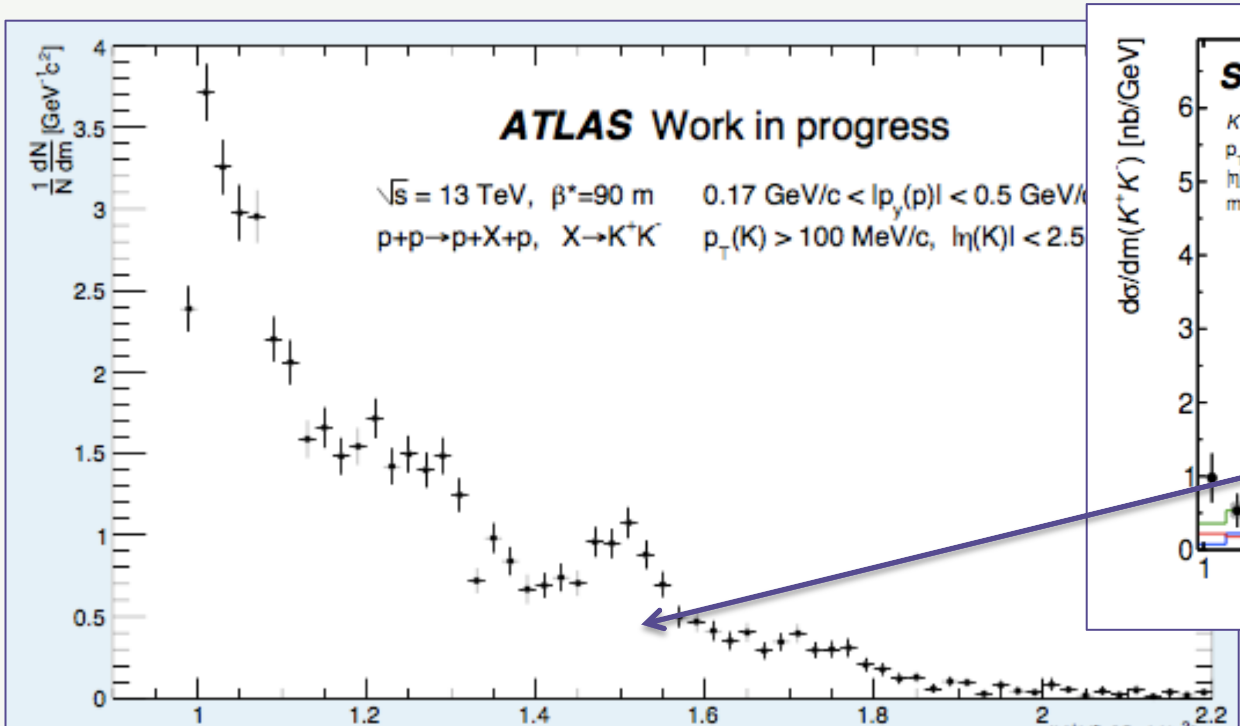
Poster: ICFA School https://indico.cern.ch/event/630418/

K^+K^- final state

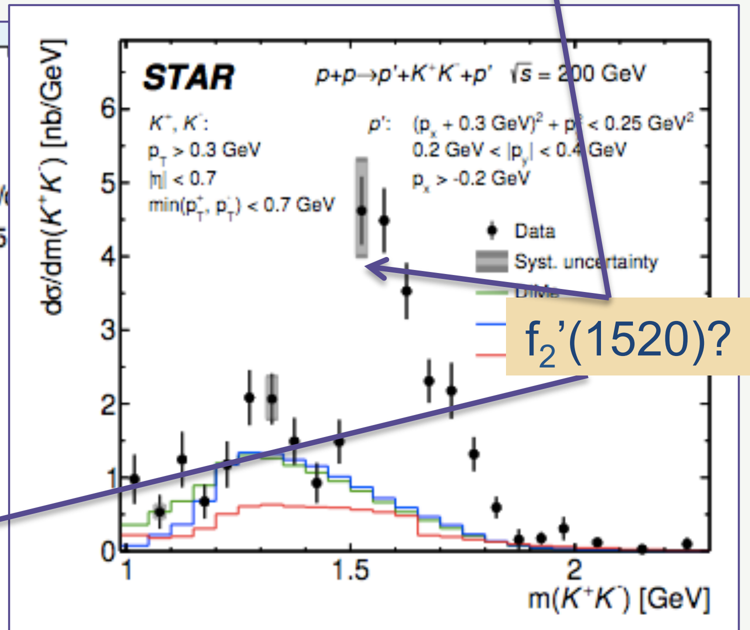
Qualitatively similar.
Detail depends on experimental configuration



T. A. Armstrong et al., Z.Phys.C 51 (1991) 351-364



Poster: ICFA School https://indico.cern.ch/event/630418/

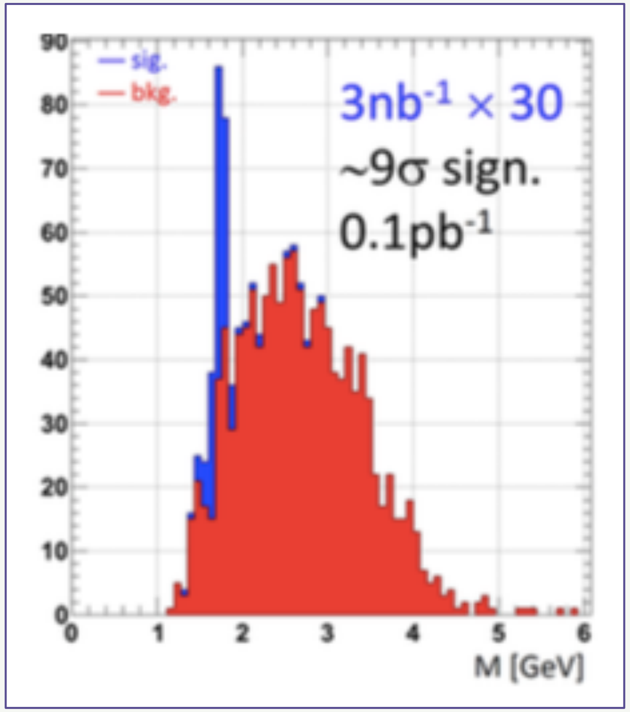


STAR collab., JHEP 07 (2020) 07, 178

Glueballs in ρρ / VV?

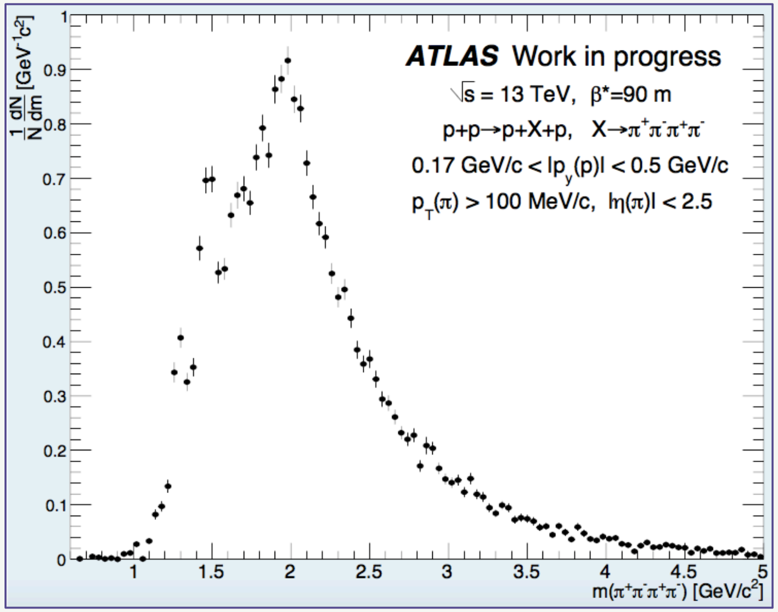
Simply reconstructed signals of 4π / 4K

CERN-PH-LPCC-2015-001



Simulated $f_0(1710)$->ρρ signal in CMS-Totem

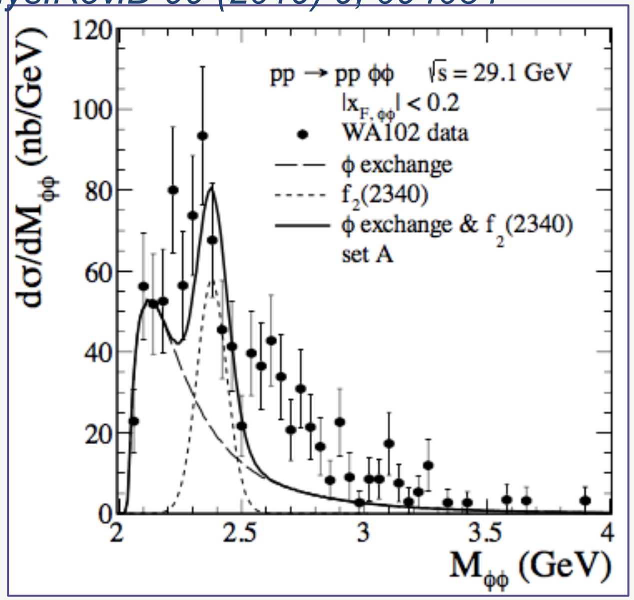
Such signals are also candidates for tetraquark, hybrid and molecular states



Poster: ICFA School

https://indico.cern.ch/event/630418/

P. Lebiedowicz, O. Nachtmann, A. Szczurek
Phys.Rev.D 99 (2019) 9, 094034

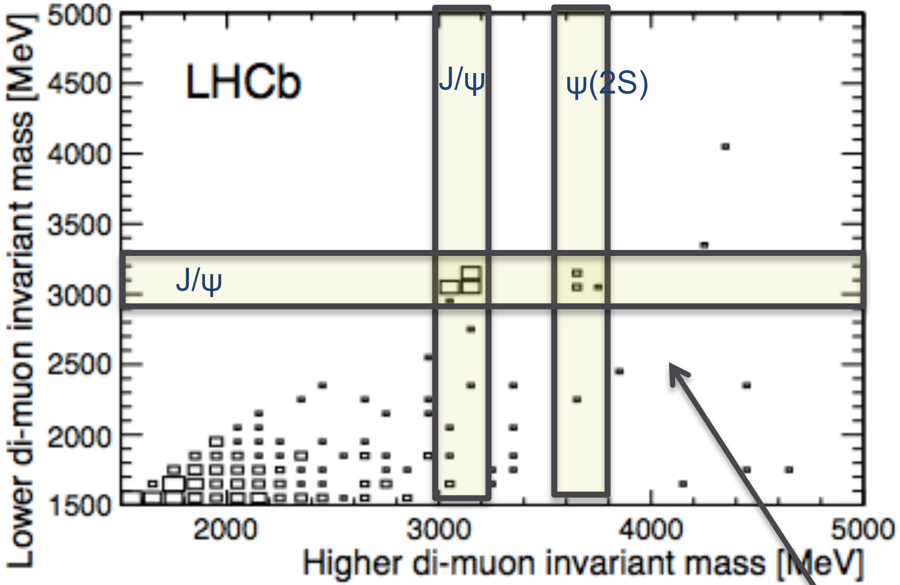


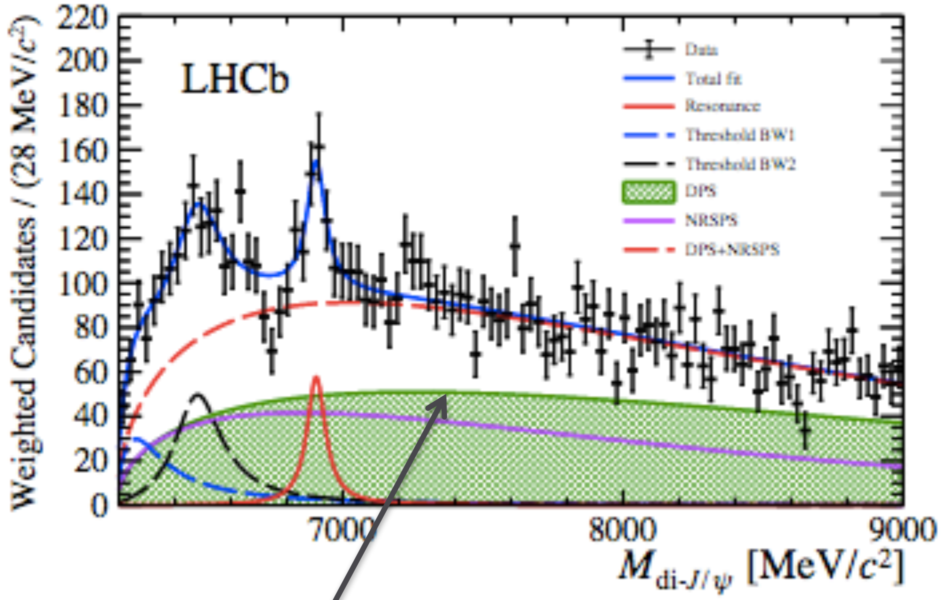
Model with f2(2340) + continuum that fits WA102 KKKK data

J/ψJ/ψ: search for exotica

LHCb collab., JPG 41 (2014) 115002

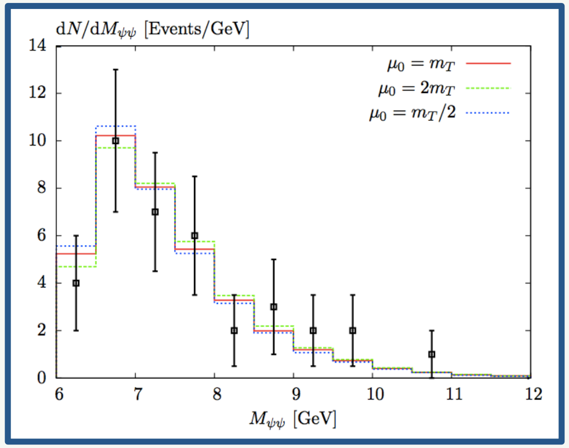
LHCb collab., arXiv: 2006.16957





EXCLUSIVE

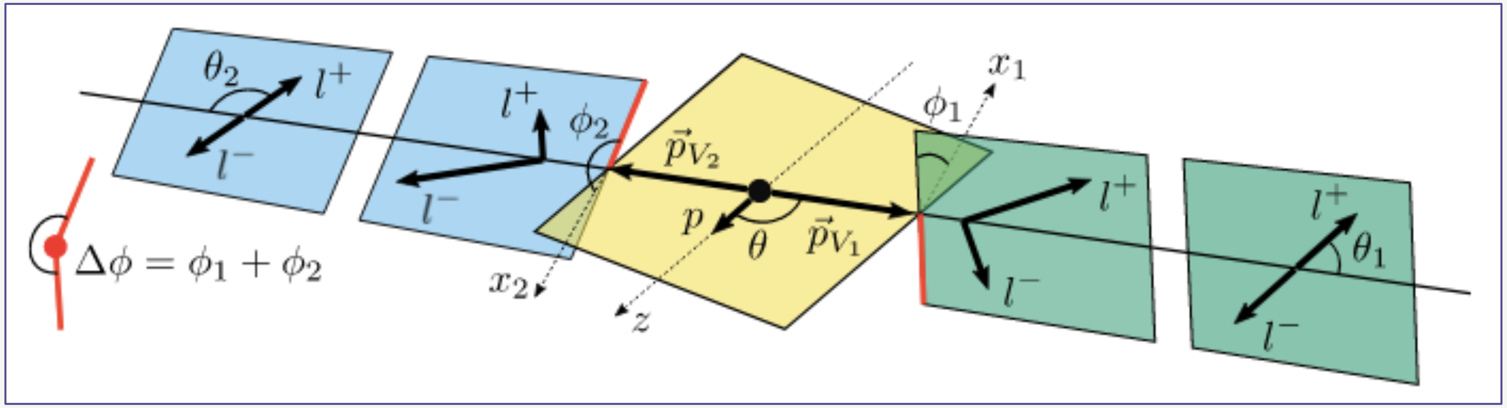
INCLUSIVE

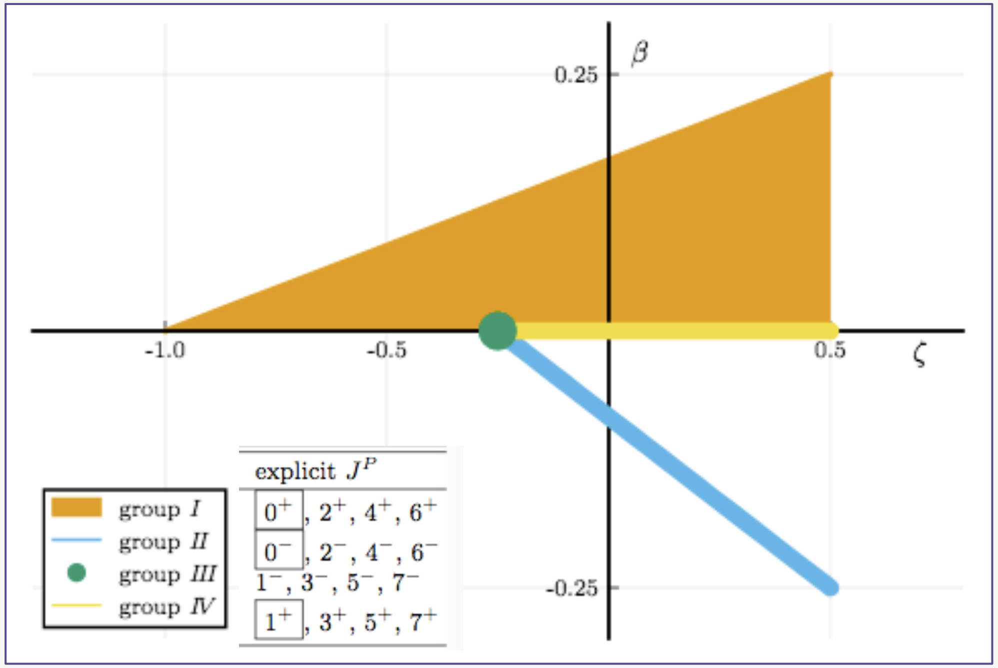


L A Harland-Lang, V A Khoze and M G Ryskin
J.Phys.G 42 (2015) 5, 055001

Angular analysis to extract J^P

M. Mikhasenko. L. An, R. McNulty, arXiv:2007.05501



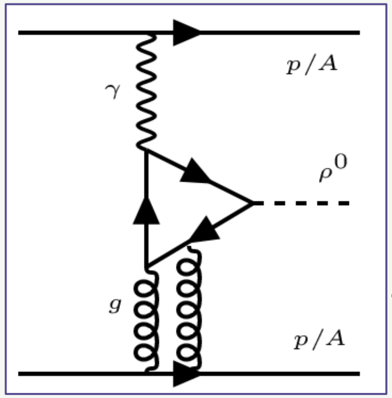


$$1+\beta\cos\Delta\phi$$

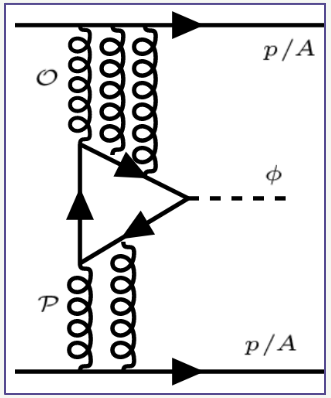
$$1+\frac{\zeta}{2}(3\cos^2\theta-1)$$

Measurement of two angles can quickly show which J^P are inconsistent

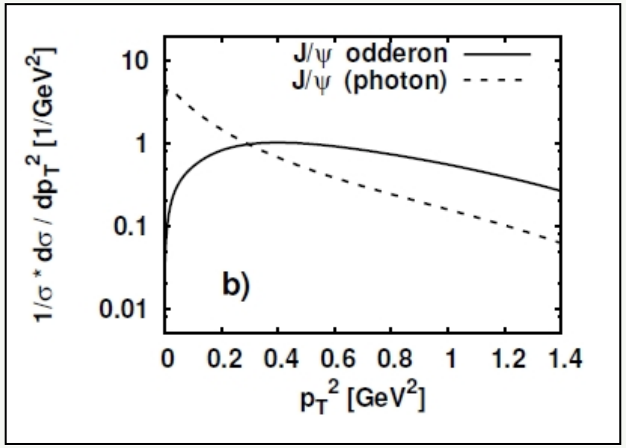
Odderon



$$\frac{d\sigma}{dt} \sim e^{bt} \sim e^{-bp_T^2}$$

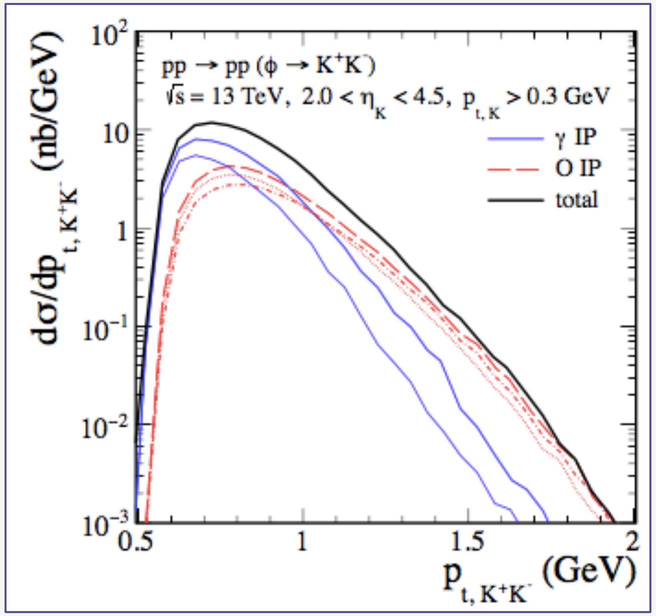


J/ψ



Bzdak, Motyka, Szymanowski, Cudell
PRD 75 (2007) 094023

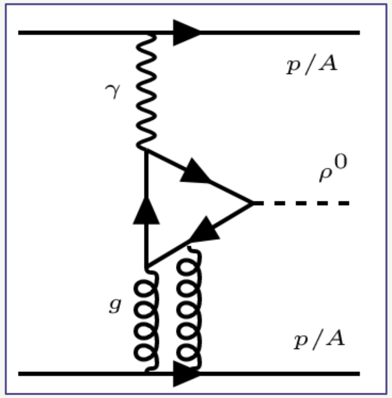
ϕ

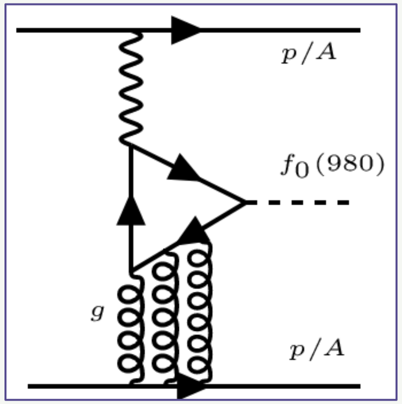


Lebiedowicz, Nachtmann, Szczurek
Phys.Rev.D 101 (2020) 9, 094012

Odderon

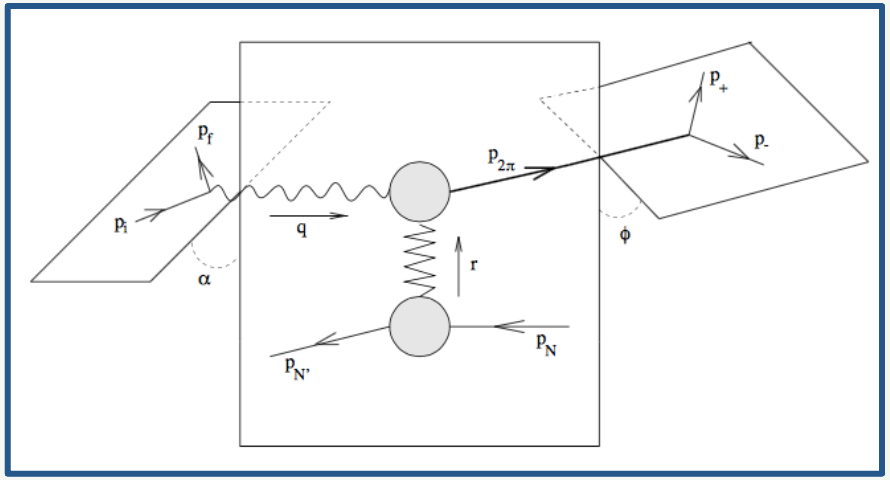
Brodsky, Rathsman, Merino, PLB461 (1998) 114.
Bolz, Ewerz, Maniatis, Nachtmann, Sauter, Schoening, JHEP 1501 (2015) 151.
Hagler, Pire, Szymanowski, Teryaev, EPJ26 (2002) 261.

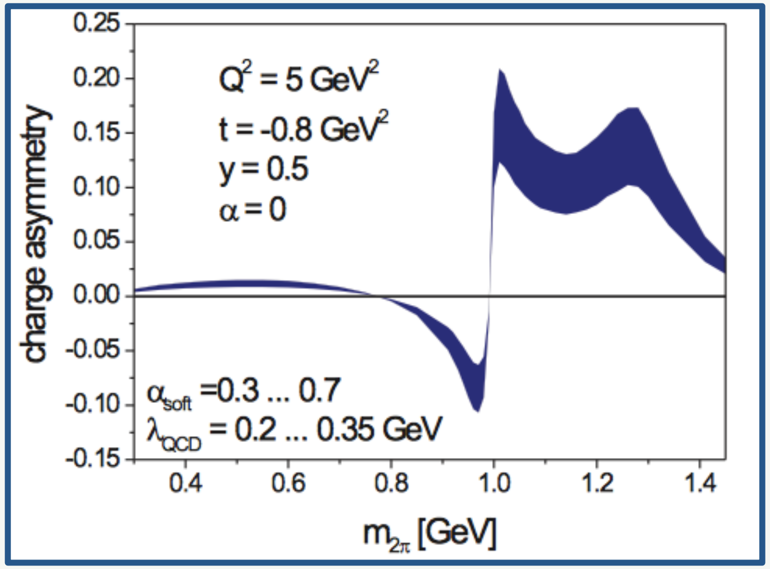




Interference of Pomeron and Odderon in photoproduction processes

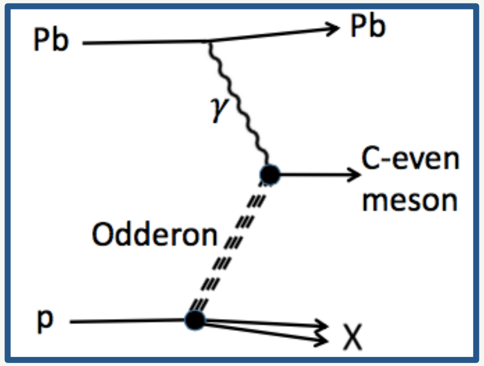
$$A(Q^2,t,m_{2\pi}^2,y,\alpha)=\frac{\sum_{\lambda=+,-}\int\cos\theta\,d\sigma(s,Q^2,t,m_{2\pi}^2,y,\alpha,\theta,\lambda)}{\sum_{\lambda=+,-}\int d\sigma(s,Q^2,t,m_{2\pi}^2,y,\alpha,\theta,\lambda)}=\frac{\int d\cos\theta\cos\theta\;N_{charge}}{\int d\cos\theta\;D}$$



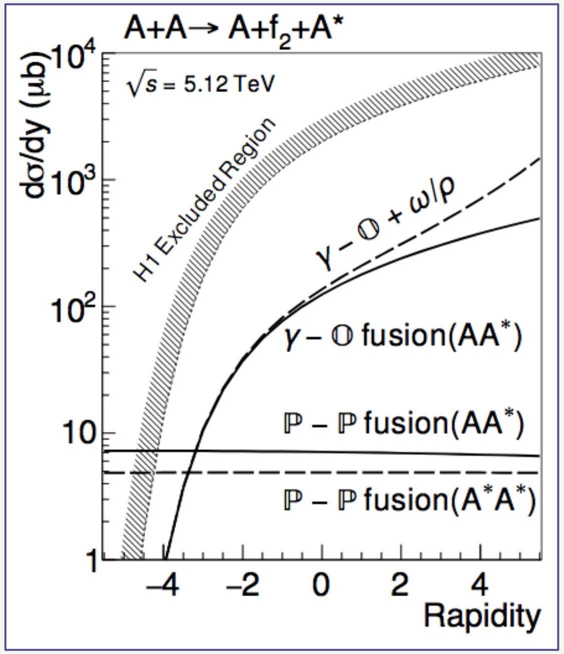


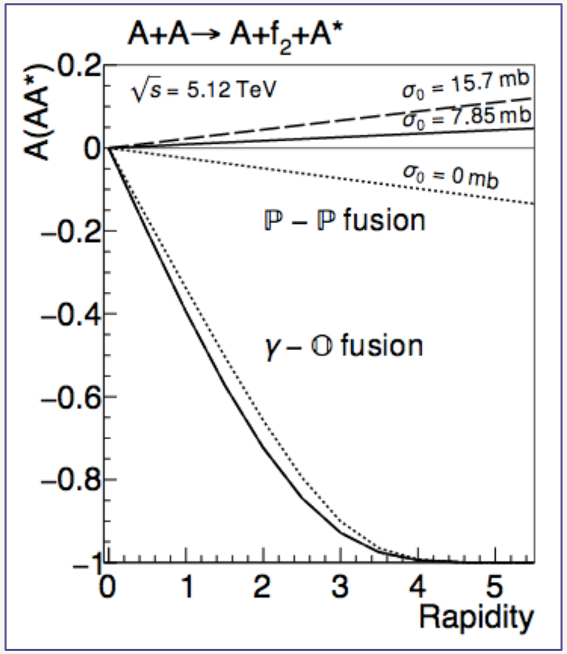
Odderon

Search in CEP photo-production where quantum numbers inconsistent with pomeron



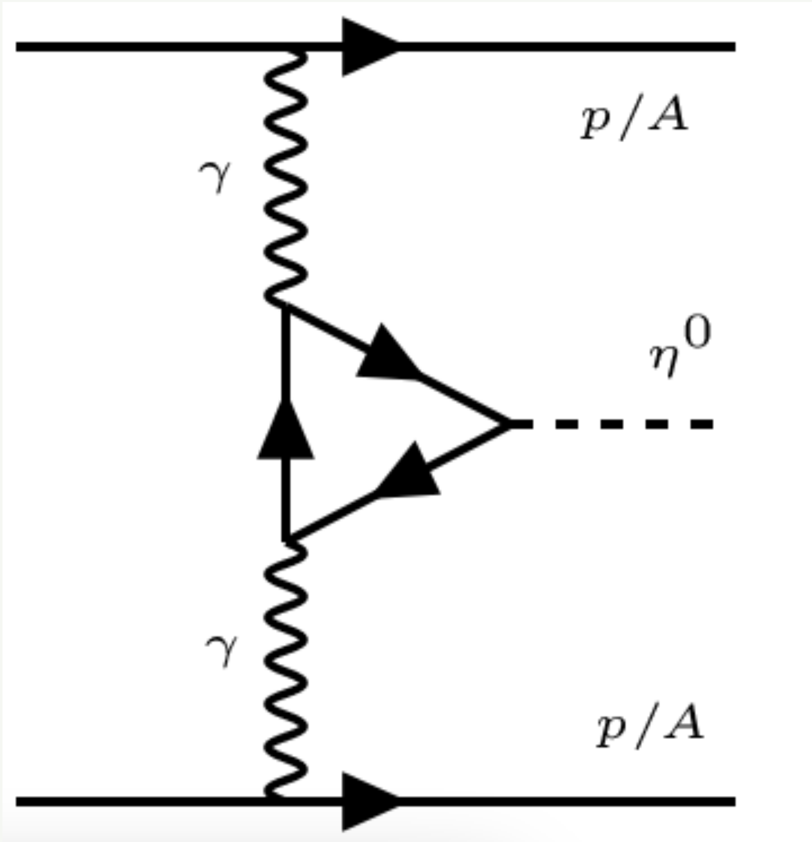
Czyzewski et al., PLB398 (1997) 400.
Berger et al., EPJ C9 (1999) 491.
M.G. Ryskin EPJ C2 (1998) 339.
Kilian & Nachtmann, EPJ C5 (1998) 317.
Harland-Lang et al. arXiv:1811.12705



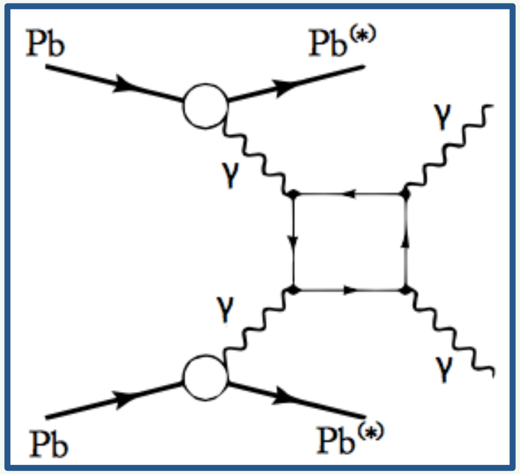


R. McNulty, V.A. Khoze, A.D. Martin, M.G. Ryskin, Eur.Phys.J.C 80 (2020) 3, 288

Gamma-Gamma collisions



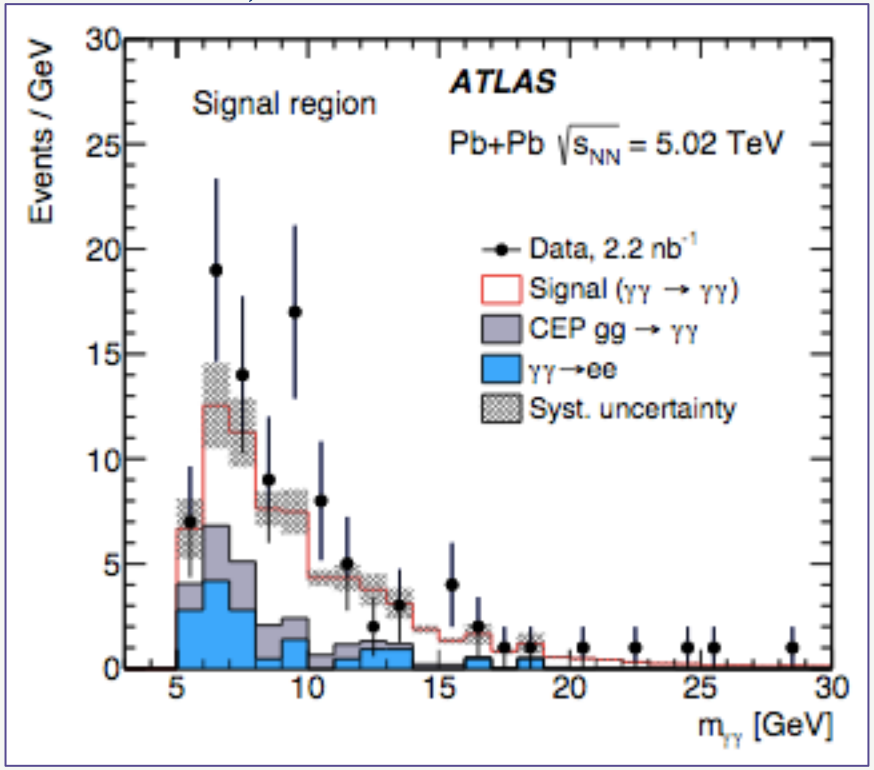
Light-by-light scattering



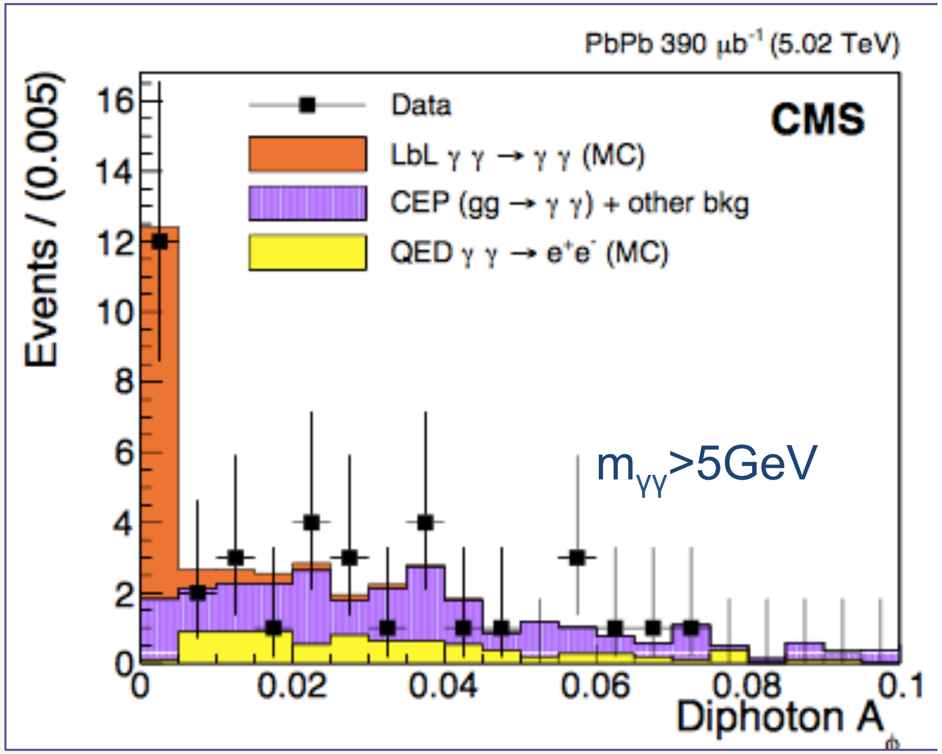
Forbidden in classical EM
Text-book illustration of QM

ATLAS collab., Nature Physics 13 (2017) 852

ATLAS collab., arXiv: 2008.05355



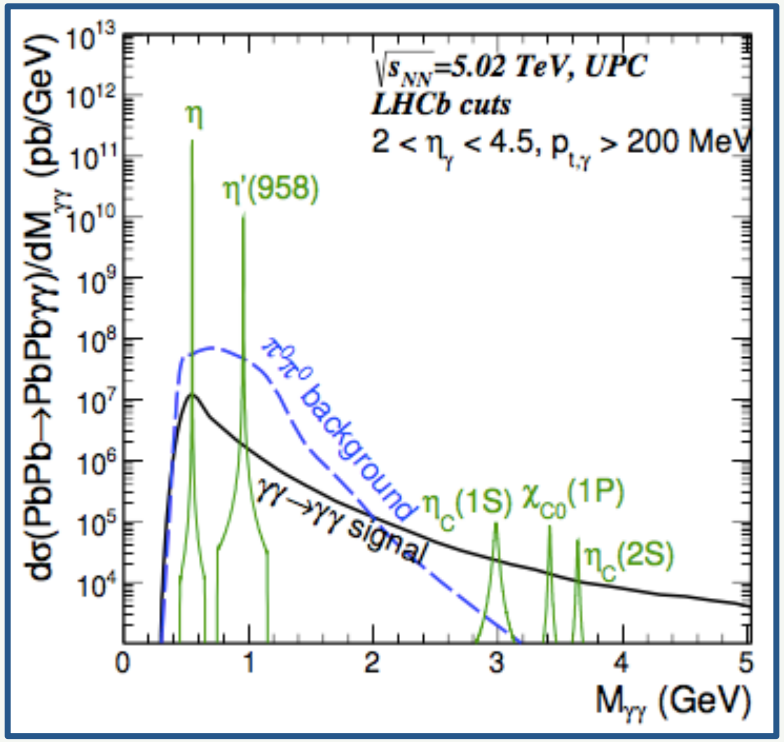
CMS. collab., Phys.Lett.B 797 (2019) 134826

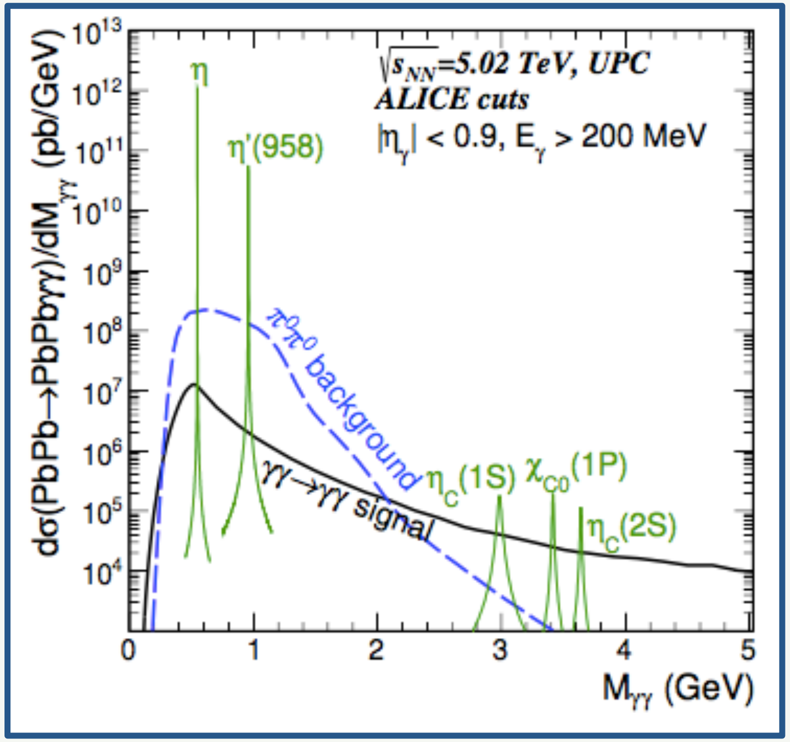


$m_{\gamma\gamma}$>5GeV

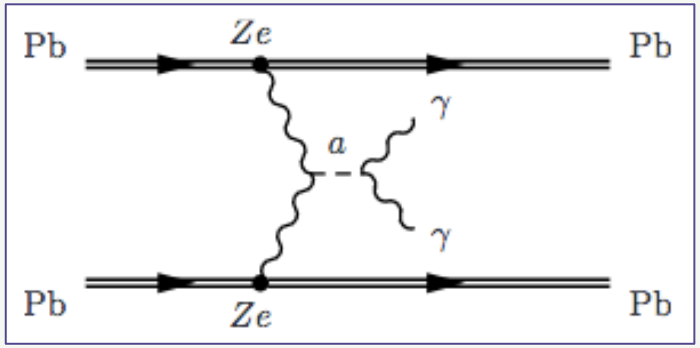
Light-by-light scattering

M. Klusek-Gawenda, R. McNulty, R. Schicker, A. Szczurek, Phys.Rev. D99 (2019) no.9, 093013



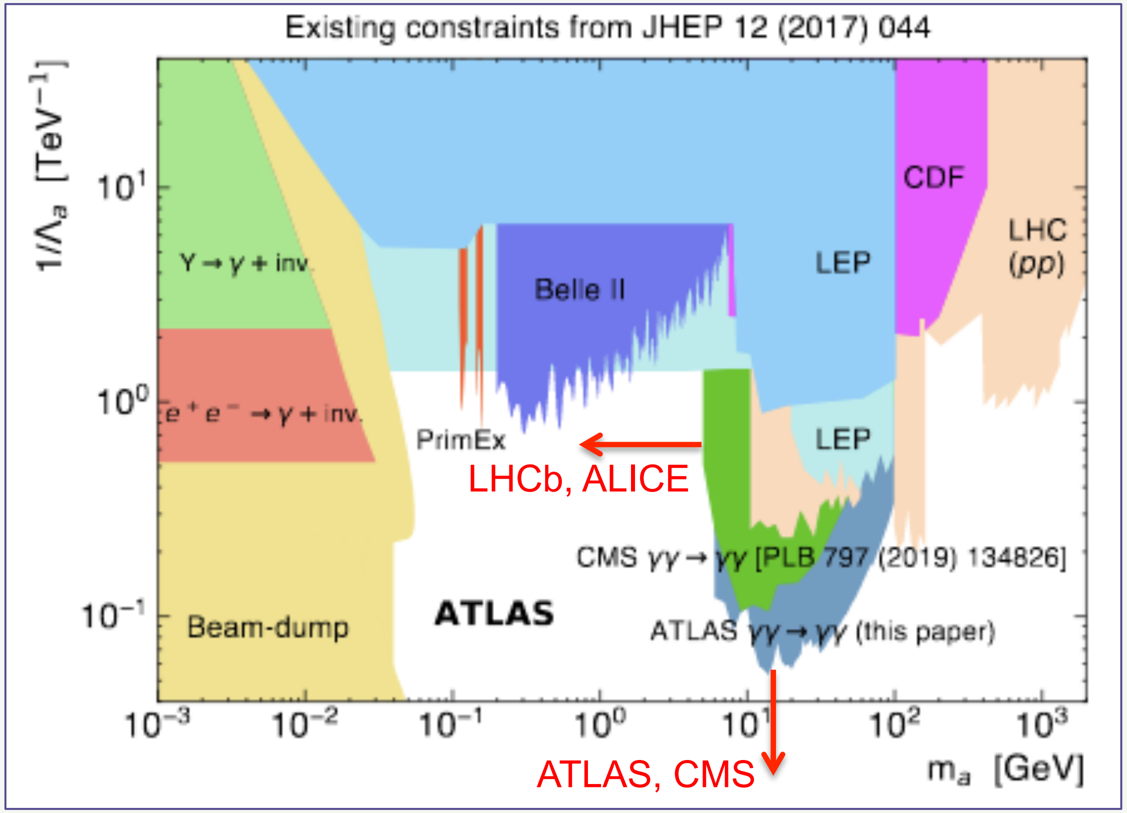


LHCb and ALICE have potential to observe this at low mass.
Important in searches for new particle decaying to photons



ALPS search

ATLAS collab., arXiv: 2008.05355

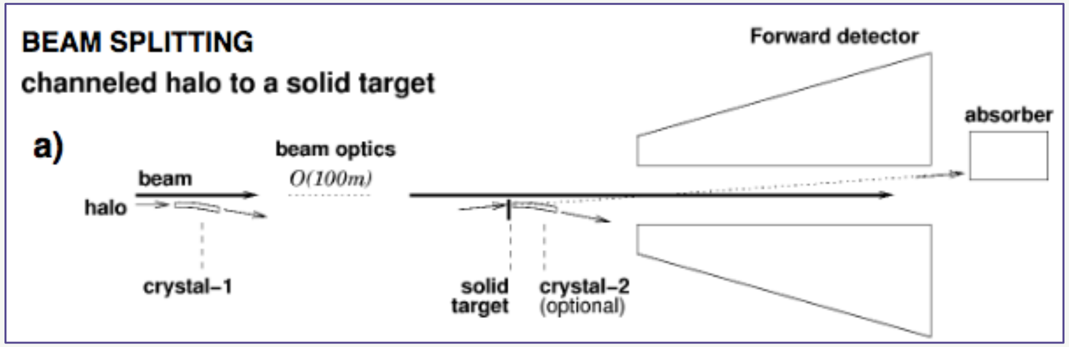


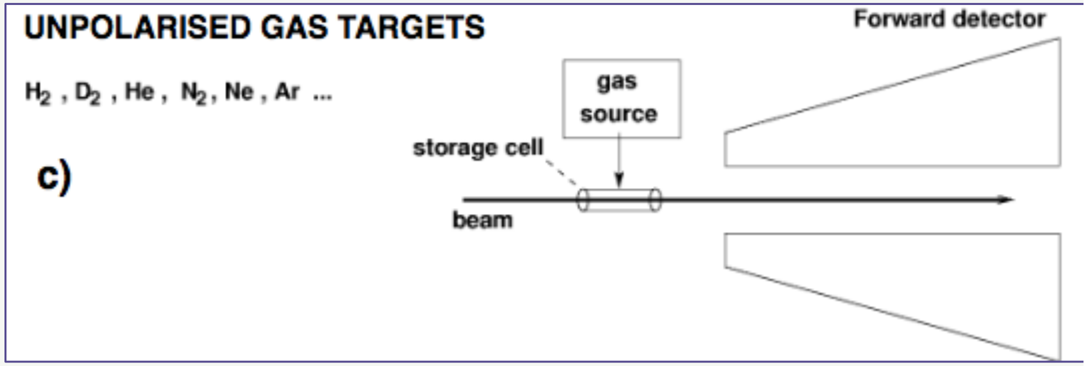
LHC Run 3&4, prospect of pushing limits down in mass and coupling strength

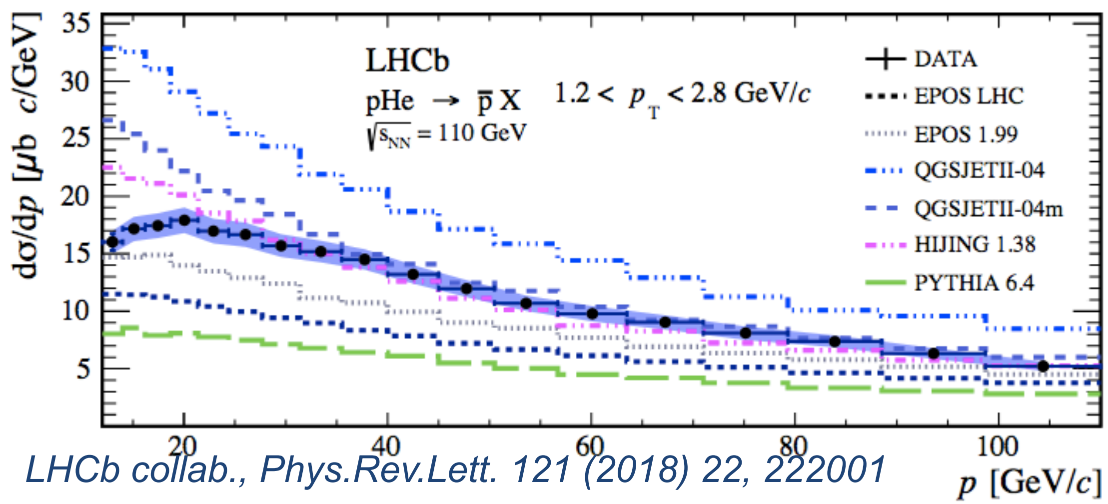
LHC: Fixed target collisions

7 TeV p beam -> $\sqrt{s_{NN}}$= 72-115 Gev.
Forward detectors

- High-x quark and gluon PDFs, GPDs and Wigner distrib.
- Spin Physics
- QGP







LHCb collab., Phys.Rev.Lett. 121 (2018) 22, 222001

SMOG results from Run2 (LHCb)
SMOG2 target cell for Run3
AFTER@LHC for Run 4?

Summary

- Central Exclusive Production has great potential for a comprehensive
- study of low mass systems.

- The ability to vary projectiles, enhance QED or QCD processes, and fully
- reconstruct the final states are powerful tools.

- Data is already in hand to look for exotic aspects of QCD and BSM physics
  - saturation
  - glueballs
  - hybrid states
  - tetraquarks
  - molecular states
  - odderon
  - axions
  - dark matter

- More data, particularly in heavy ion collisions, available in Run3 and Run4