Tagging Photoproduction at the LHC

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Photoproduction @ LHC

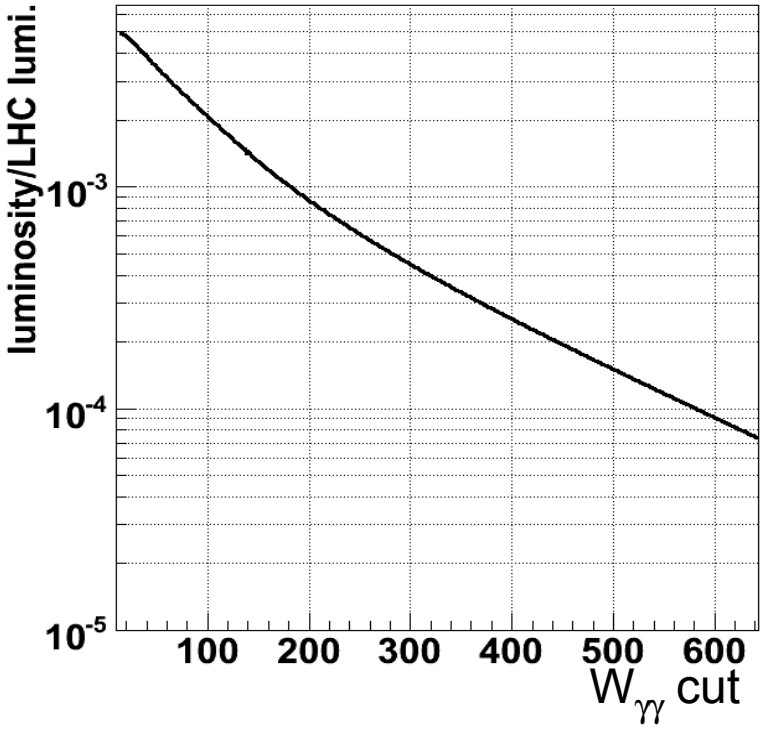
Factorization of photon emission allows using the LHC as a photon-photon or photon-proton collider.

Clean Signal, High QED cross-sections

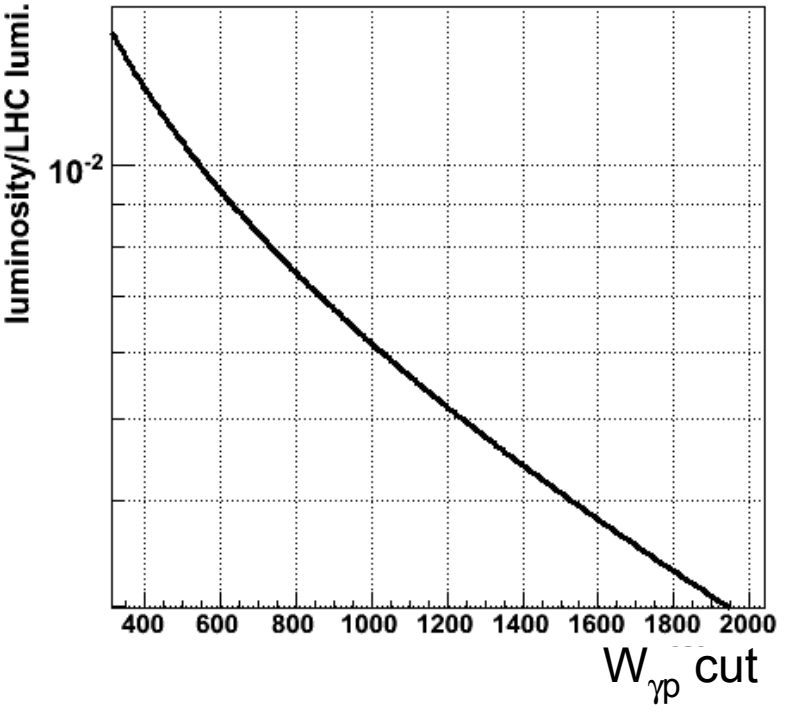
$$d\sigma_{pp} = \sigma_{\gamma\gamma}\, dN_{\gamma}\, dN_{\gamma}$$

$W\gamma\gamma(p)$ = photon – photon (proton) center of mass energy

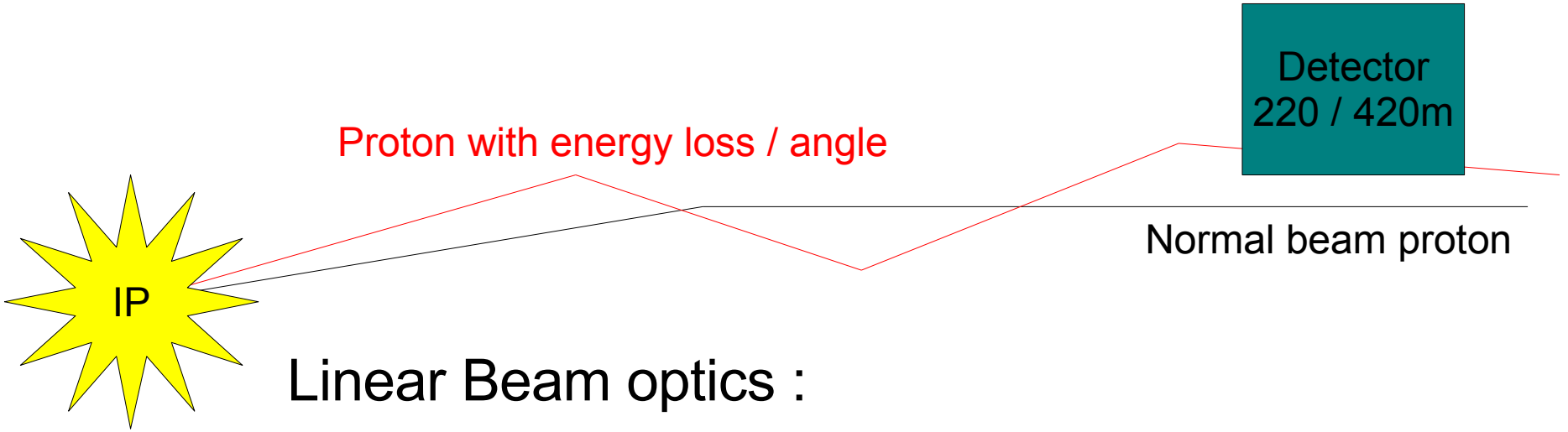
Photon – Photon luminosity / LHC lumi :



Photon – Proton luminositv / LHC lumi :



Tagging photoproduction



Linear Beam optics :

$$x_s = a_s x_0 + b_s x'_0 + d_s E$$
$$x'_s = \alpha_s x_0 + \beta_s x'_0 + \gamma_s E$$

IP variables reconstruction :

$$E = \frac{b_2 x_1 - b_1 x_2}{b_2 d_1 - b_1 d_2}$$

Chromaticity correction : a,b,α,β change with E

Beam Simulation

Using HECTOR (matrix-based)

$$X(s) = X(0) \underbrace{M_1 M_2 ... M_n}_{M_{\text{beamline}}}$$

Where :

X is the phase-space vector of the particle

M_i are the magnets associated matrices

With corrections for high energy losses.

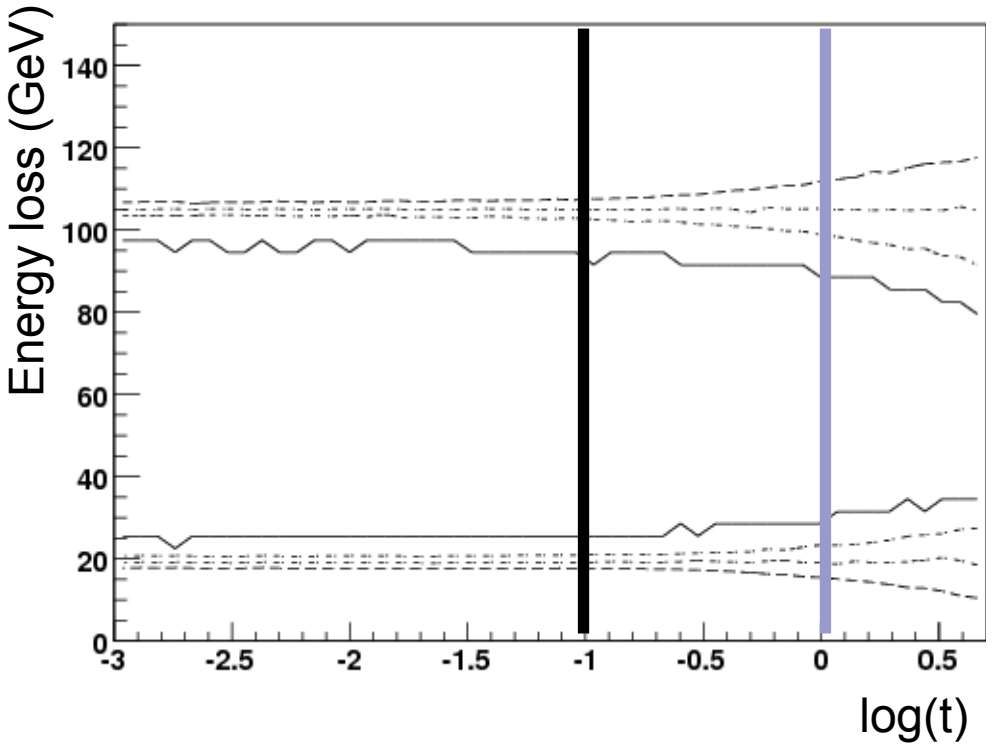
⟶ Fast simulation (> 3000 protons/s)

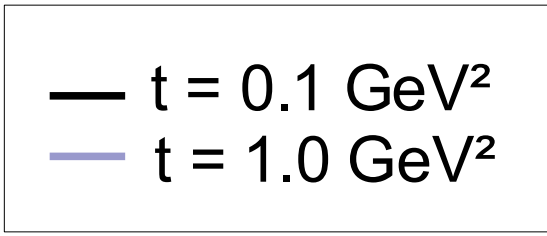
+ Aperture checks

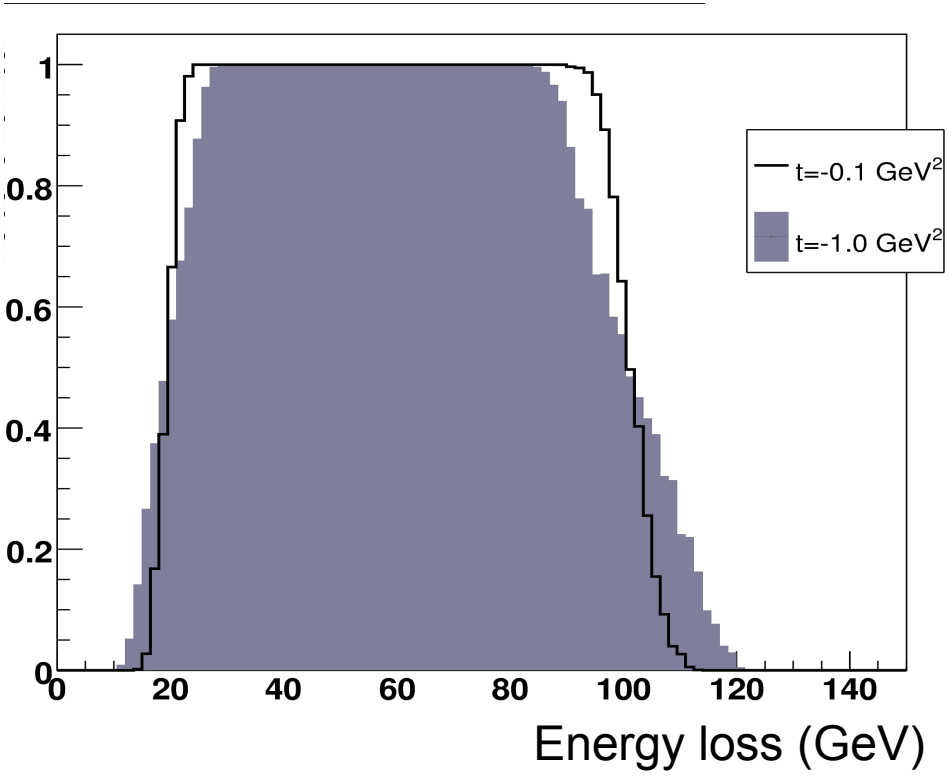
- Cross-checked with MAD-X
- All material : www.fynu.ucl.ac.be/hector.html

Detectors acceptances

RP acceptance @ 420 m

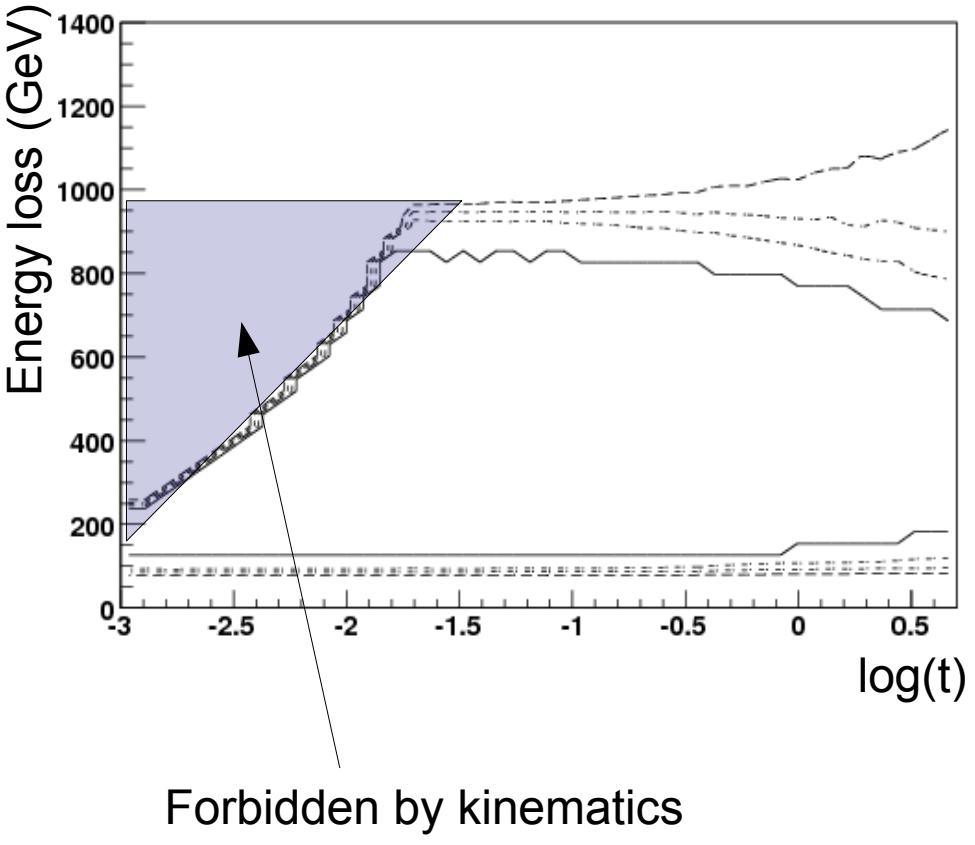




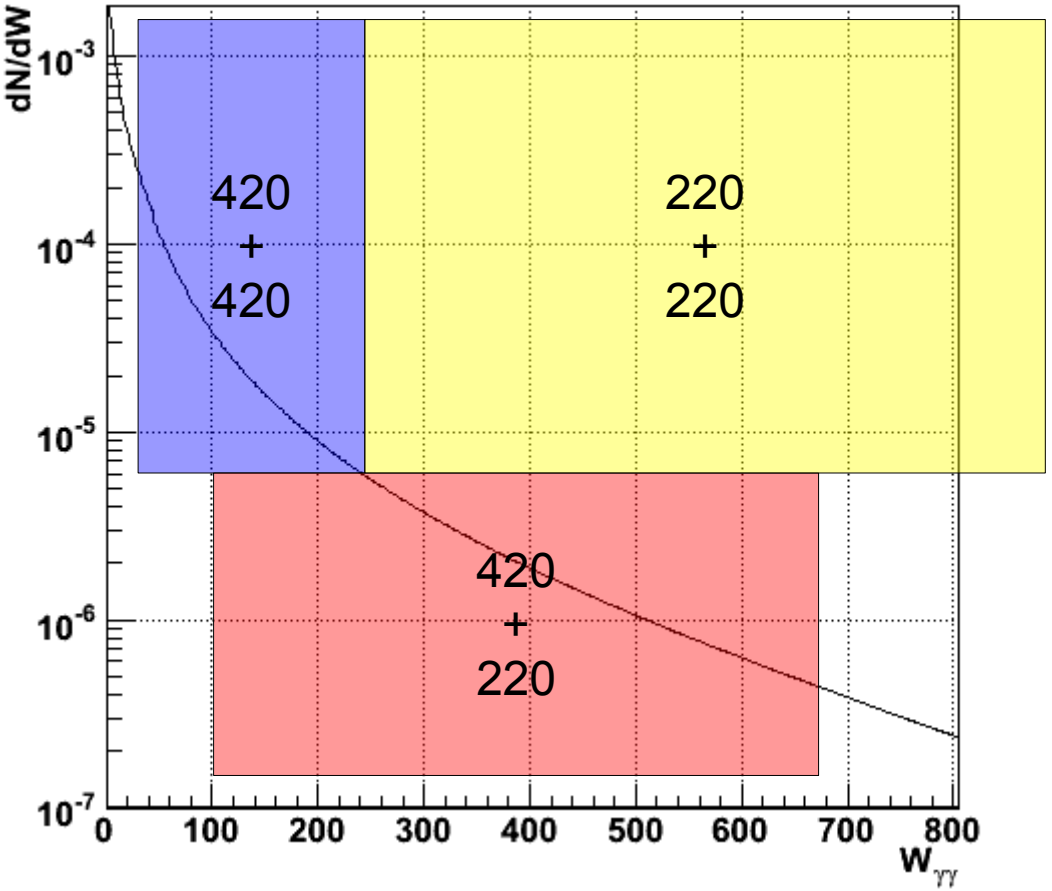


Acceptances (II)

RP acceptance @ 220 m



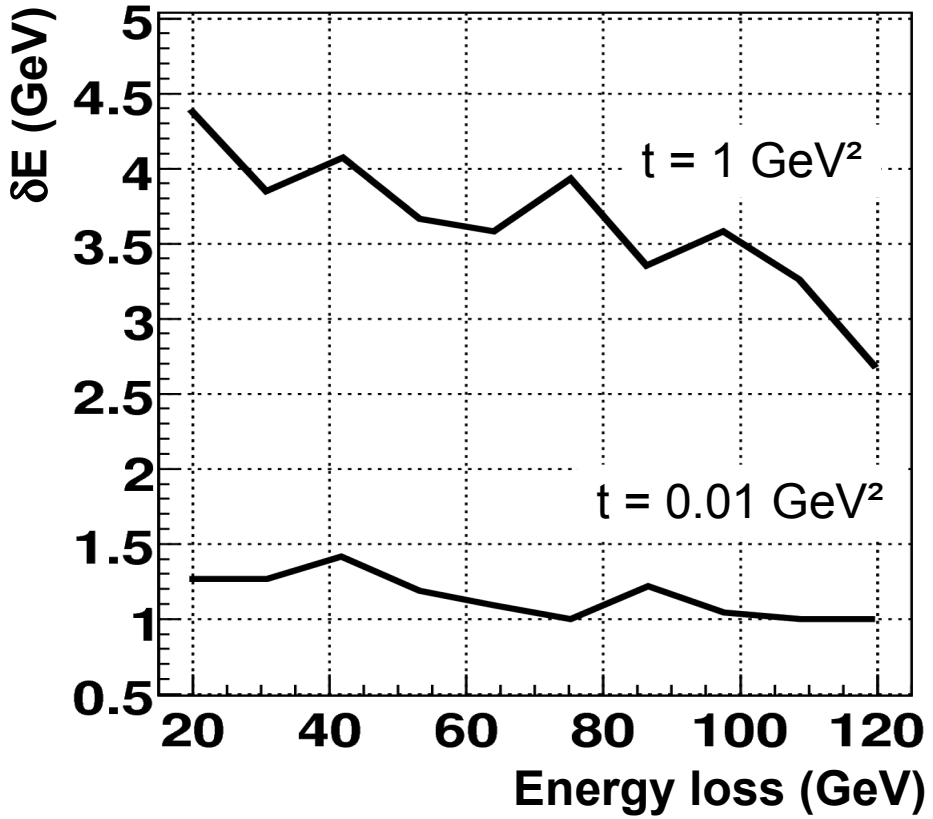
Forbidden by kinematics



IP state reconstruction

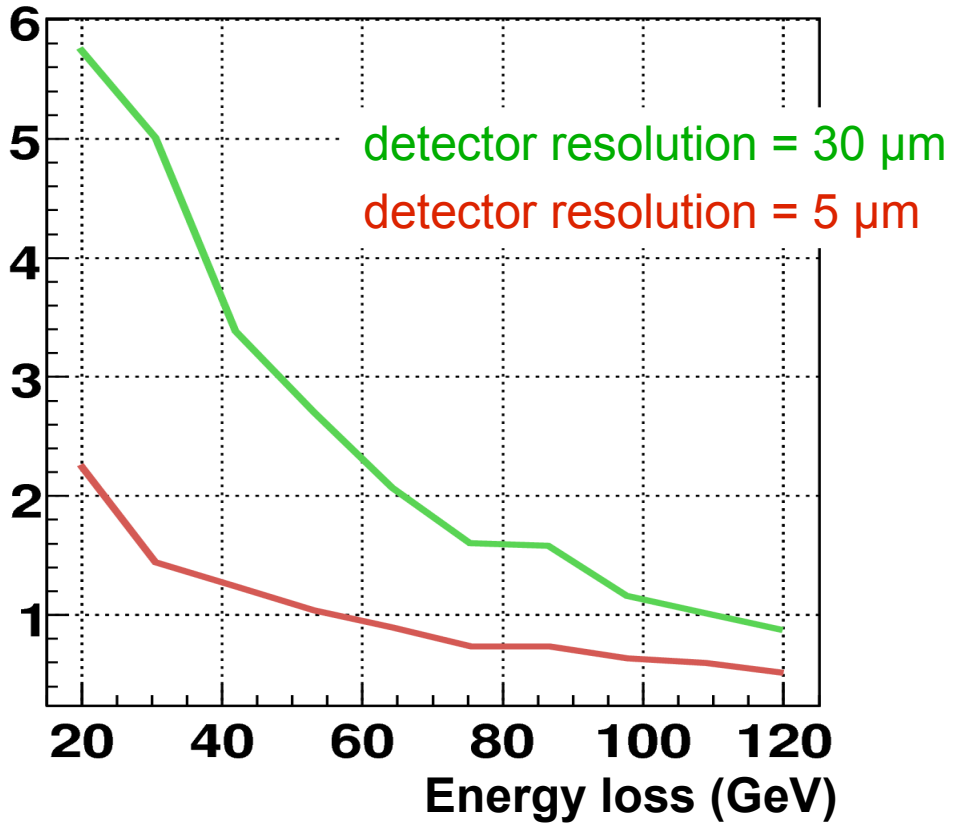
Position and angle measurement @ 420m allows photon energy (and angle) reconstruction.

Simple method



Weakly dependent on detector resolution

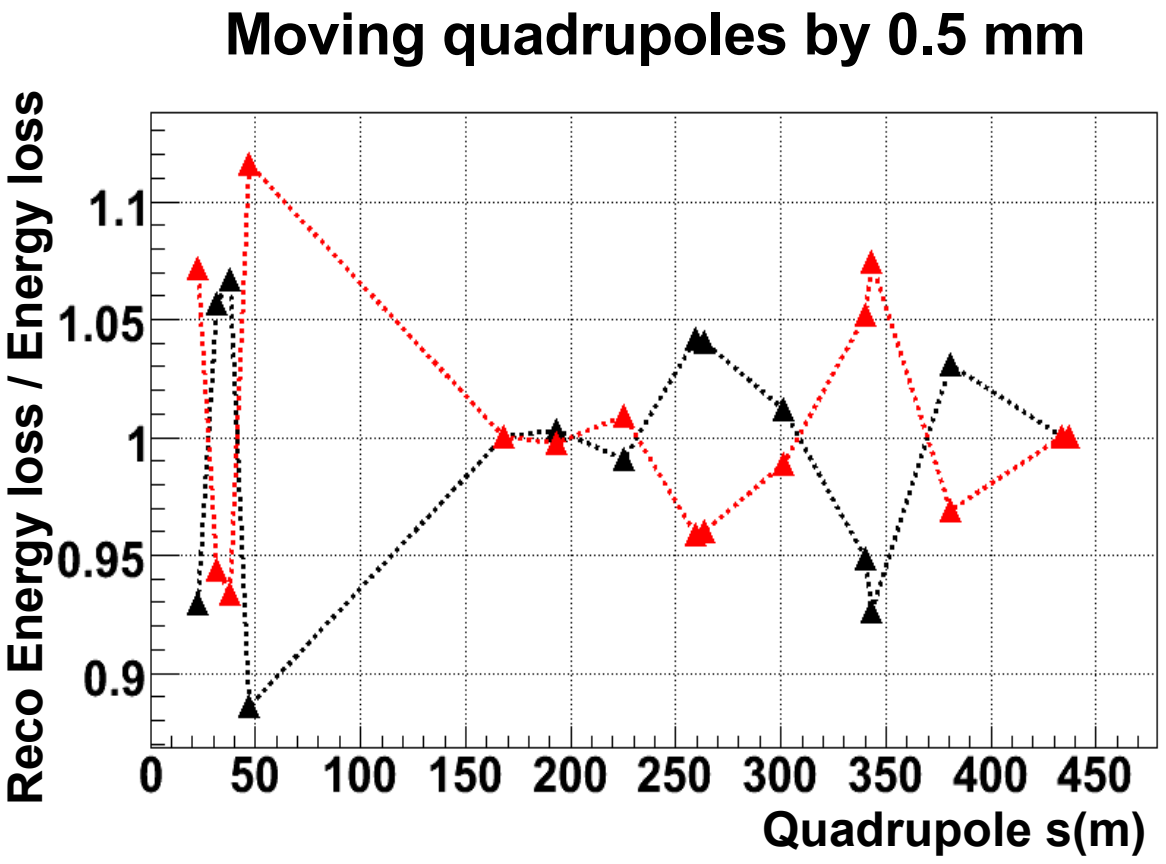
Advanced method
(angle compensation)



Weakly dependent on momentum transfer

t is low for photon emission → δe ~ 1 GeV

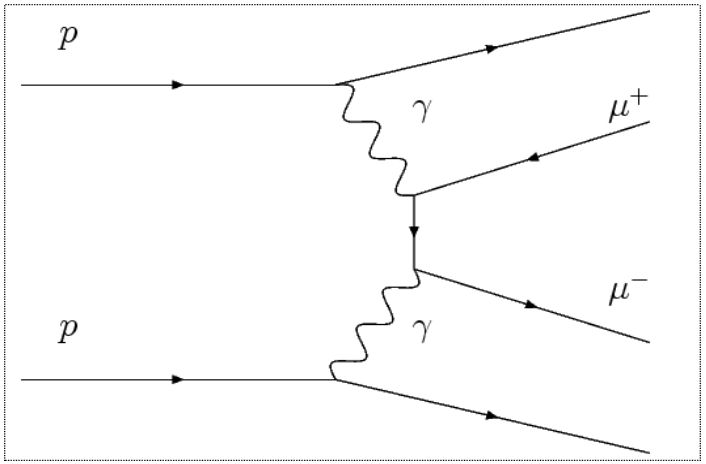
Quadrupoles misalignment



- According to LHC people, quadrupoles could move by ~ 1mm !
- A transverse displacement of that size would lead to big errors in energy reconstruction using forward detectors
- One could correct using beam position measurement, but it is insufficient in many cases.
- Anyway, this causes unavoidable acceptance losses

Detectors calibration using physics

Photon-Photon di-muon production can be used for calibration :

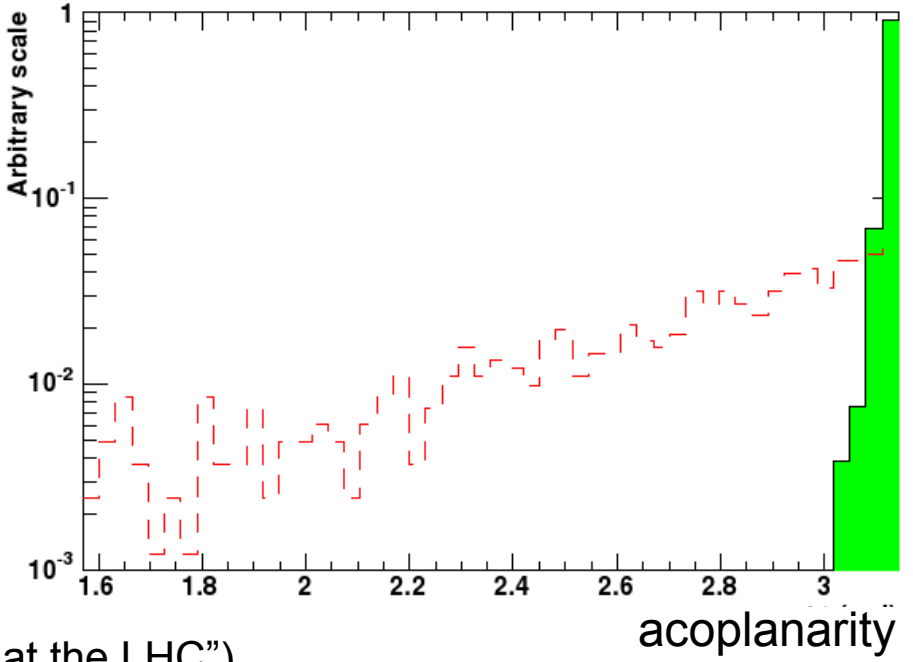


Cross-section (LPAIR) with :

- Both muons central
- Pt > 4 GeV
- Single proton tag

σ ~ 3 pb (triggered)

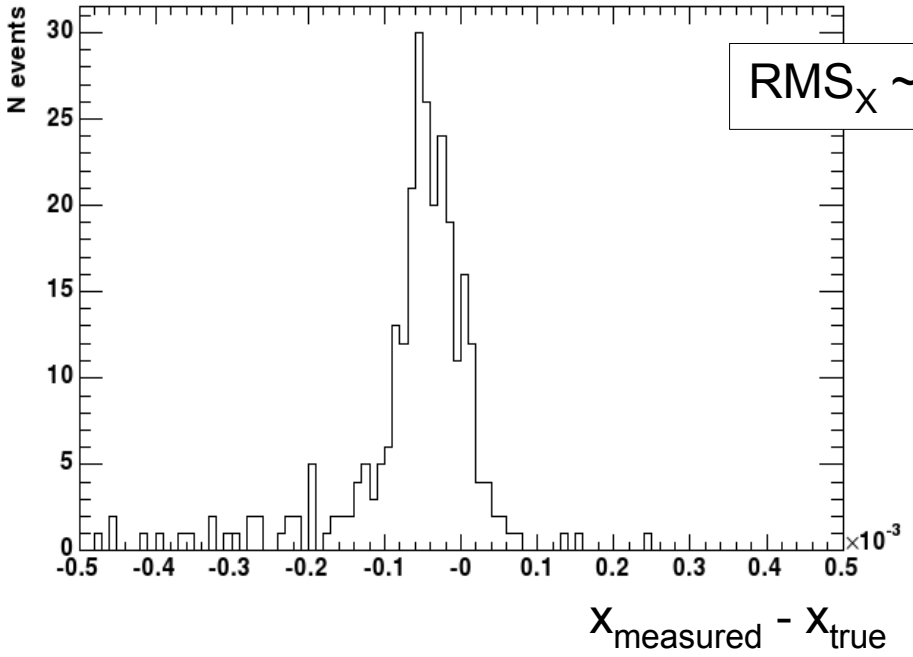
Signature : acoplanarity



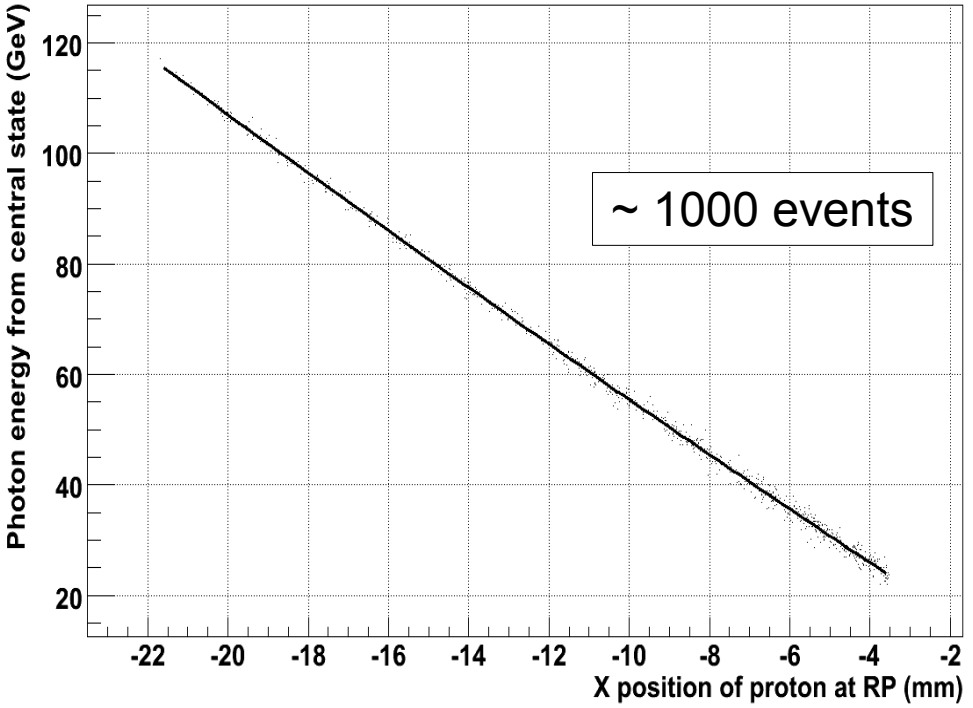
(from : “Prospects for Diffractive and forward physics at the LHC”)

Calibration (II)

Photon energy fraction (x) reconstructed from μμ system



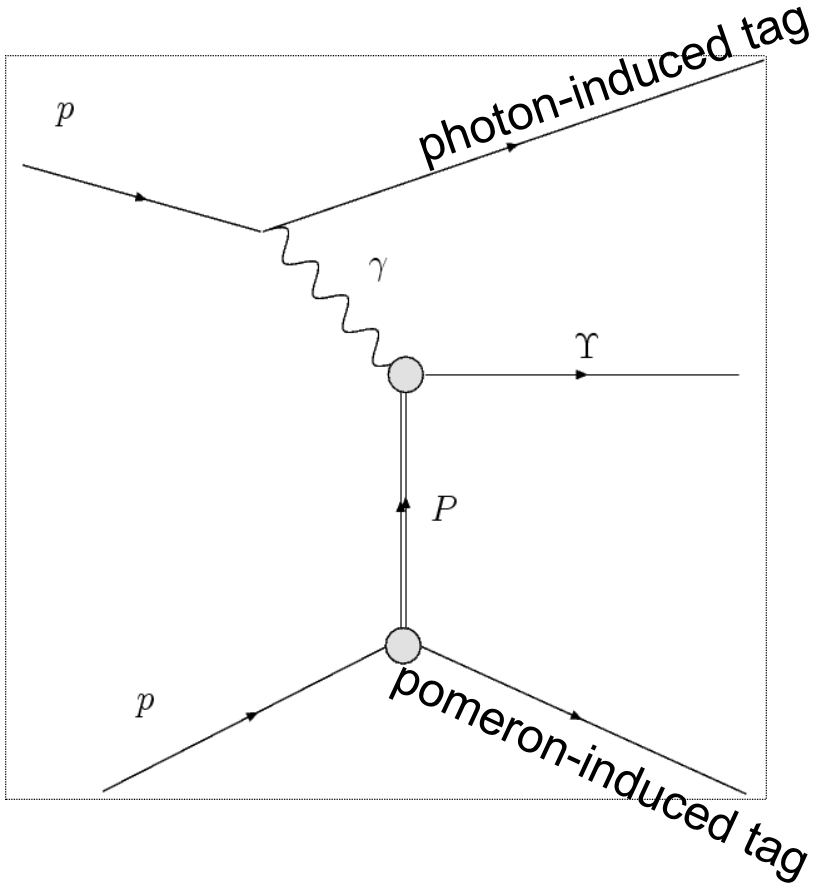
- For detectors @ 420 m : > 100 evts / run
- 220 m detectors get 15 times less events



This gives the basic calibration for protons with no angle at IP ($t \sim 0.01$ GeV²)

Upsilon photoproduction @ LHC

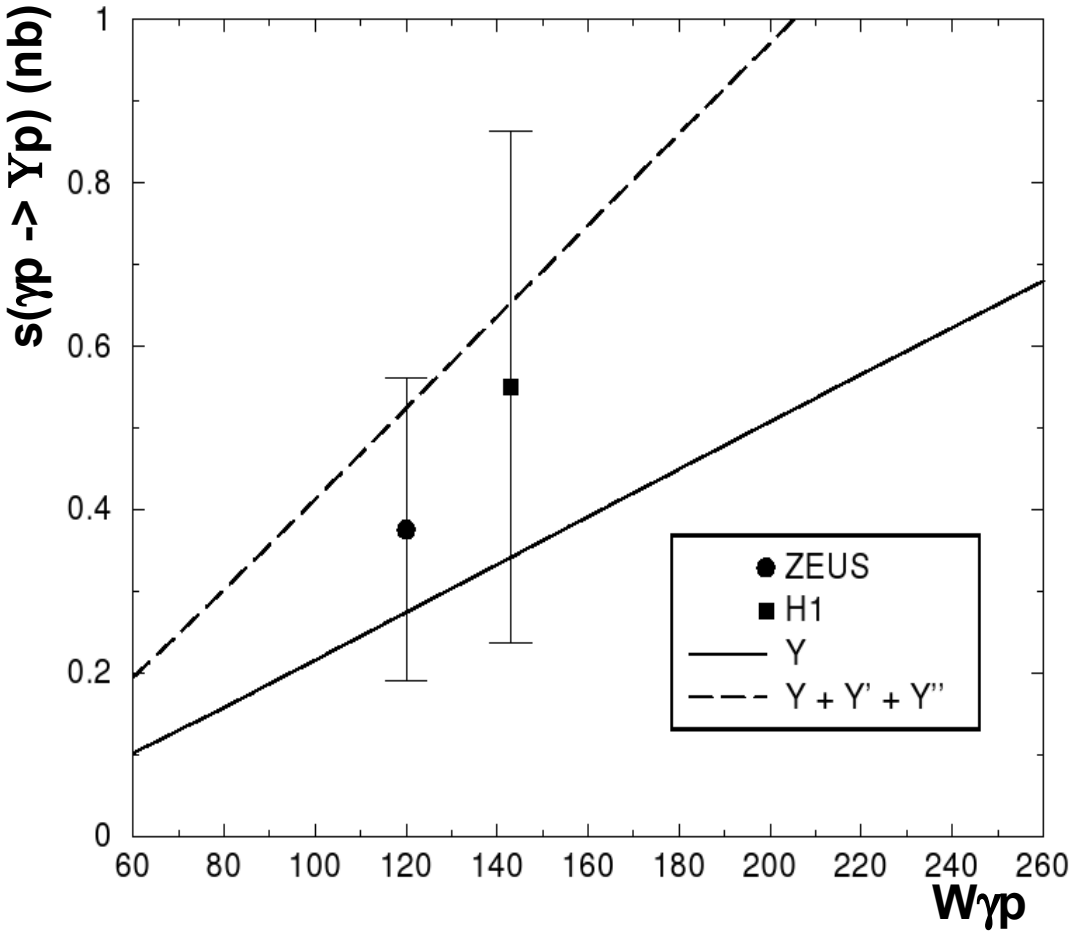
Different interests :



- Depends on double gluon exchange and gluon correlations
- In the μμ decay channel, can help the calibration of low Pt tracks
- Opens a window to odderon
- Cross-section (RP 420 single tag) :
  ~ 160 pb

Upsilon (II) : simulation

Based on HERA results :



Distribution :

$$\frac{d\sigma_{pp}}{dW}(W_{\gamma p}) = \sigma_{\gamma p}(W_{\gamma p}) \times \frac{dN}{dW}(W_{\gamma p})$$

HERA

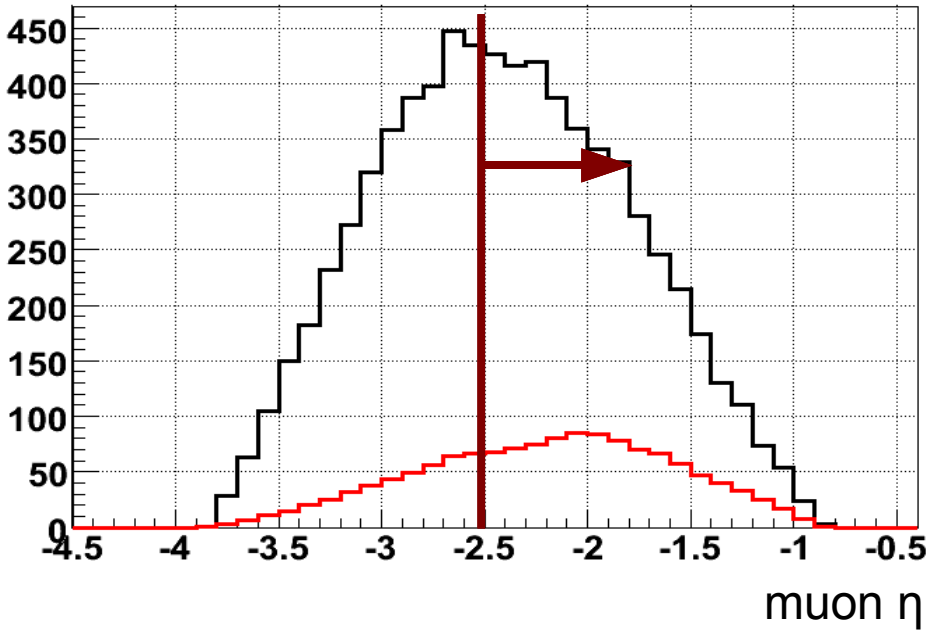
EPA photon flux

- Photon Energy
- Upsilon Pz
- Pomeron Energy

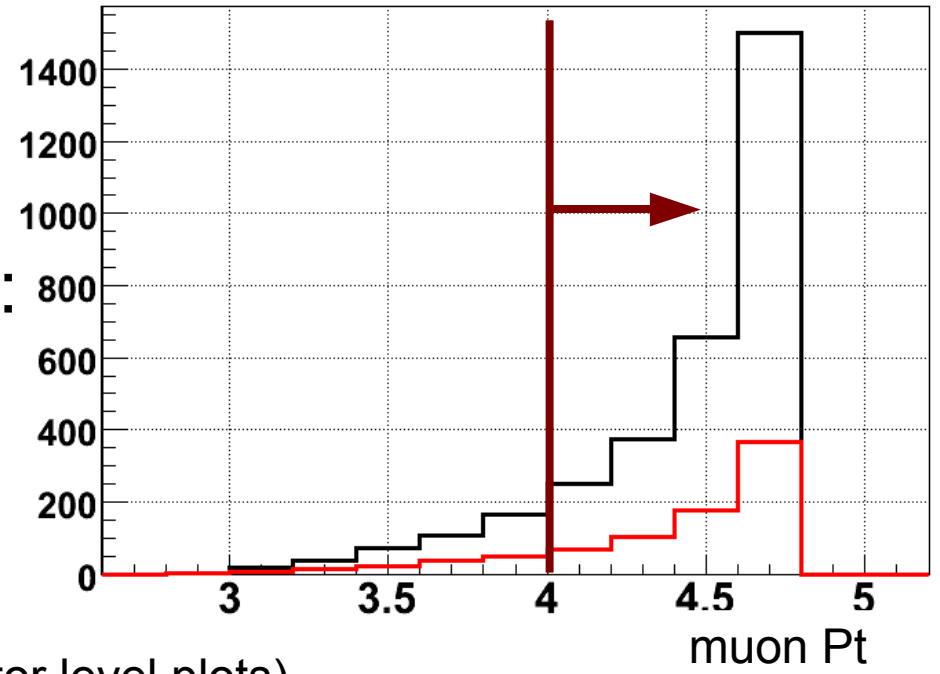
→ Pythia

Upsilon (III) : acceptance

We need 2 central muons with decent Pt (> 4 GeV) :



— : photon-induced tag
— : pomeron-induced tag



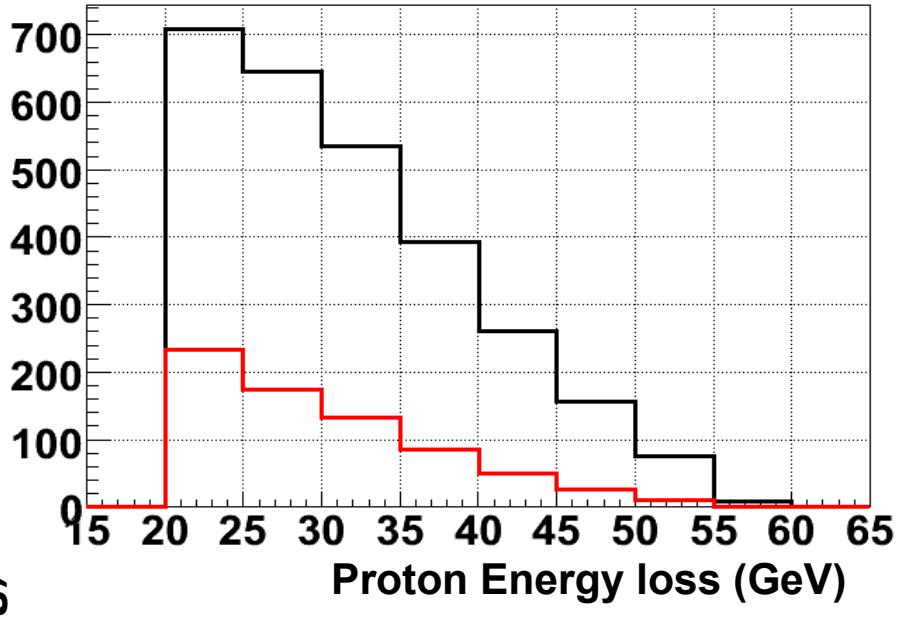
Final cross-sections (tagged) :

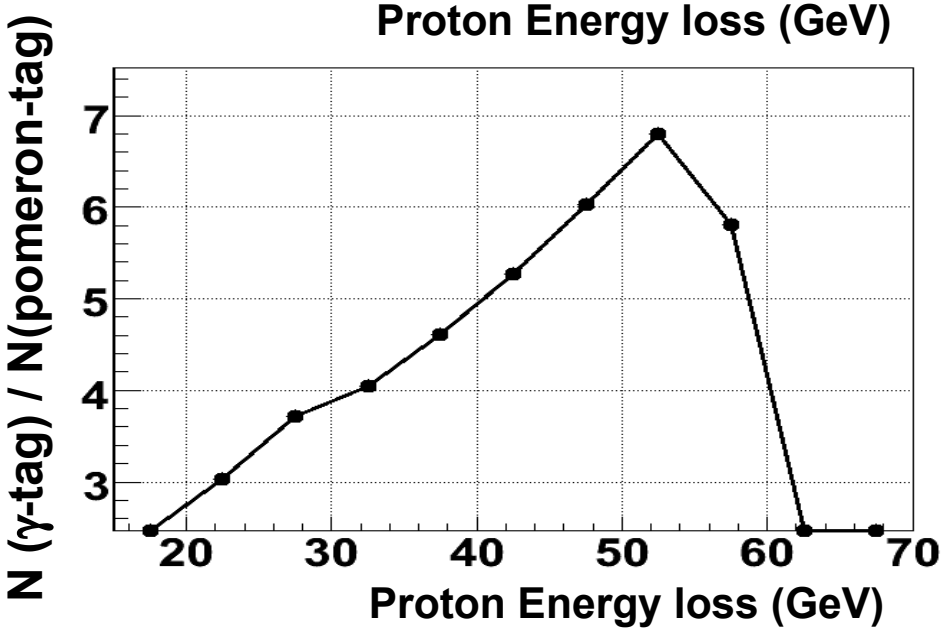
- photon : 28 pb
- pomeron : 7 pb
- total : 35 pb x BR (~ 2.5 %)

(Generator level plots)

Upsilon (III) : open questions

How to distinguish between photon- and pomeron-induced tag to extract $\sigma(W_{\gamma p})$?





- Photon tag dominates more at high energy loss

- Momentum transfer is higher for pomeron tag → Difference in Pt (not simulated yet)

Conclusions & Prospects

Conclusions :

• Photon physics at LHC offers the possibility for complementary studies to nominal hard pp ones
• Tools for particle propagation event simulation have been set
• Calibration of fp420 can be achieved using QED muon pair production
• The same final state allows the study of Upsilon photoproduction at high energy

Prospects :

• Full simulation (detector + trigger) of Upsilon production is needed
• We need a proper way to distinguish between pomeron- and photon-induced tag.
• Backgrounds have to be studied