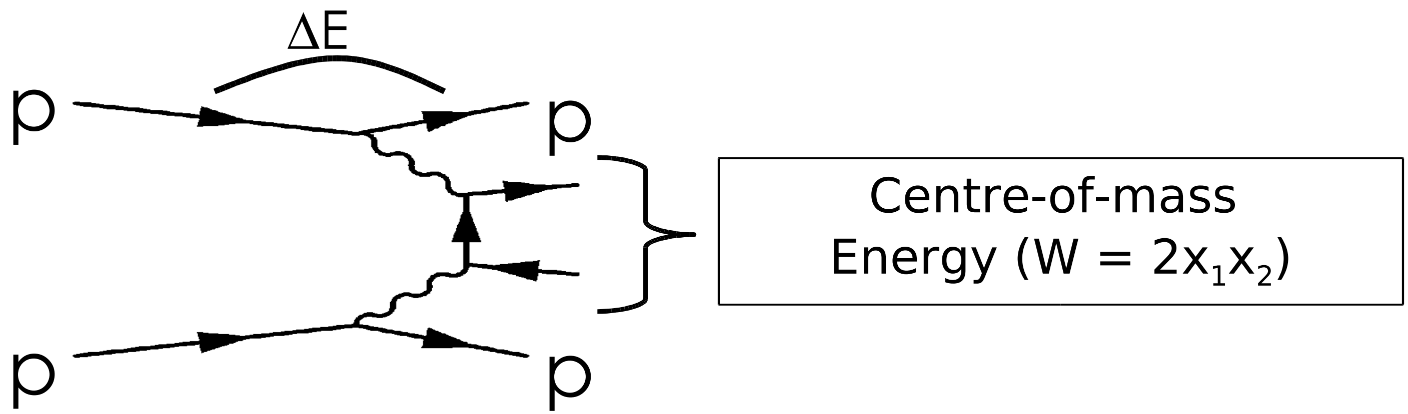
Study of High-Energy Photon Induced Physics at the LHC

Contents (1)

1. An Introduction to $\gamma\gamma$ Physics
   - Motivation
   - Roman pots
   - Processes
2. Generating Events
3. Beam Simulation
4. Dedicated Detectors
5. Future Plans

Introduction

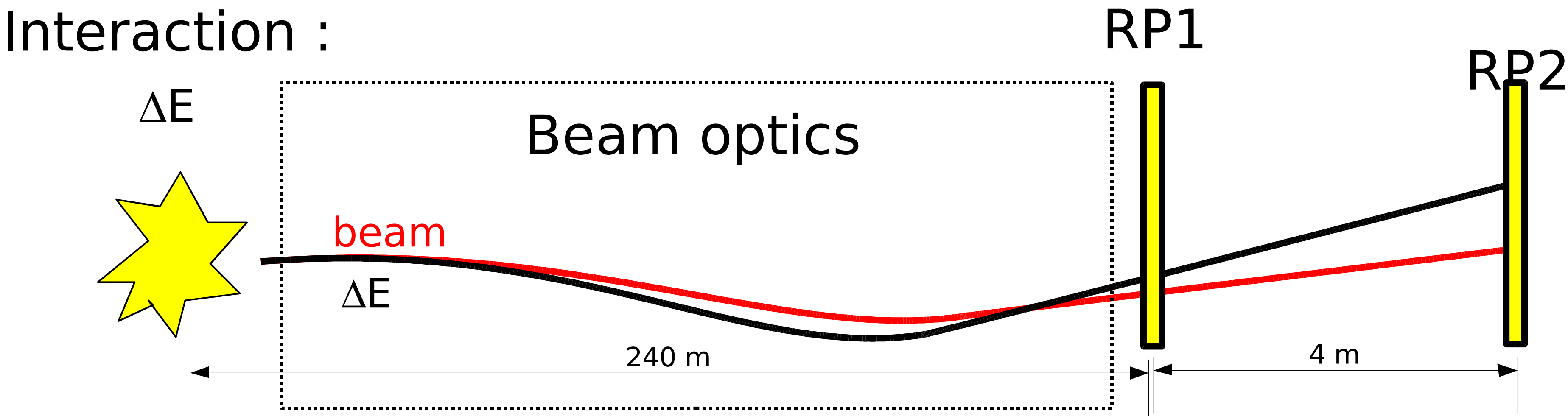
1. Motivation



1. New class of events at the LHC !
2. Tagging is possible using detectors far from the IP;
3. Initial state reconstruction and cleaner events allows e^+e^- - type analysis;
4. Energy and Luminosity of photon interactions are high.

Introduction (II)

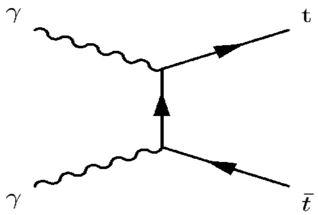
2. The way : the Roman Pots



Measurement of position and angle for the reconstruction of the photon energy and virtuality

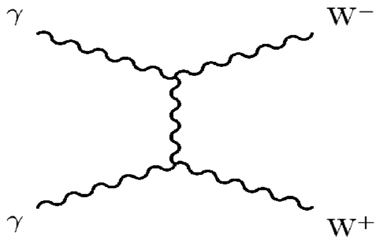
Introduction (III)

Which processes are we interested in ?

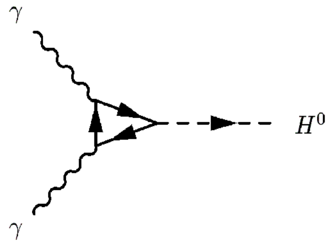


All Charged particle pairs :

- W bosons
- Top quarks
- Supersymmetric particles
- ...

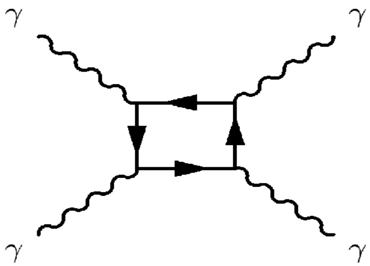


But also :



- Higgs production
- Possible $\gamma\gamma$ diffraction due to magnetic monopoles
- ...

The list is still open !



Contents (2)

1. An Introduction to $\gamma\gamma$ Physics
2. Generating Events
   - PHOTIA
   - First W results
     - Standard Model
     - Anomalous
3. Beam Simulation
4. Dedicated Detectors
5. Future Plans

Events Generation

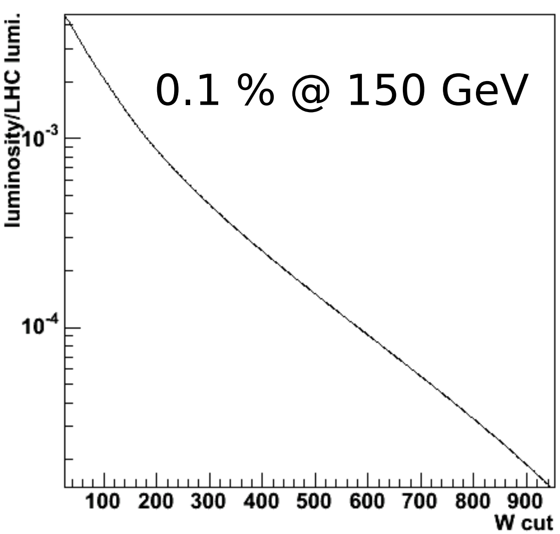
- Basic processes generated using PYTHIA 6.210
- Anomalous couplings and all processes not included in PYTHIA : COMPHEP
- But the main challenge was to get a realistic spectrum of the photon energy : PHOTHIA

Events Generation (II)

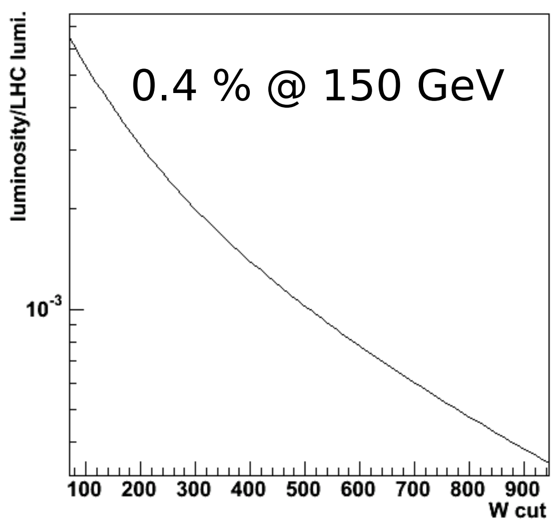
PHOTHIA can handle 3 cases :

- γγ « elastic » : both photons have low virtuality (Q^2), both protons can be detected thanks to the energy loss $x = \Delta E/E$;
- γγ « inelastic » : one of the protons does not survive the interaction (dissociative mass < 20 GeV);
- γp : only one proton emits a photon. This photon is emitted elastically, so the proton can be detected.

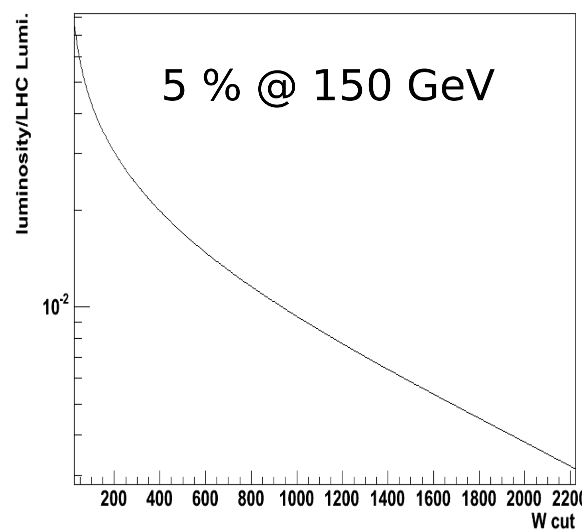
γγ, elastic



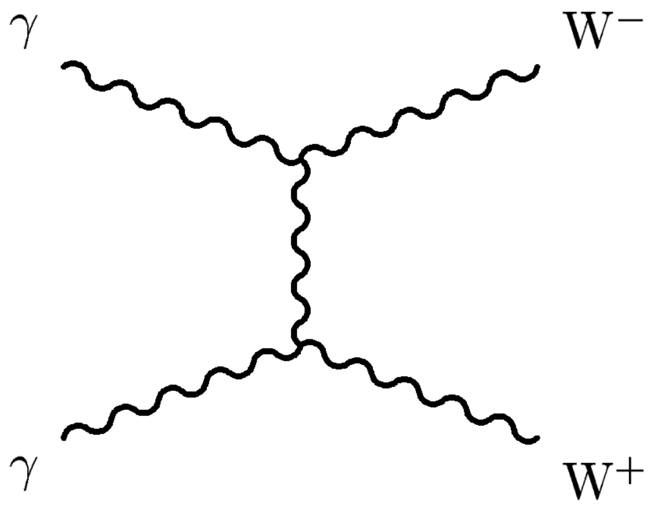
γγ, inelastic



γp



First W results : Motivation



- Measurement of a possible anomalous γWW coupling via parameters κ and λ
- Possible Signature of
  Large Extra Dimension ?
- Background to other $\gamma\gamma$ processes

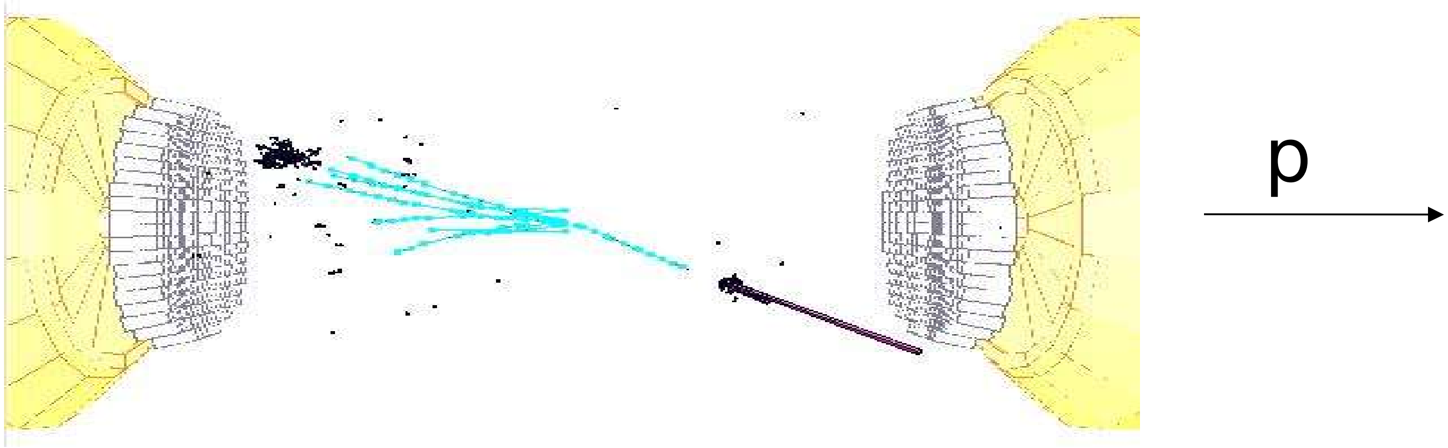
Cross sections estimated with PHOTHIA :

Process	σ_{pp} (pb)	Events/year*
$\gamma\gamma$ -> WW (el.)	0.12	2,400
$\gamma\gamma$ -> WW (in.)	1.24	24,800
γp -> WX	10.2	204,000

* At low lumi = $2*10^{33}$ cm^{-2} s^{-1}

First W results : Selection

First look at leptonic final states : $\gamma p \rightarrow W \rightarrow l\nu$



Efficiency at L1 and HLT (ORCA 8_1_2)

L1 : 48 %

HLT : 29 %

First W results : anomalous

- Anomalous γWW coupling effects computed with CalcHep based on effective lagrangian :

$$L = e\left(W^{\dagger}_{\mu\nu}W^{\mu}A^{\nu} - W^{\mu\nu}W^{\dagger}_{\mu}A_{\nu} + \kappa W^{\dagger}_{\mu}W_{\nu}A^{\mu\nu} + \frac{\lambda}{M_W^2}W^{\dagger}_{\rho\mu}W^{\mu}_{\nu}A^{\nu\rho}\right)$$

- Current results (Moriond 2004) :

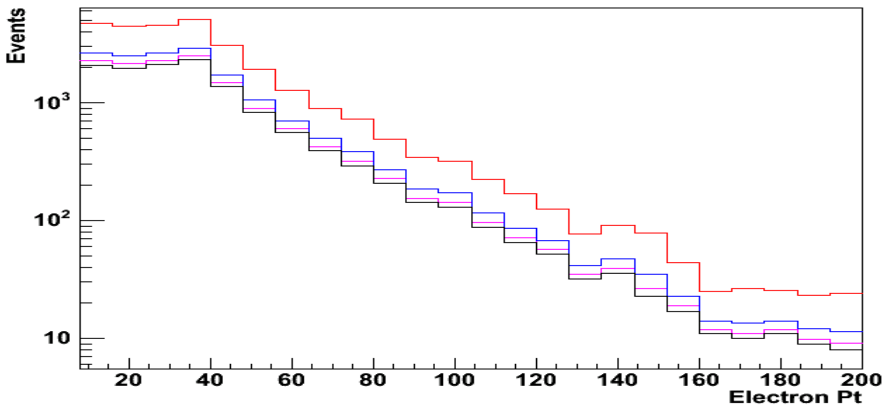
$$-0.063 < \Delta\kappa < 0.026$$

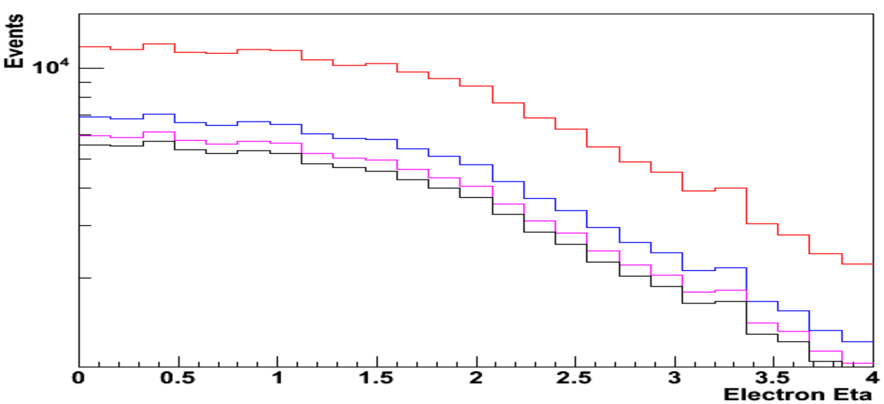
$$-0.039 < \lambda < 0.005$$

First W results : anomalous (II)

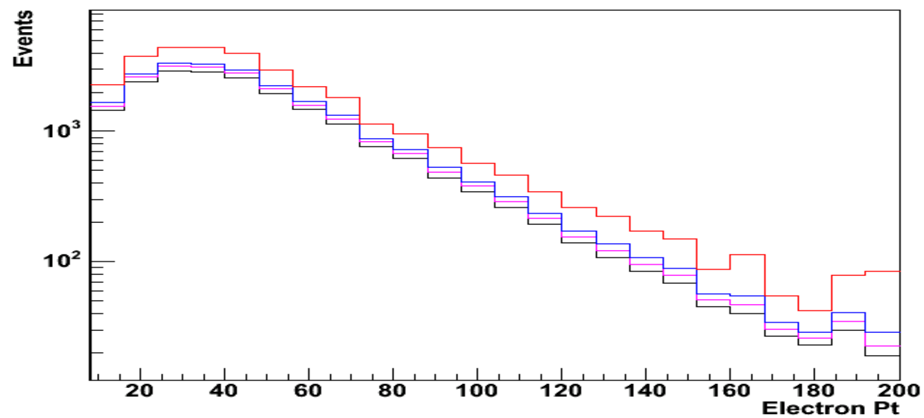
Effect on the distributions (electrons) :

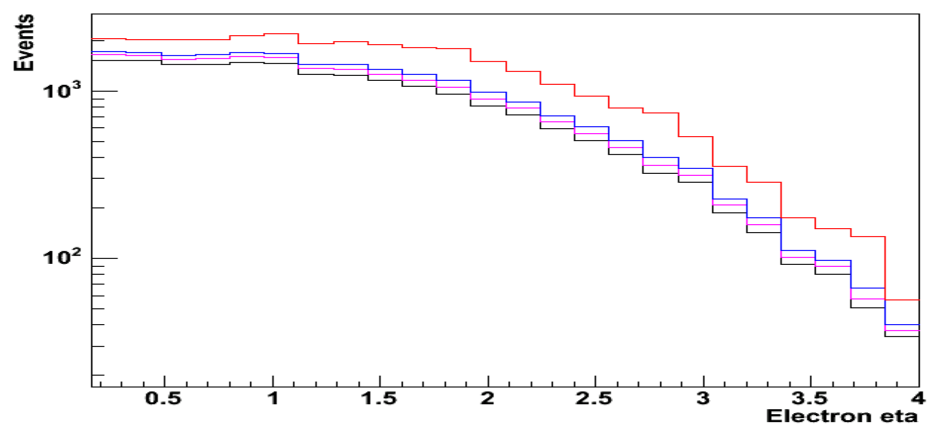
γp -> W , λ = 0, .03, .05, .1





$\gamma\gamma$ -> WW , λ = 0, .03, .05, .1

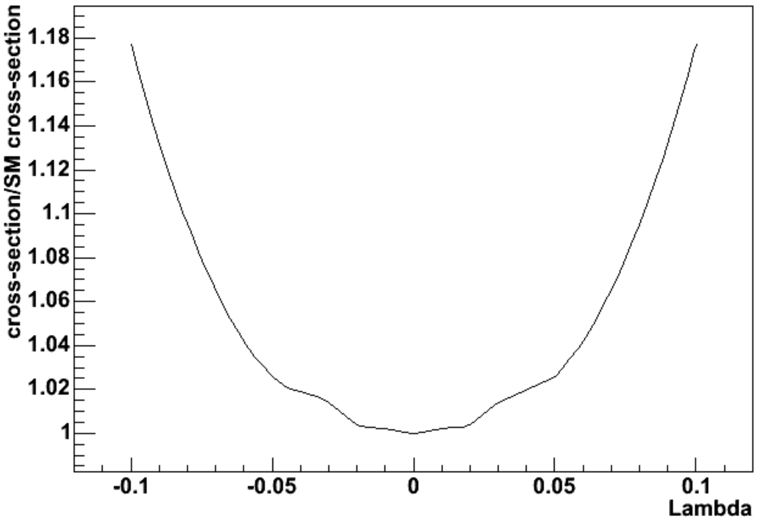




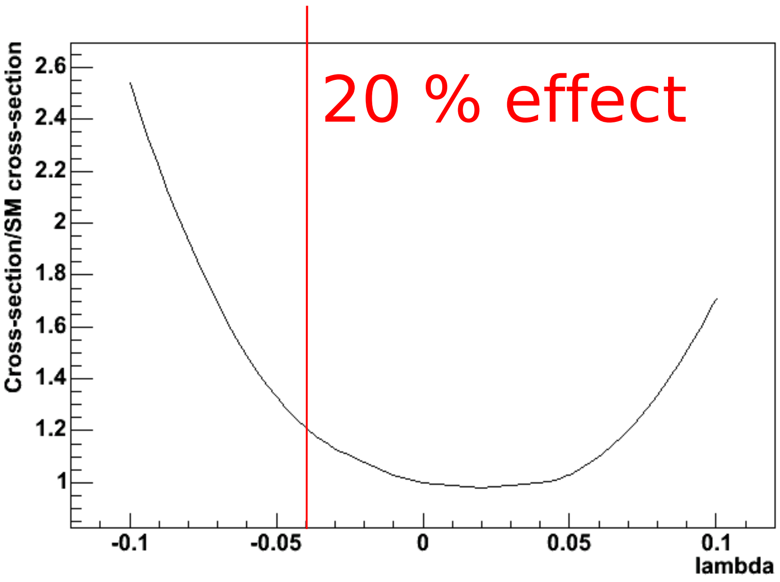
First W results : anomalous (III)

Effect on the total cross-sections (preliminary):

γp -> WX



$\gamma\gamma$ -> WW



Contents (3)

1. An Introduction to $\gamma\gamma$ Physics
2. Generating Events
3. Beam Simulation
   - Tagging with roman pots
   - Design of roman pots
4. Dedicated Detectors
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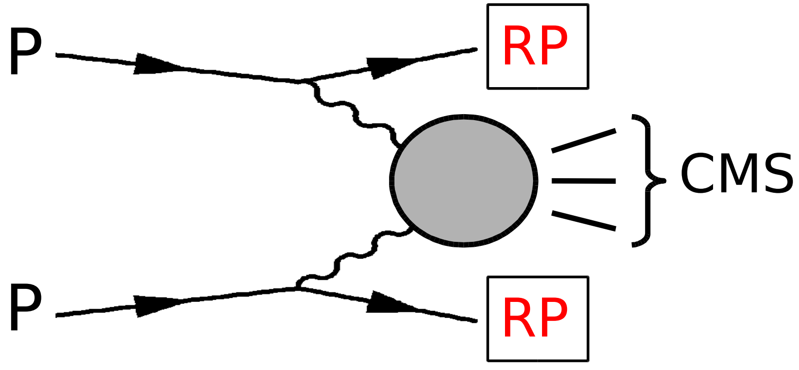
Tagging with the roman pots

The principle is simple :



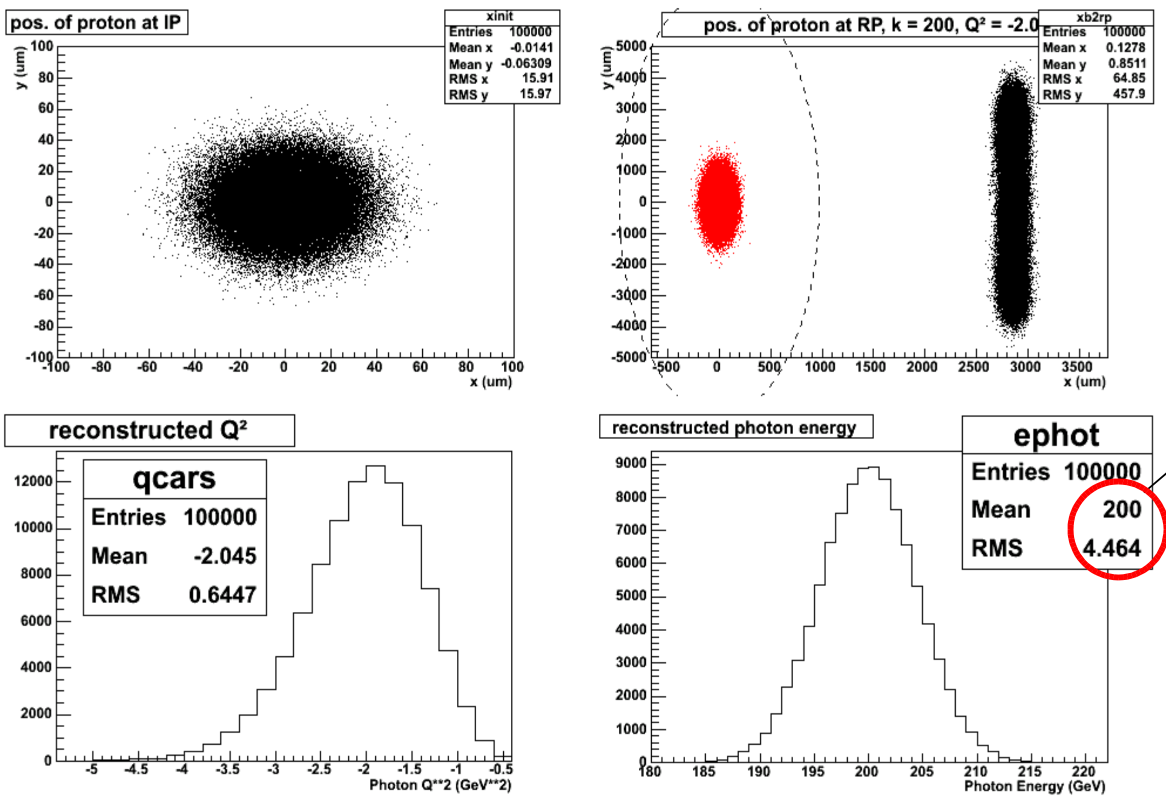
- Allows to tag low Q² photons;
- Measurement of position and angle of the proton at the RP leads to a good reconstruction of the photon Energy and Q²

$$Q^2 \simeq E^2(\theta_x^2 + \theta_y^2)$$

Tagging with the roman pots (II)

Simulation of the beam optics effect :
First simplified simulation

= 15 σ from beam



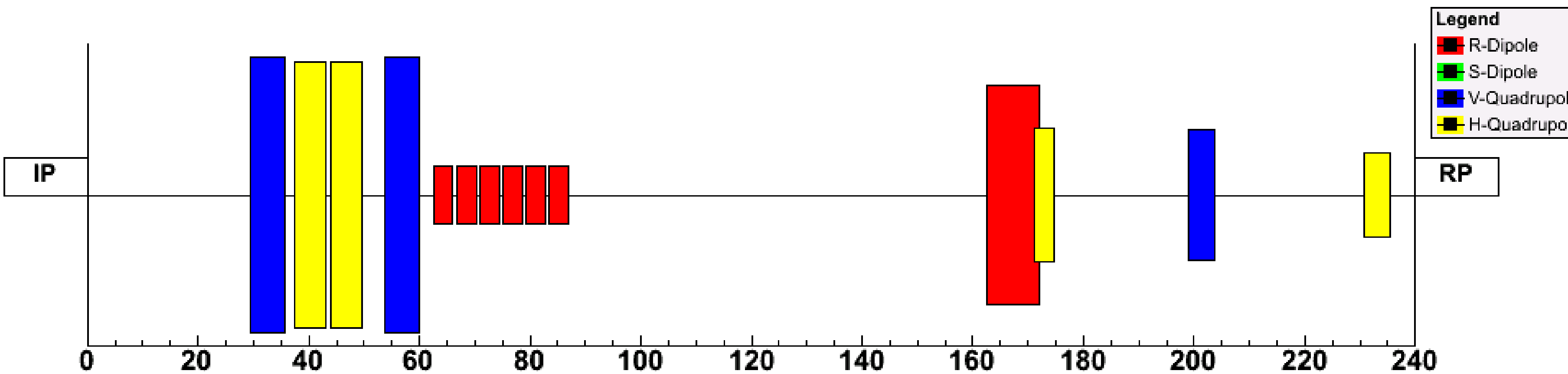
Energy can be reconstructed with σ = 4.5 GeV !

Tagging with the roman pots (III)

Now working on a (more) realistic Matrix-based simulation :

$$\begin{pmatrix} x \\ x' \\ y \\ y' \end{pmatrix}_{RP} = M \begin{pmatrix} x \\ x' \\ y \\ y' \end{pmatrix}_{IP} , \quad M = \prod_i M_i , \quad x' = \frac{\partial x}{\partial s}$$

The problem is that nobody knows what the matrix really is...



* Height of the elements gives an idea of their strength

Design of roman pots

Requirements on detector candidates :

- Radiation hardness (fluence reaching 10^{15}n/cm^2)
- As close as possible from the beam (~1mm)
- Insensitivity of the edge as small as possible
- Compatible with the CMS DAQ (for easy integration)

Proposed solution :

Edgeless Silicon Microstrip Detector operated at cryogenic temperatures

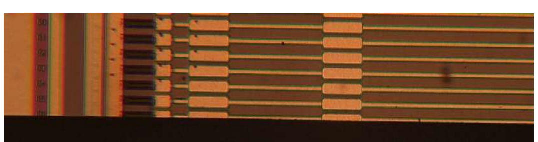
Contents (4)

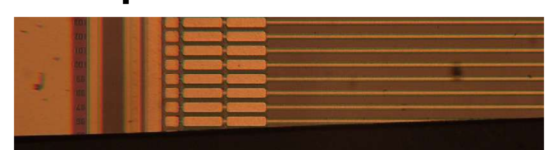
1. An Introduction to $\gamma\gamma$ Physics
2. Generating Events
3. Beam Simulation
4. Dedicated Detectors
   – Sensor technology
   – Detection electronics and tests
5. Future Plans

Sensors

Taking part to the CERN RD-39 collaboration (with the GREAT help from O. Militaru), a first prototype of edgeless detector is under construction.

- 320µm thick, n type silicon substrate
- single sided sensor
- 196 parallel straight strips with 120µm pitch.
- 2.5 x 2.0 cm²
- cut in BNL with 2 geometries
  (parallel and *angular* cuts)
- no guard rings means cryogenic operation





Cryogenic operation

The low temperature (<200K) helps

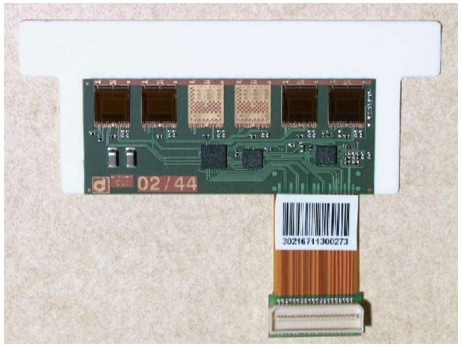
- improving the leakage current
- improving the radiation hardness
- getting a better S/N ratio and a faster signal

but requires

- a dedicated tooling for cooling
- deep tests of readout electronics

CMS tracker hybrid

To ease the integration of such new detectors into the CMS DAQ, the candidate for acquisition electronics is the CMS tracker front-end hybrid



pros

- 100% compatible with CMS !
- good knowledge of it
- easily tested here

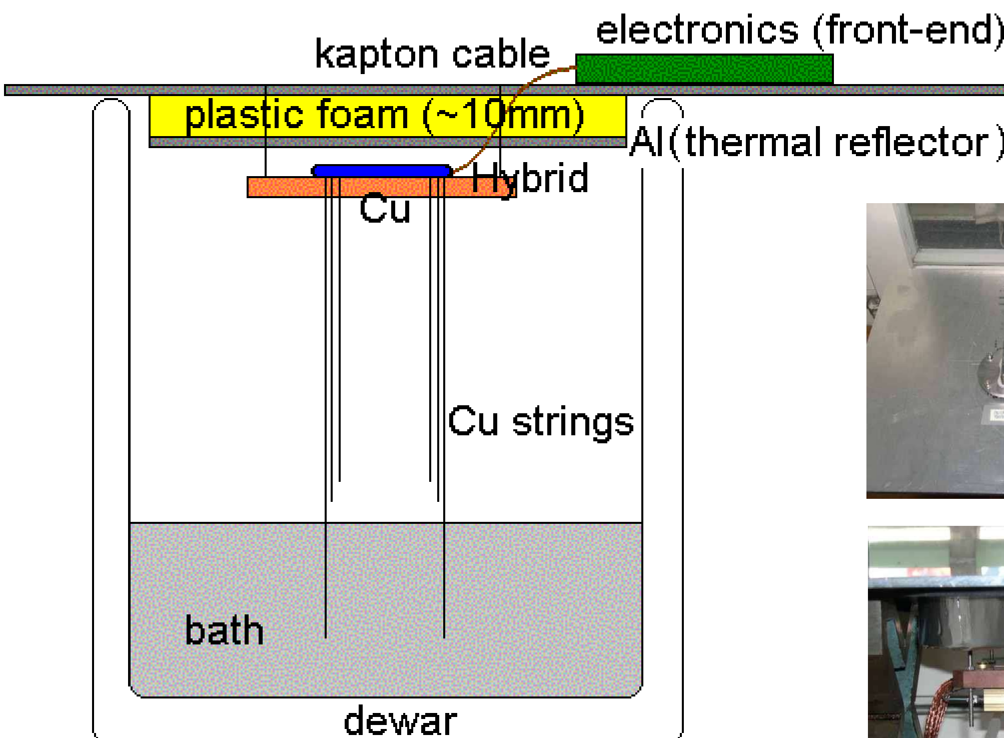
cons

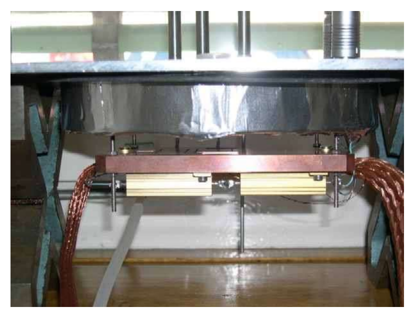
- not meant for low temperature operation

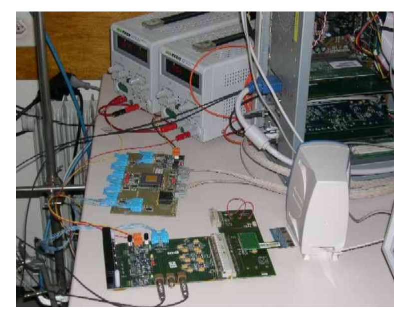
==> Characterization needed at low temperature !

Setup for lowtemp test

A dedicated setup has been designed for low temperature test of CMS hybrid.

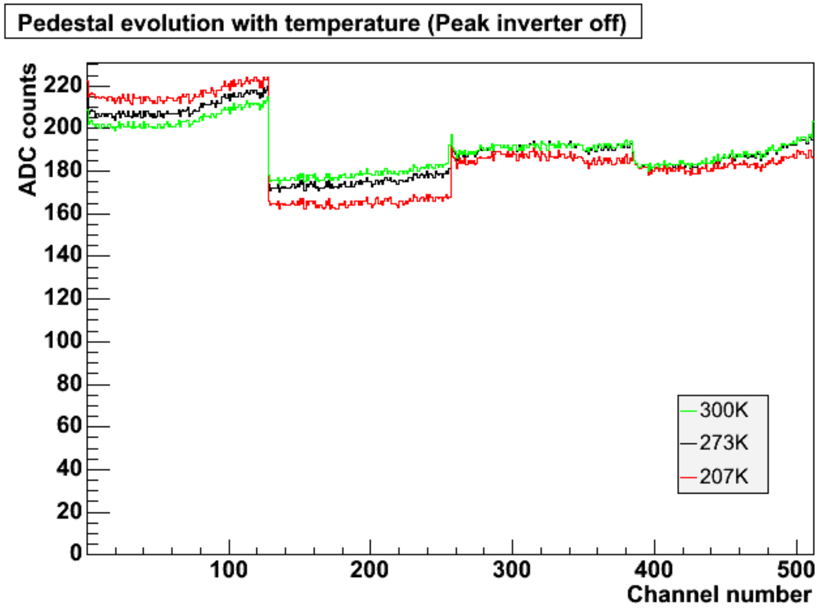


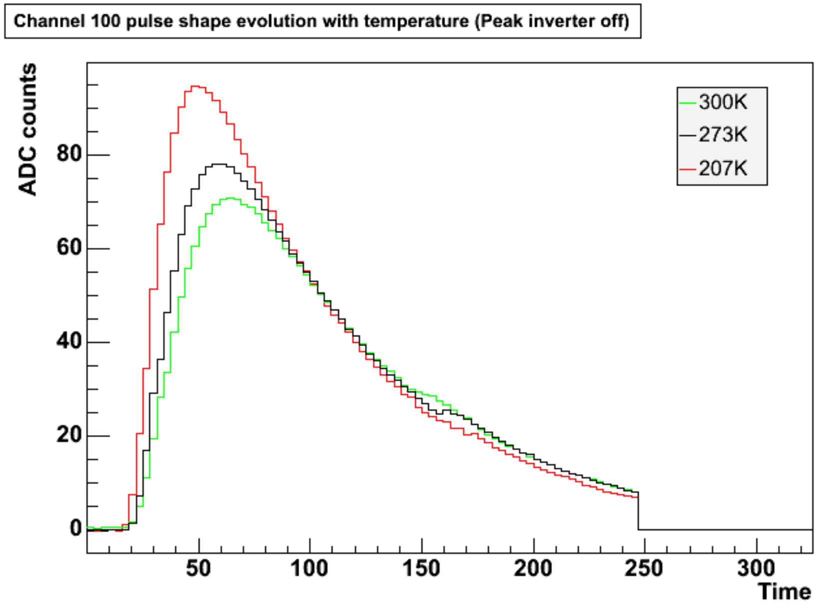




Preliminary results (I)

First tests, down to 207K last February and first results (on one single hybrid)

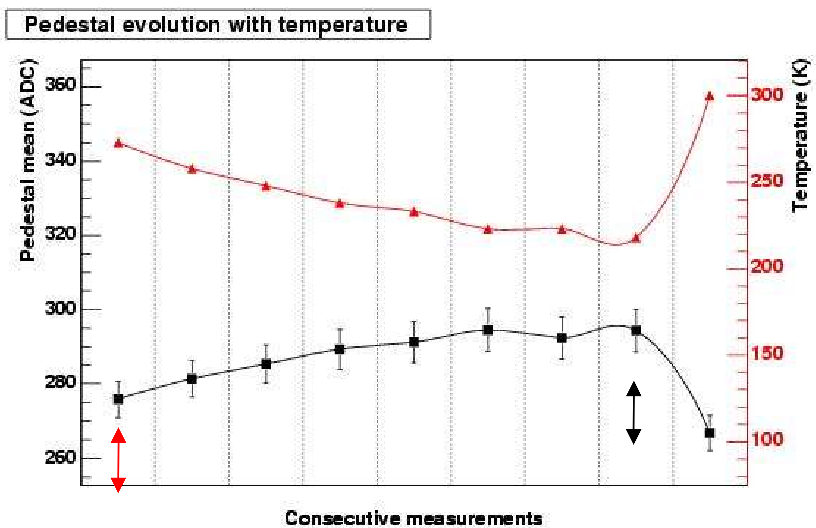


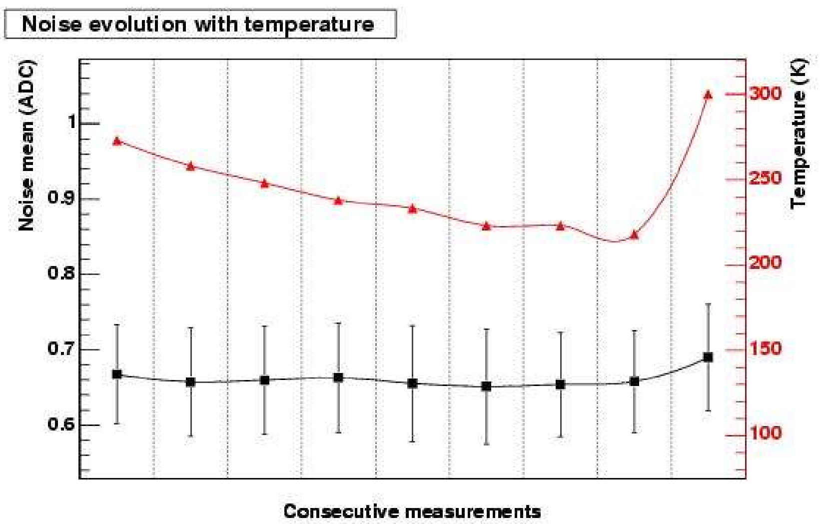


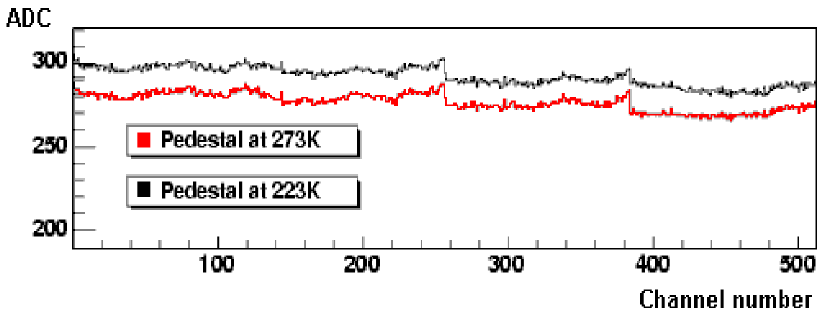
Faster signal response, better gain, constant noise, lower pedestal

Preliminary results (II)

More hybrid were tested, last weeks







Increasing pedestal, constant noise...

(No info on signal response or gain yet)

Contents (5)

1. An Introduction to $\gamma\gamma$ Physics
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4. Dedicated detectors
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Future plans (close future)

Tomorrow and next weeks

1) Monte Carlo's and phenomenology

- get distributions at detector level
- use them to compute sensitivity to anomalous couplings

2) Hybrid test and detector assembly

- enhancing the automation of analyses of hybrid tests.

3) Beam line simulation

- including real element parameters

Future plans (behind the horizon)

Next year(s?)

1) Monte Carlo's and phenomenology

- get distributions at detector level
- use them to compute sensitivity to anomalous couplings
- other processes

2) Hybrid test and detector assembly

- enhancing the automation of analyses of hybrid tests.
- detector assembly and test in the cold
- test beam at CERN (Sept 2004 ?)

3) Beam line simulation

- including real element parameters
- drawing conclusions related to detector design