Exotic particle searches with AFP

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LHC forward physics workshop
CERN, 12 February 2013

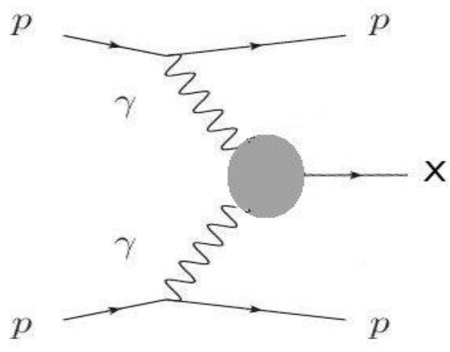
- What makes AFP interesting for exotic particle searches?
- Enhancement of e^+e^- signatures
- Search for invisible particles
- Preliminary conclusions

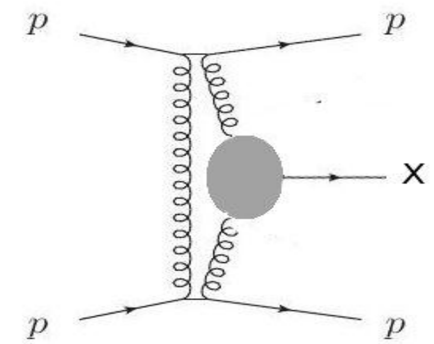
Massive particle X produced without proton disruption:

Photon fusion

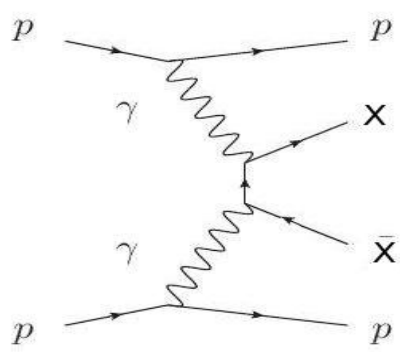
Pomeron exchange

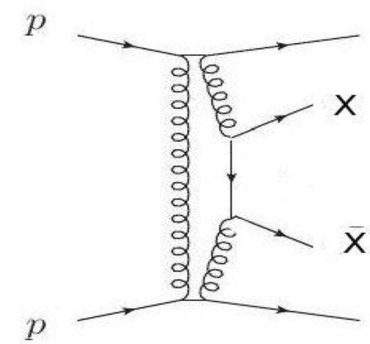
X has spin 0 or 2





X has spin 1/2



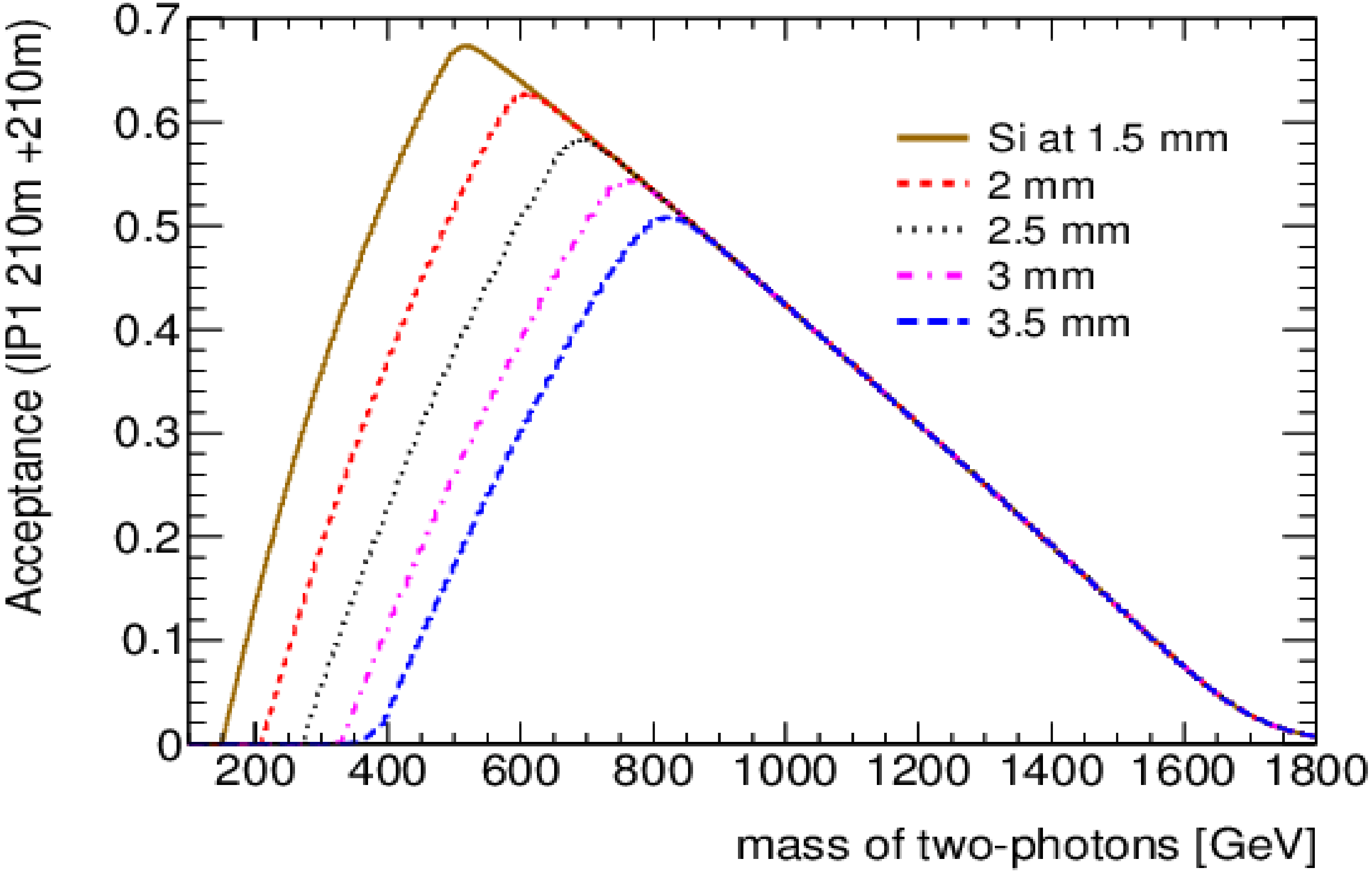


→ high-invariant mass signature in AFP

Sensitivity of AFP @ 210 m

– Singly produced particles 200 < m_X < 1800 GeV
– Pair-produced particles 100 < m_X < 900 GeV

(Plot: Oldrich Kepka)

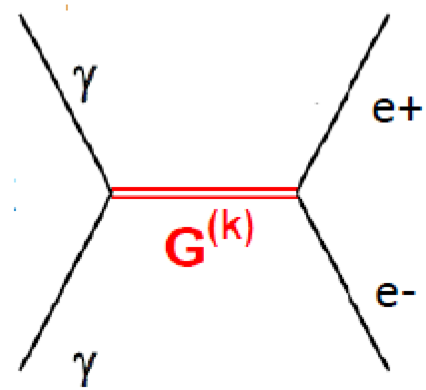


Two interesting scenarios

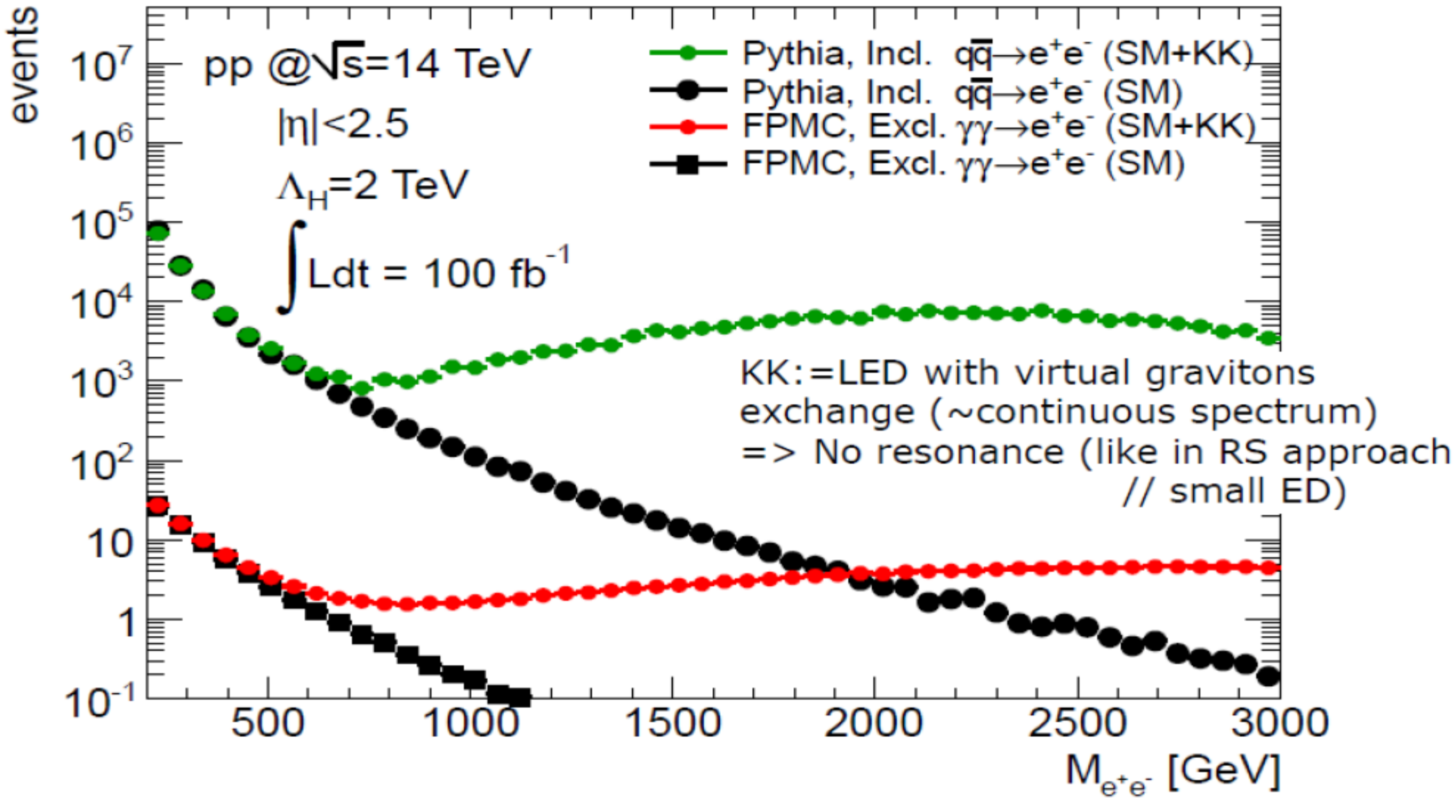
1) Particle X decays into state with large irreducible backgrounds
   - Additional AFP constraints to eliminate backgrounds
   - Generally at the cost of much lower signal rates (protons must remain intact and be scattered within AFP acceptance)
2) Particle X is invisible
   - Unique signature of high invariant mass in AFP and nothing in central detectors
   - Need independent AFP trigger

First example: e^+e^- signature

- Case study: virtual KK graviton going into two electrons
- Red curve shows exclusive two-photon process



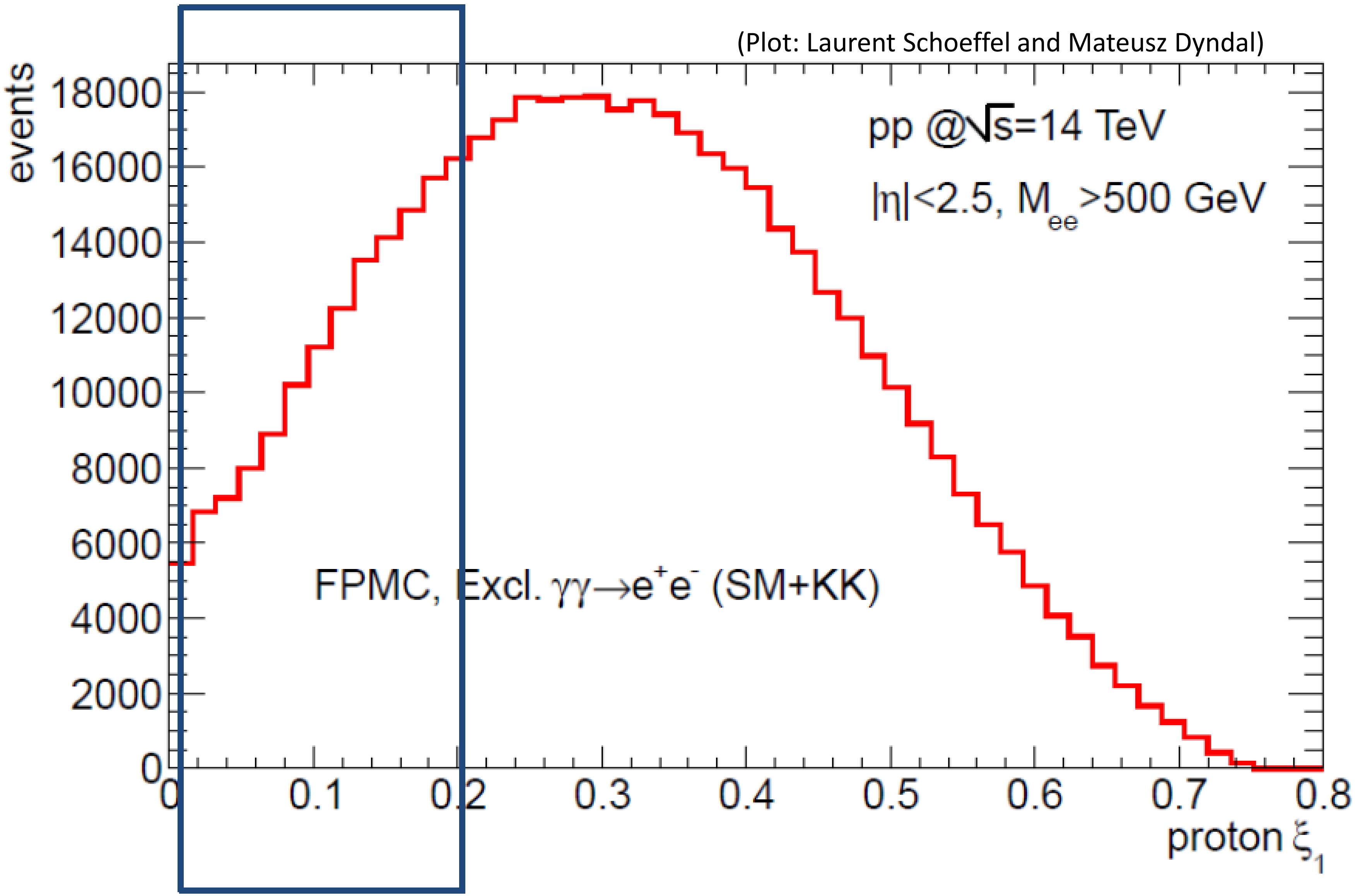
(Plot: Laurent Schoeffel and Mateusz Dyndal)



AFP acceptance requirement

(e^+e^- signature with KK graviton)

(Plot: Laurent Schoeffel and Mateusz Dyndal)

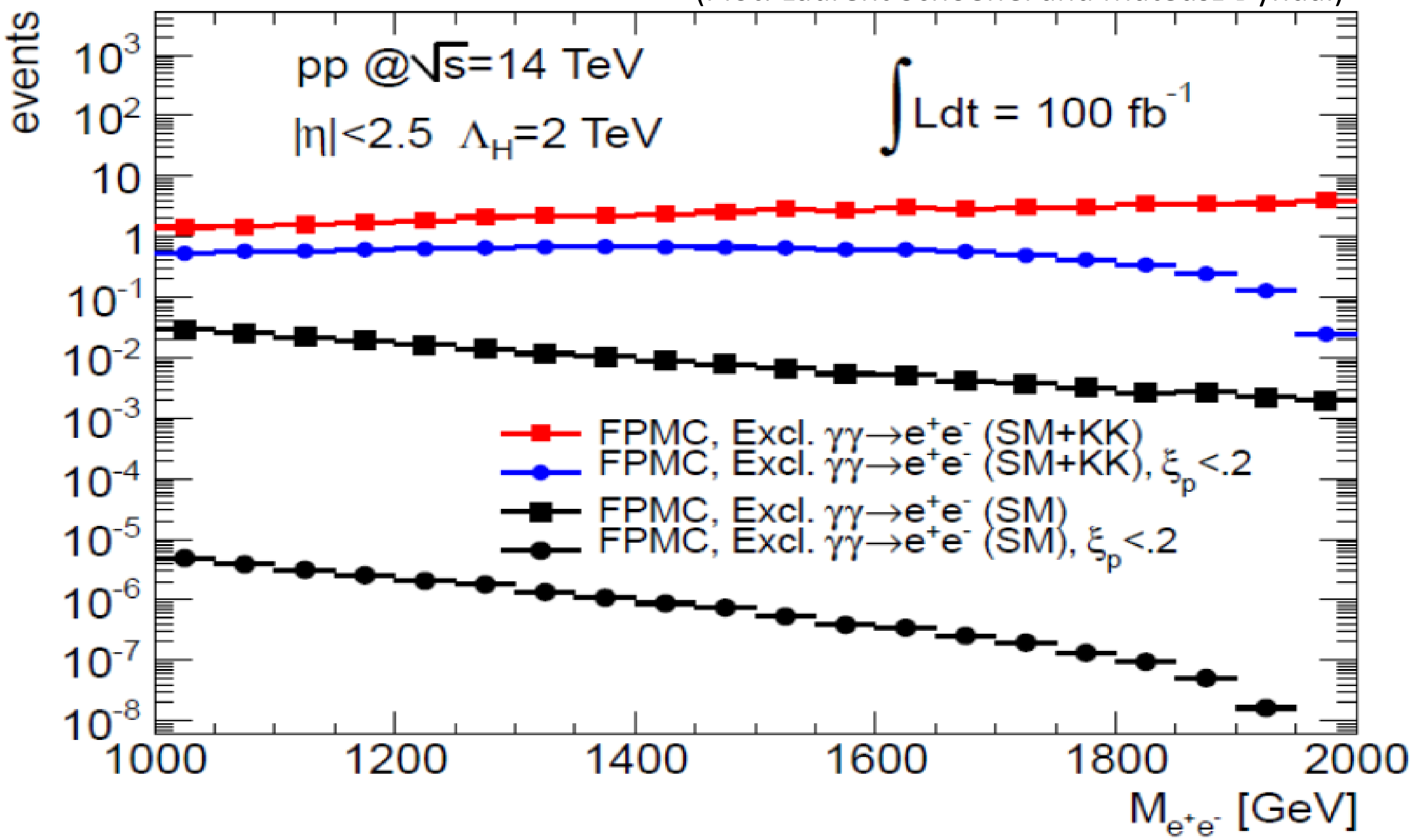


Result

(e⁺e⁻ signature with KK graviton)

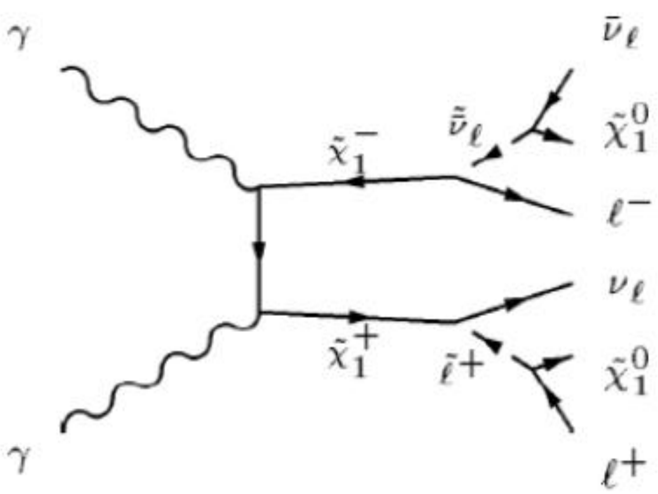
> 10 background-free events after 100 fb⁻¹
(blue curve takes AFP acceptance into account)

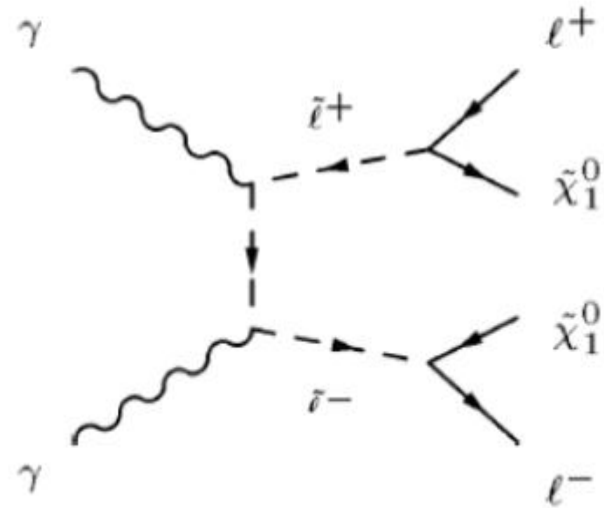
(Plot: Laurent Schoeffel and Mateusz Dyndal)



Second example: two isolated leptons + MET

- Case study: chargino or slepton pair produced in photon-photon





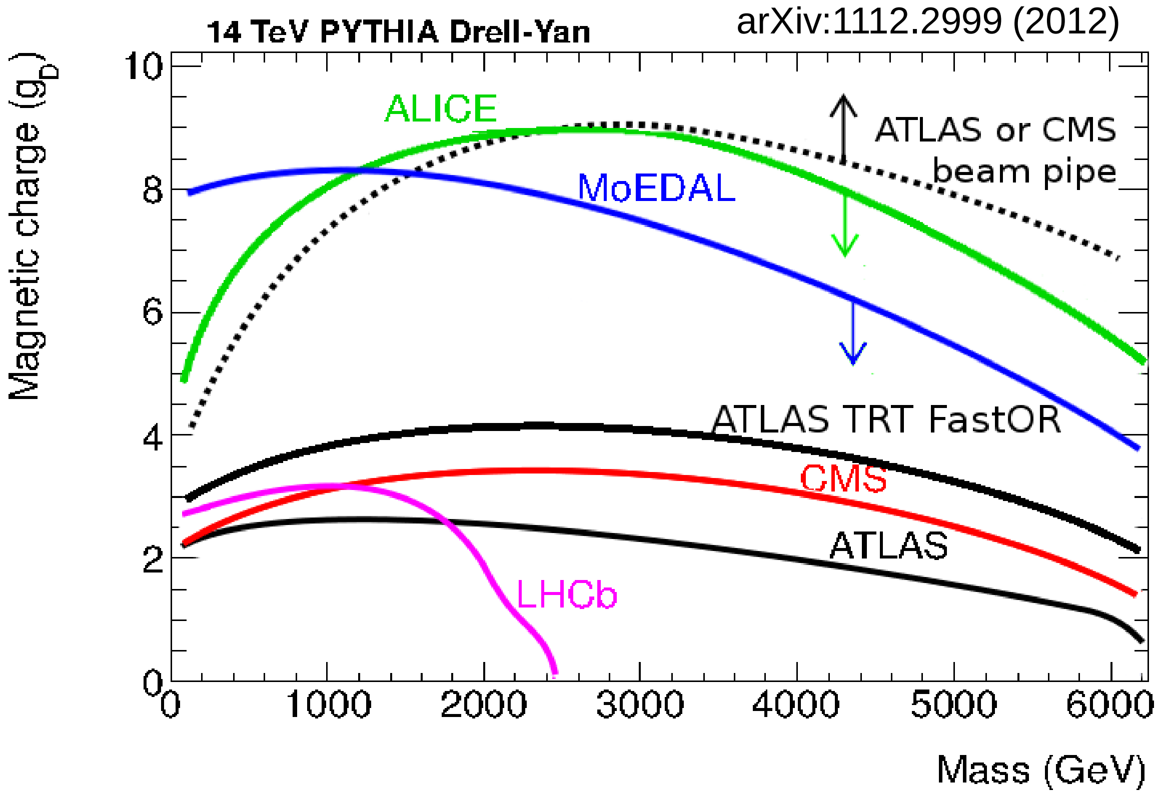
- **Result**: a couple of events after 100 fb^{-1}

(Study from Laurent Schoeffel and Mateusz Dyndal)

Invisible massive particles in ATLAS

Only three known strategies:

- Search for monojets/monophotons
- Search with AFP
- Special case: search for stopped monopoles in the beam pipe



AFP and invisible particles

- AFP double proton tagging
  - Trigger: large scattering angles for both protons
  - Selection: veto on central detector activity
    $\rightarrow$ invisible particle
- Look at in high invariant mass region
  - Excess: sign of new physics!
  - No excess: set generic cross section limits on exotic massive particle production
- Data-driven estimate of the backgrounds
  - Use control regions where some activity in the event is required

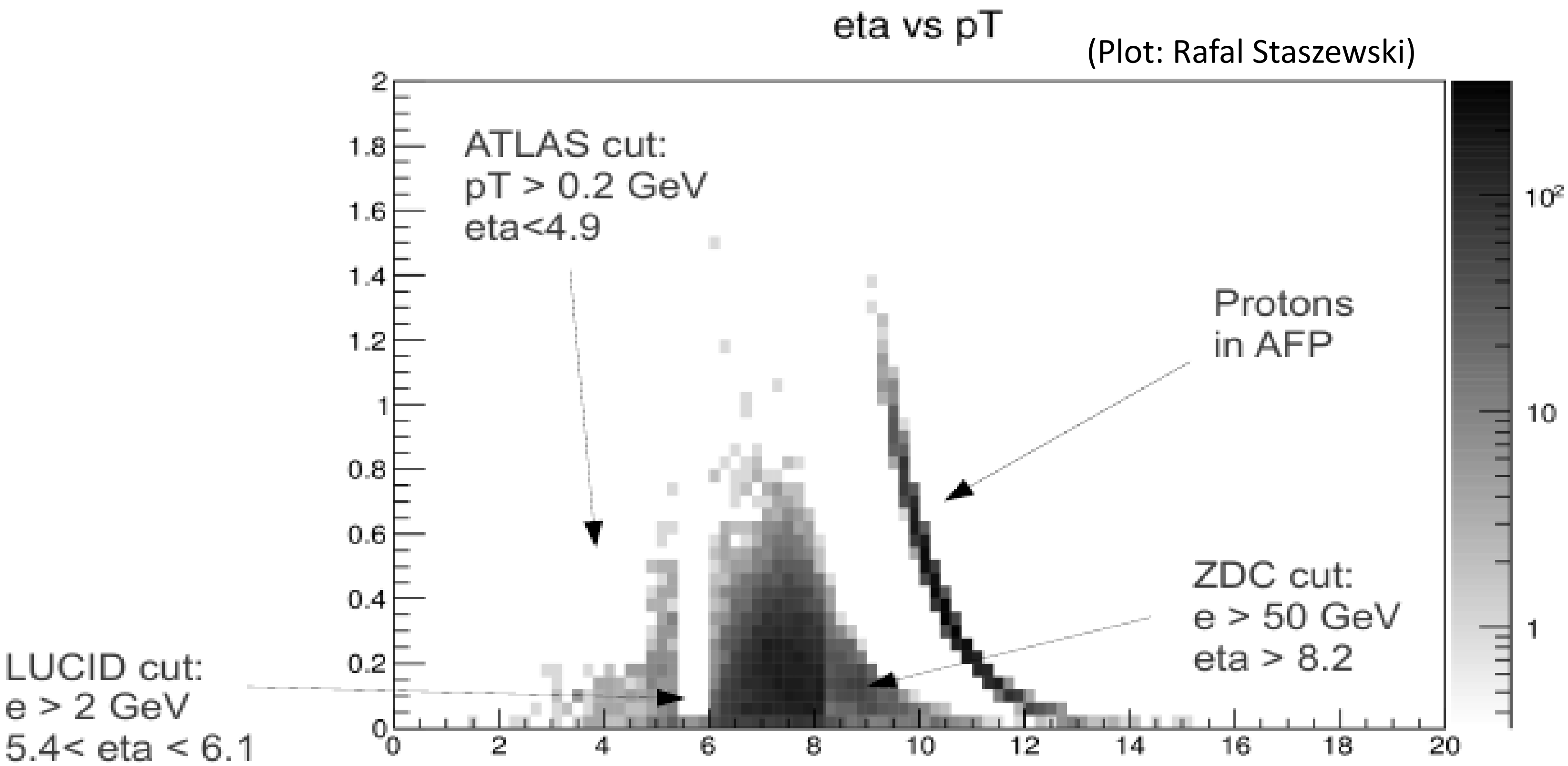
AFP trigger?

- Coincidence and look-up table for a rough mass discriminator at L1
  - Cables, timing, electronics...
- Veto on ATLAS central activity at L2
- Rate expected to be dominated by:
  - Pileup – can be estimated from simulations
  - Beam backgrounds – difficult to estimate
  - Careful studies are needed

Expected dominant background in search for invisible particles

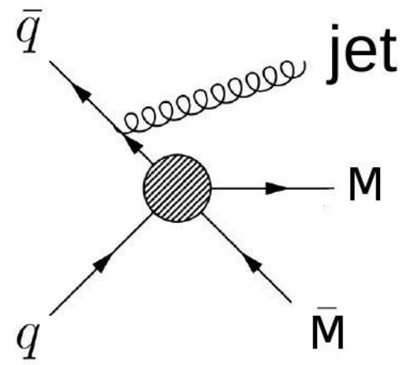
Double-diffractive events with protons in AFP

- Cannot be reduced effectively due to lack of vetoing detectors in region $\eta = 7$

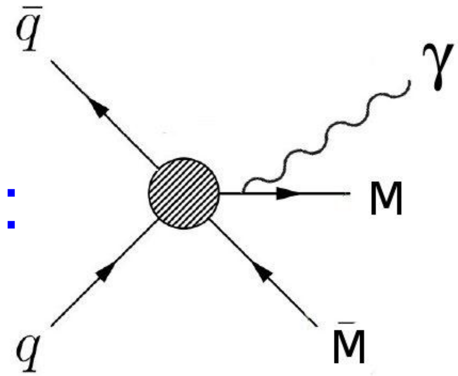


(Plot: Rafal Staszewski)

Invisible particles: AFP vs. monojet/monophoton



- Limitations of AFP:
  - Need intact protons
  - Limited proton angular coverage



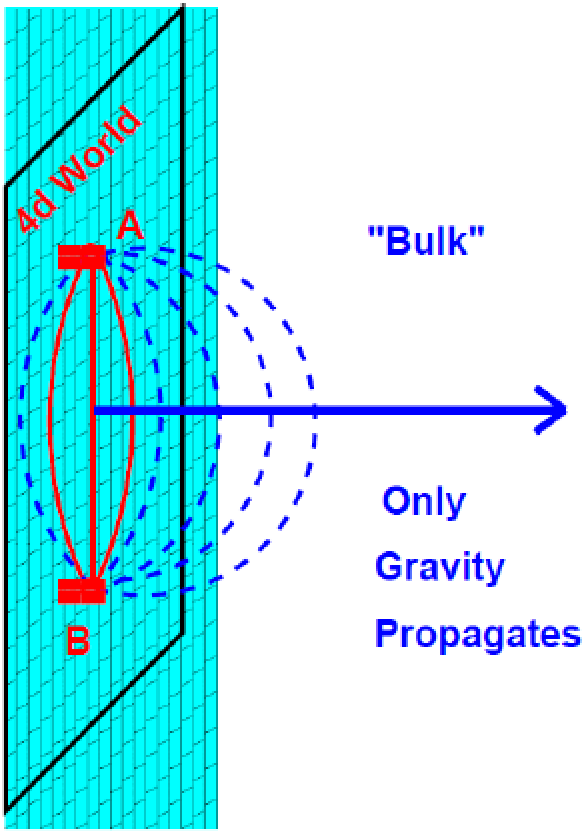
- Limitations of monojets/monophotons:
  - Need ISR/FSR
  - High trigger energy thresholds
- Different methods are complementary
  - Studies need to be done to quantify the sensitivity of each method for given model assumptions

Summary

- AFP can be used to enhance signatures with large irreducible backgrounds
  - Low gamma-gamma cross sections make such an approach rather uncompetitive
  - However, AFP provides independent complementary information in case of new physics discovery
- AFP can probe invisible particles with masses below 1.8 TeV
  - One of only two ways to discover generic invisible particles in ATLAS
  - Triggering with AFP is challenging
  - This is an exciting possibility and we are only beginning to explore it

Extra slides

Kaluza-Klein and Virtual Graviton's



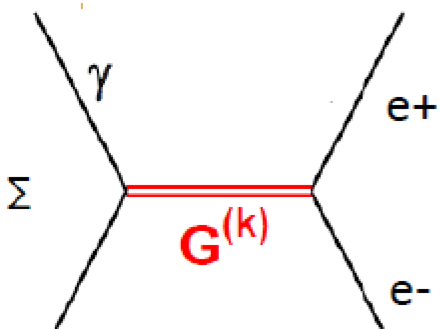
n additional dimentions where
only gravity is allowed to propagate

Flux lines of gravity between A and B
are 'diluted' in Extra-Dimensions
=> Gravity appears weaker in 4D

$M_{Planck}{}^2 = R^n M_D{}^{n+2}$

$M_D \sim 1$ TeV: $n=1 \rightarrow R \sim 10^{13}$ m
$n=2 \rightarrow R \sim 1$ mm
$n=3 \rightarrow R \sim 1$ nm ...

=> In 4D, there are massive Gravitons $G^{(k)}$ ($m(k)^2 = k^2/R^2$) that couple to all field
of SM with a coupling $\sim 1/M_{Pl}$
note: Gravitons are massless in 4+n dim with moment



Application for a particular process **γγ->ll:**

$A \sim 1/M_{Pl}{}^2 \sum 1/[s - m(k)^2]$
$\sim \lambda/M_D{}^4$ with $\lambda \sim O(1)$ *after regularisation*

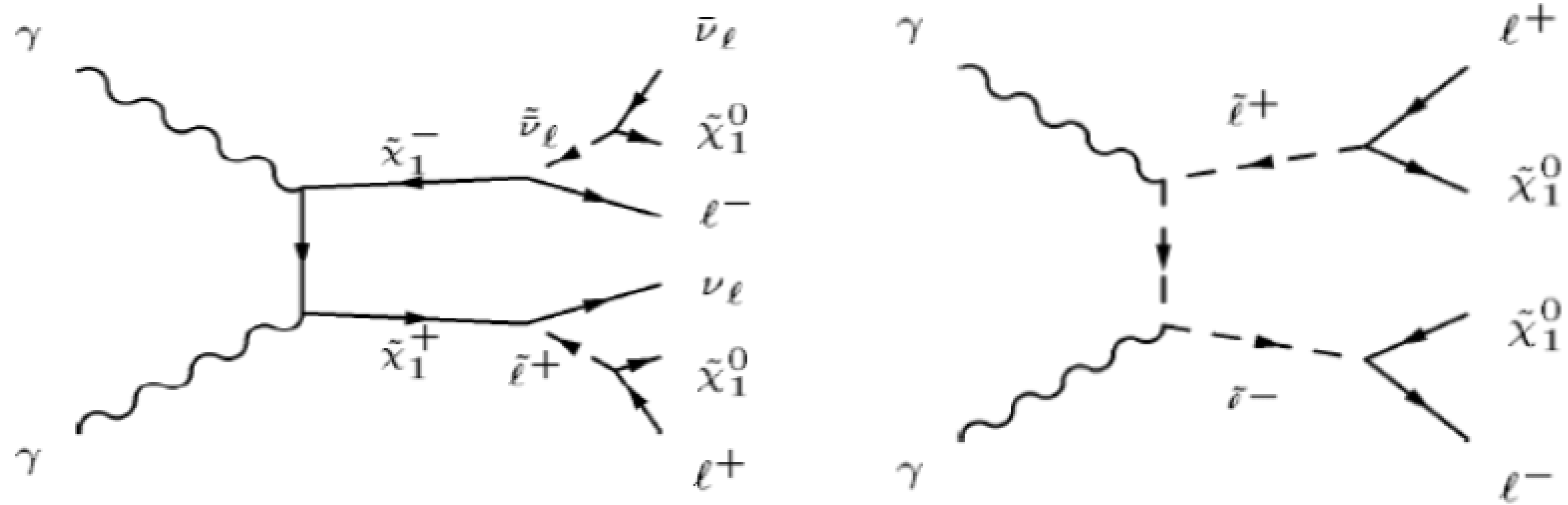
Sleptons and charginos in γγ collisions

A. Cross sections have simple forms for Fermions (charginos) and Scalars (slepto

$$\sigma(\gamma\gamma \to \tilde{\chi}^+\tilde{\chi}^-) = \frac{4\pi\alpha^2}{s}\left[\left(1+\frac{4m^2}{s}-\frac{8m^4}{s^2}\right)\log\left(\frac{1+\beta}{1-\beta}\right)-\beta\left(1+\frac{4m^2}{s}\right)\right]$$

$$\sigma(\gamma\gamma \to \tilde{\ell}^+\tilde{\ell}^-) = \frac{2\pi\alpha^2}{s}\left[\beta\left(1+\frac{4m^2}{s}\right)-\frac{4m^2}{s}\left(1-\frac{2m^2}{s}\right)\log\left(\frac{1+\beta}{1-\beta}\right)\right]$$

B. Decays:



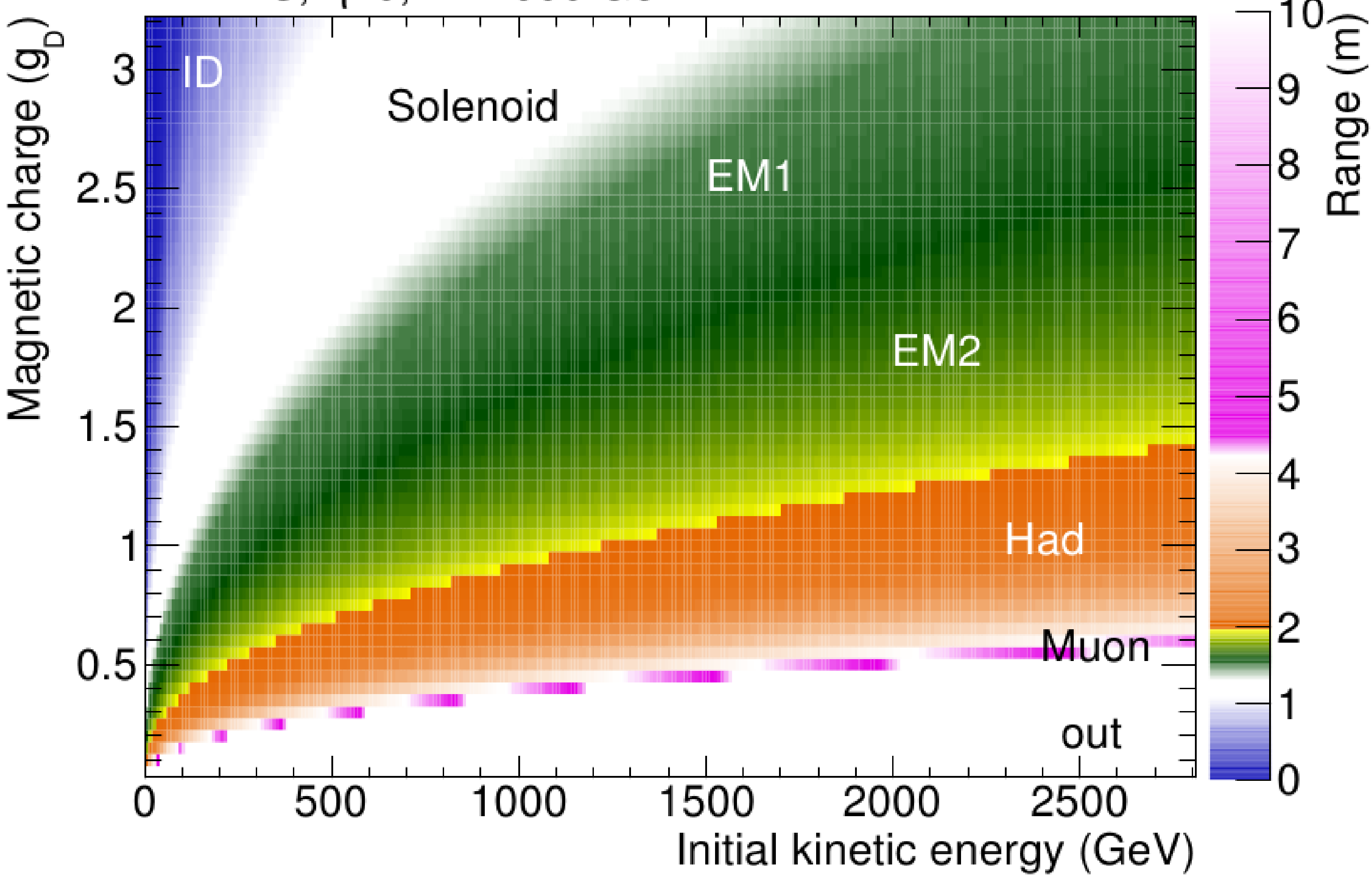
C. Analysis architecture:

AFP tags,
2 isolated (same flavor) leptons,
Missing energy,

Idea: the missing E will be larger for SUSY as 2 massive LSP are produced/event

Monopoles in ATLAS

arXiv:1112.2999 (2012)

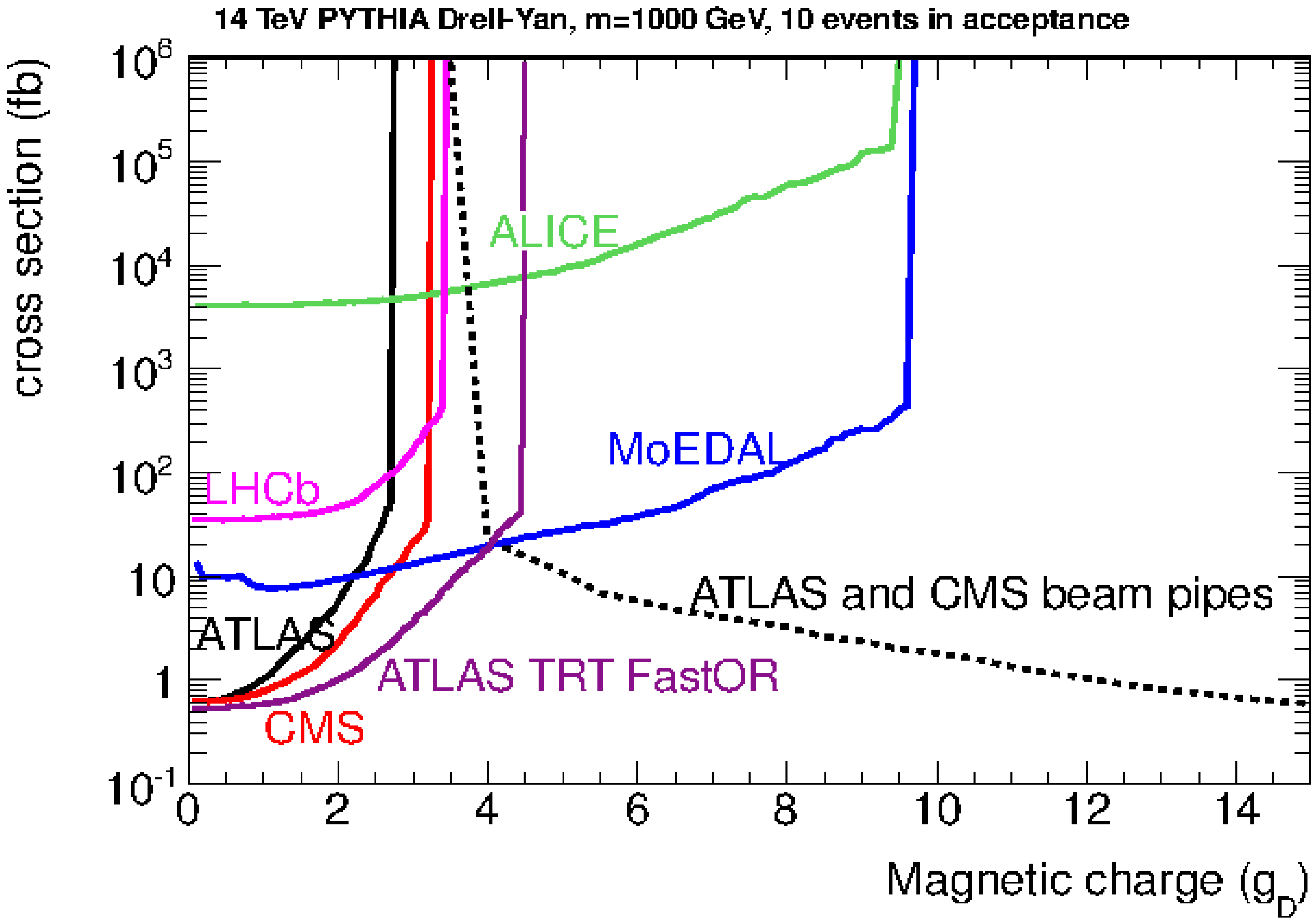


Monopoles with high charges stop in ID or solenoid

→ can produce no trigger

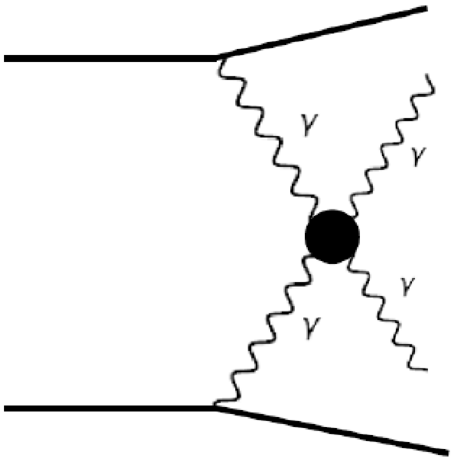
Monopoles at the LHC

arXiv:1112.2999 (2012)

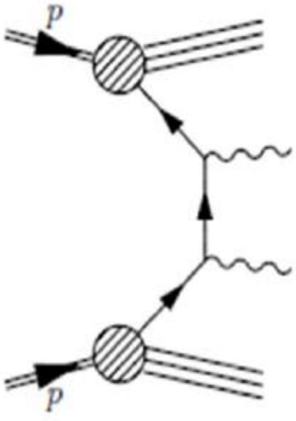


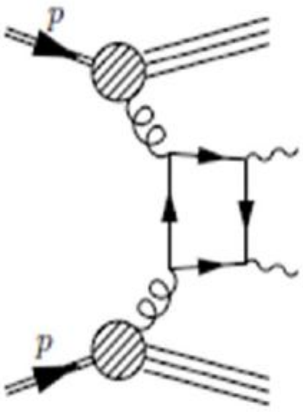
Still another example of background suppression using AFP

- High-mass diphoton signature
  - KK graviton, monopole-pair/monopolium annihilation, etc.



- Large irreducible backgrounds in the region where AFP is sensitive (200 – 1800 GeV)
  - S/B much improved by tagging both protons
  - System fully constrained with additional independent variables
  - Could be sufficient for a signal to stick out





Diphoton signature in ATLAS