Exclusive π^0 signal in COMPASS

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COMPASS Collaboration

COMPASS II proposal and DVCS tests

- GPDs program is a part of the COMPASS II (2013-2015) proposal
  -- recommended by SPSC (29 Sept) to the RB for approval
  -- http://cdsweb.cern.ch/record/1265628/files/SPSC-P-340.pdf

- 2008 DVCS test run: first observation of exclusive single-photon production (predominantly the Bethe-Heitler process).

- 2009 DVCS test run: first evaluation of relative contributions of the DVCS, BH processes and DVCS-BH interference.
  -- Clear signal of DVCS process.
  -- Study of the π^0 background to DVCS.
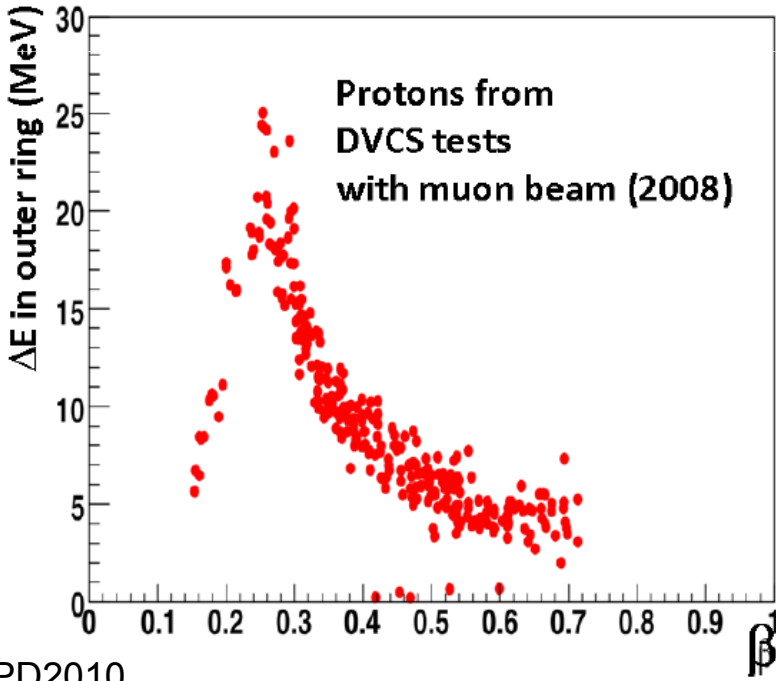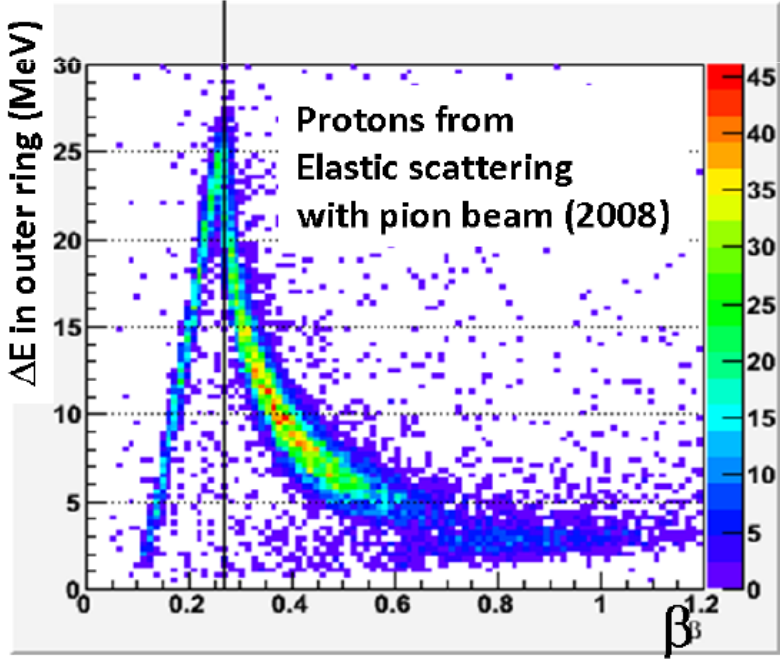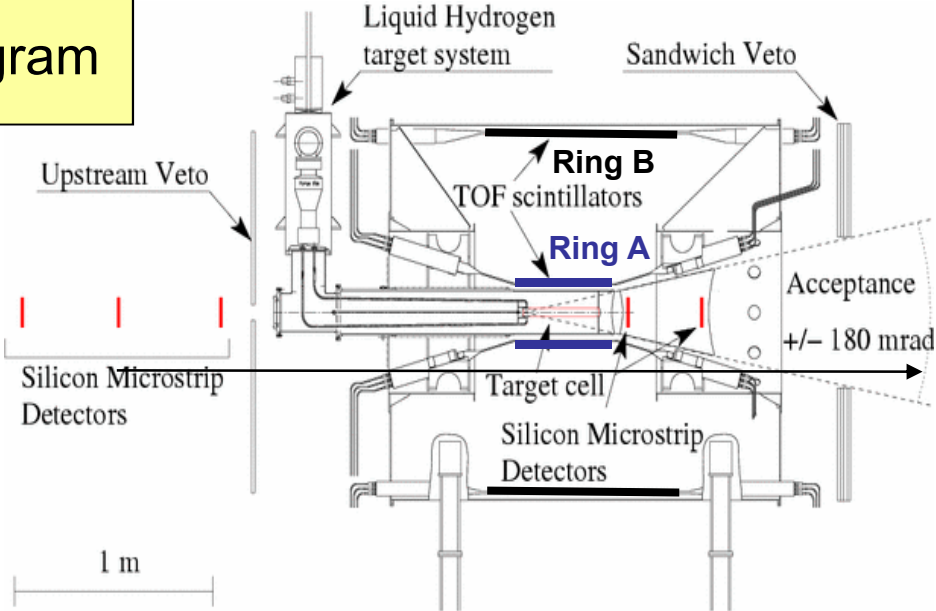
DVCS test runs 2008 & 2009

-- Set up for hadron spectroscopy
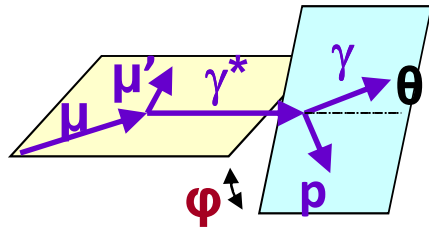-- Easy switch from π beam to μ one

$$\mu\, p \rightarrow \mu\, p\, \gamma$$

ECAL1 & ECAL2

LH$_2$ 40 cm   in the RPD   in EMCals
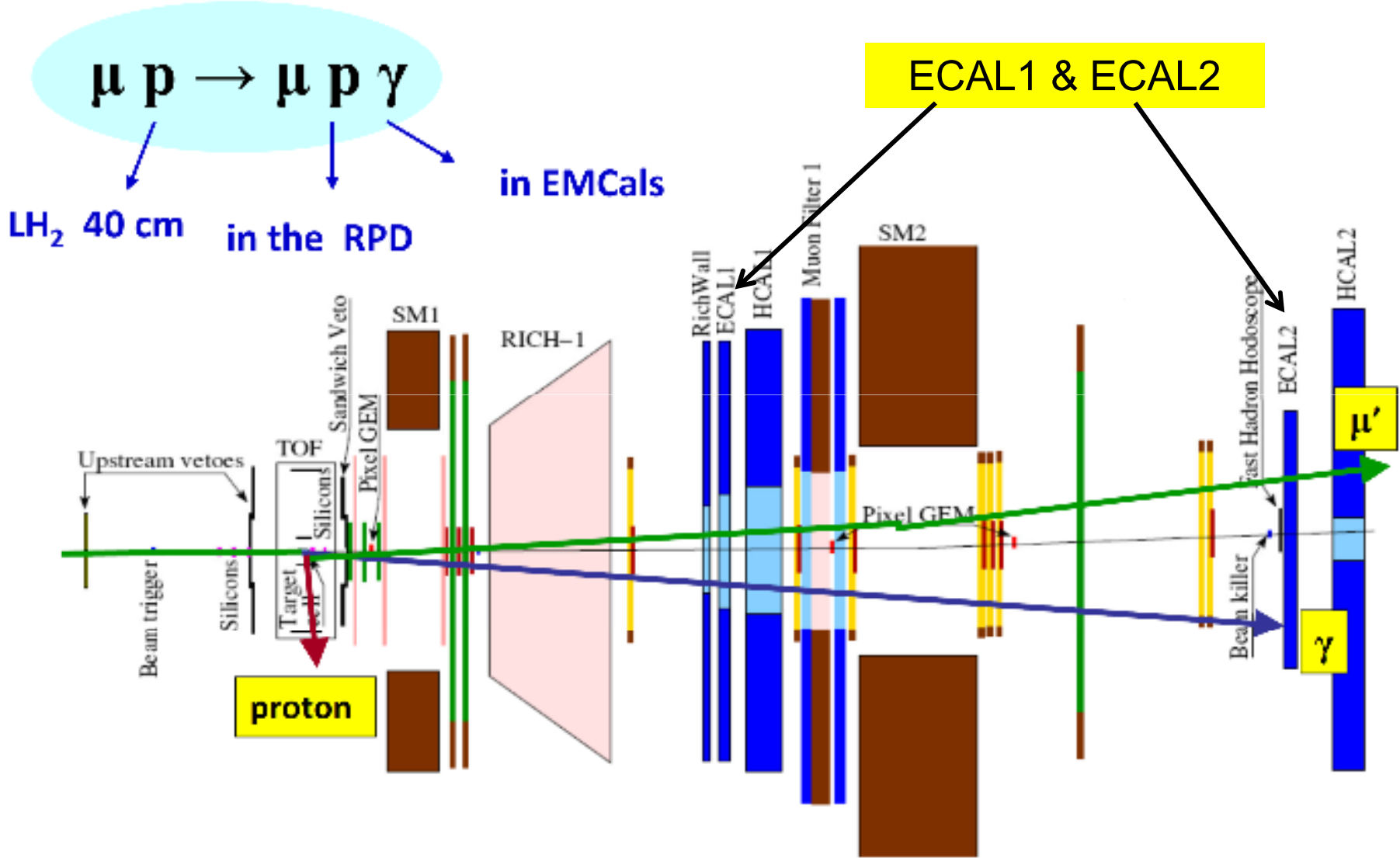
Recoil proton detector for hadron program

1 m long Recoil Proton Detector and a
40 cm LH$_2$ target in 2008/2009

Proton identification in RPD

Liquid Hydrogen target system

Sandwich Veto

Ring B

TOF scintillators

Ring A

Upstream Veto

Acceptance

+/− 180 mrad

Silicon Microstrip Detectors

Target cell

Silicon Microstrip Detectors

1 m

ΔE in outer ring (MeV)

Protons from
Elastic scattering
with pion beam (2008)

β

ΔE in outer ring (MeV)

Protons from
DVCS tests
with muon beam (2008)

β

1

4

DVCS test 2008: clear BH signal observed at $Q^2 > 1$ GeV^2

**Monte-Carlo simulation
of BH (dominant) and DVCS**

COMPASS 2008 DVCS TEST RUN - PRELIMINARY -

**After all cuts,
$Q^2 > 1$ GeV^2**
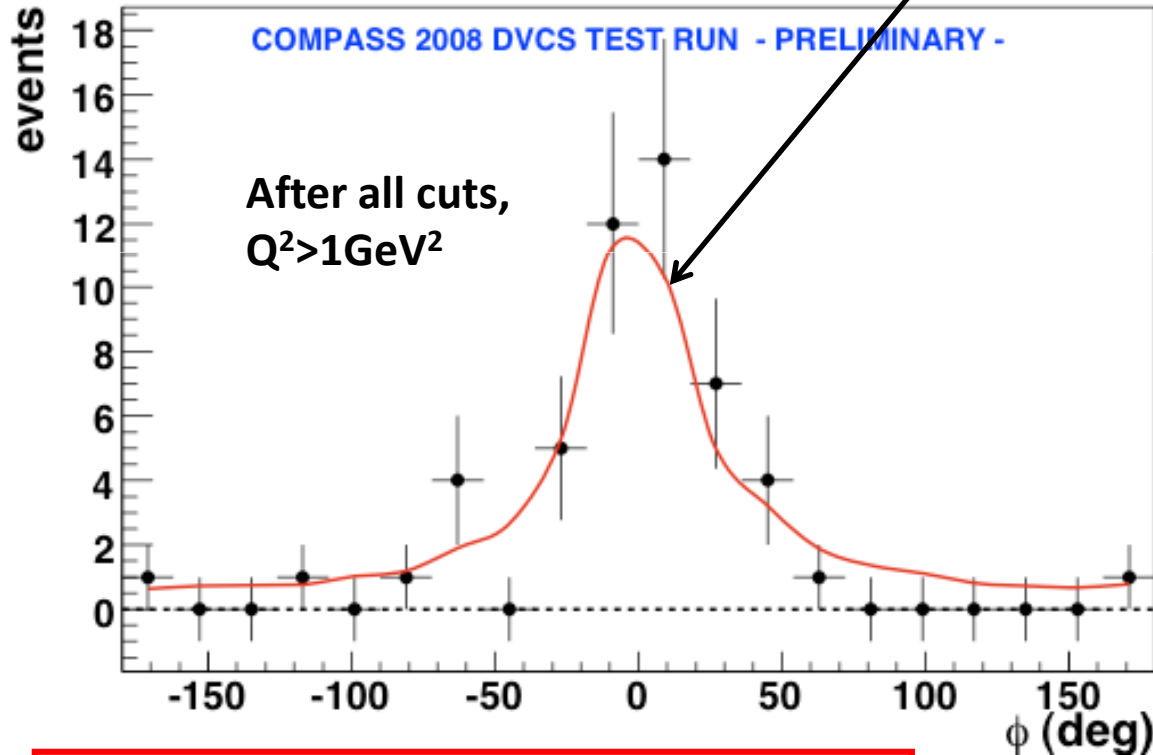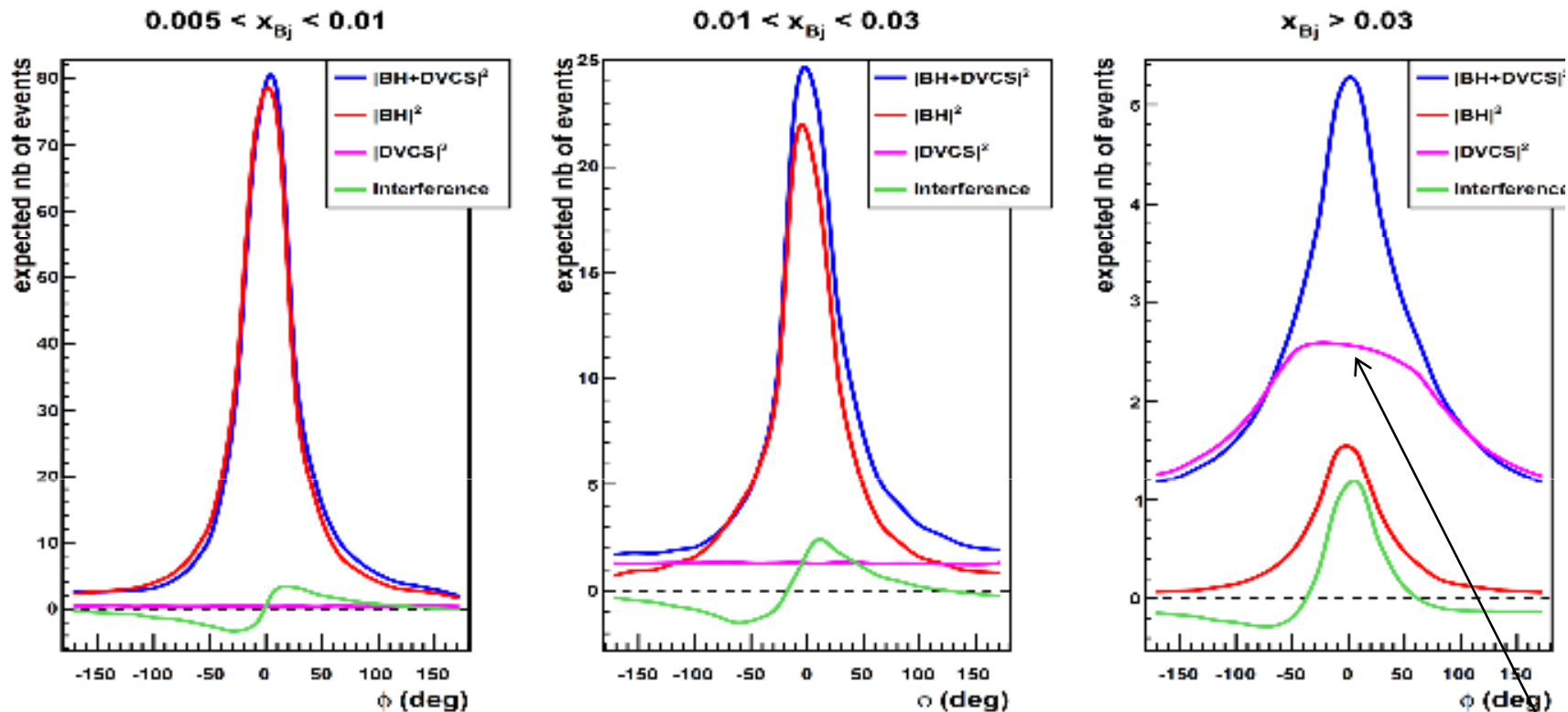
Detection efficiency :
$\epsilon_{\mu+p->\mu+p+\gamma} = 0.32 \pm 0.13$

Global efficiency :
- $\mu+p->\mu+p+\gamma$ efficiency
- SPS & COMPASS availability
- Dead time
- trigger efficiency

$\Rightarrow \epsilon_{global} = 0.13 +/- 0.05$

BH signal observed at $Q^2 > 1$ GeV^2
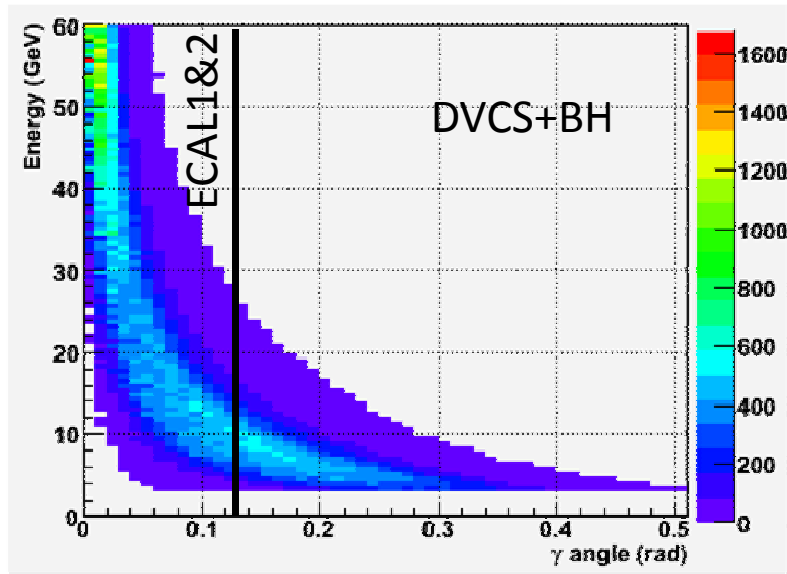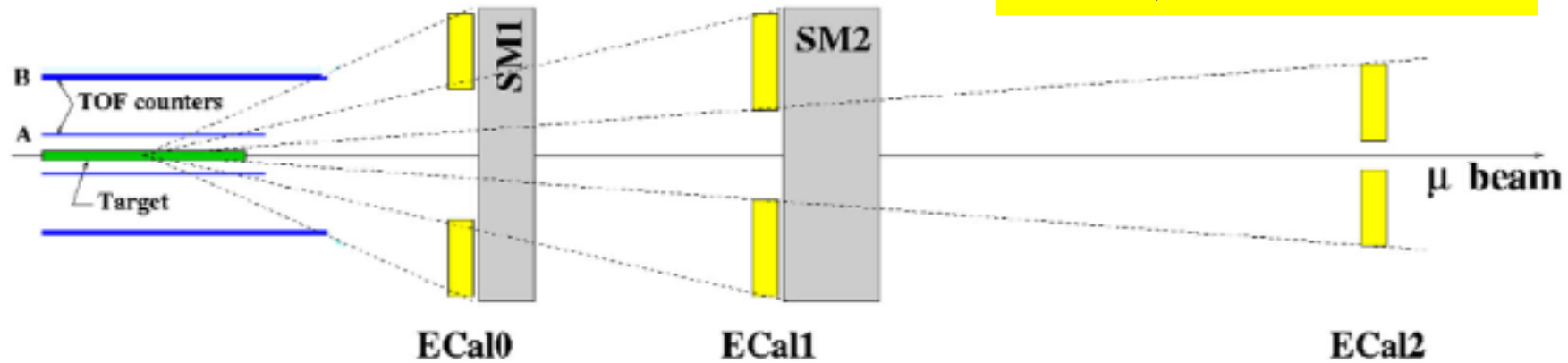
For LoI/Proposal was used
$\epsilon_{global} = 0.1$

Simulation 2009 test run using VGG for DVCS
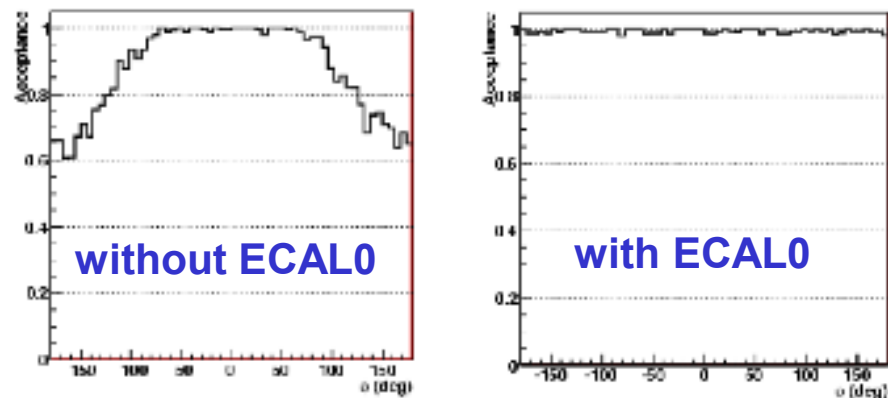

Current spectrometer acceptance shows non-uniformity ==> DVCS distribution should be flat in ϕ

MC was normalised on the low x_{Bj} bin (0.005-0.01) of data

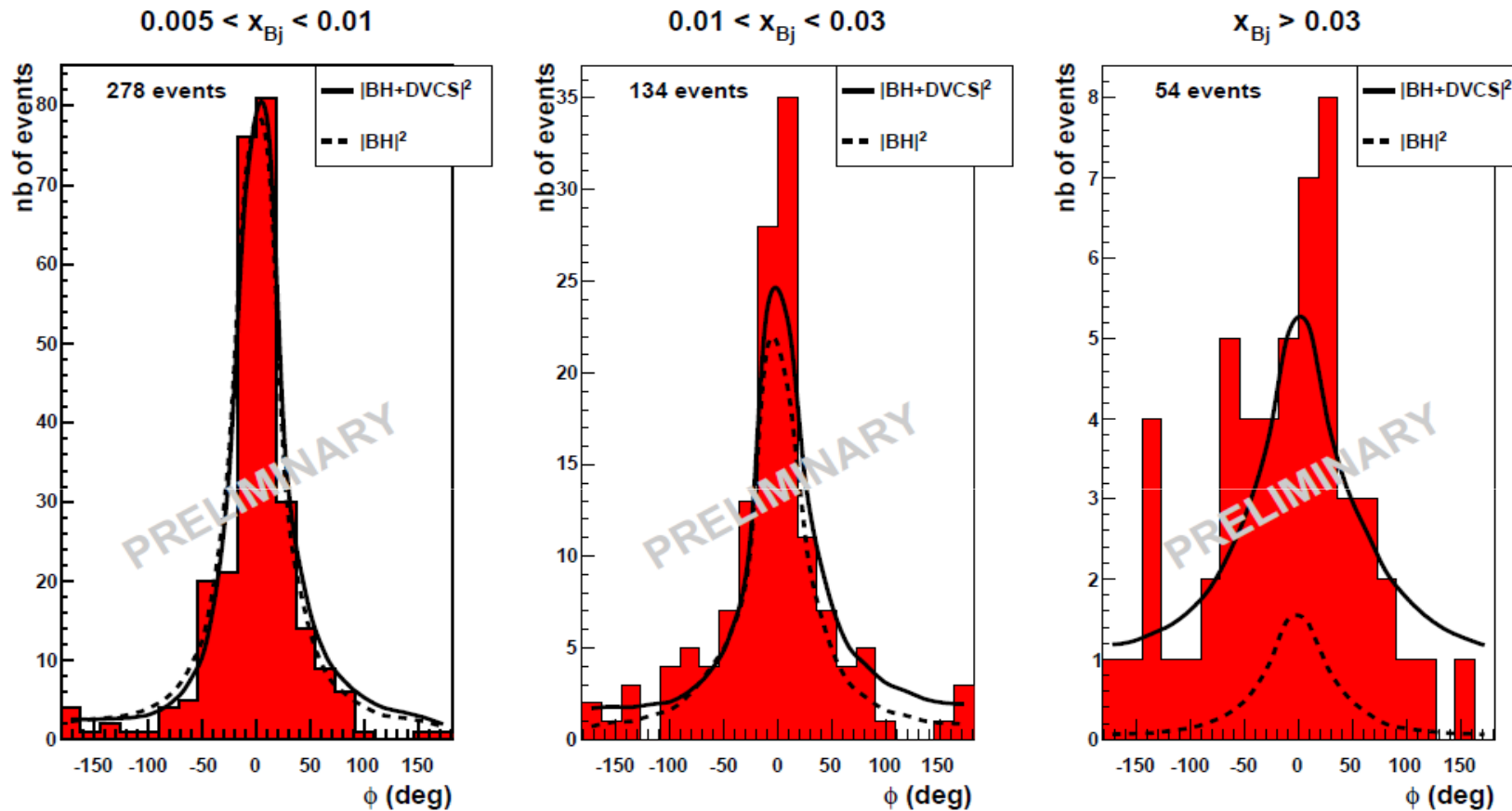# Future large-angle electromagnetic calorimeter ECAL0

sketch, not to the scale

φ-dependence of acceptance

DVCS+BH

without ECAL0

with ECAL0
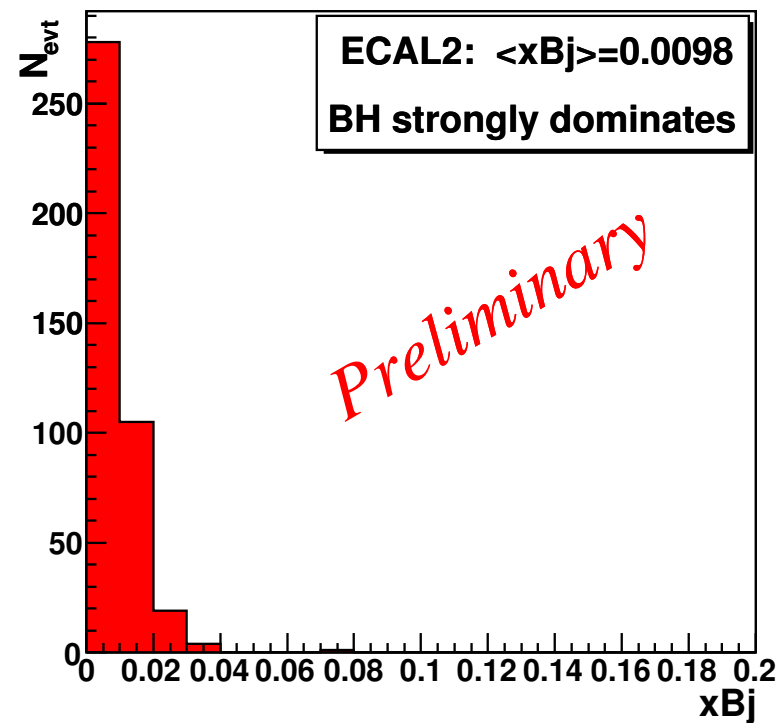
$Q^2 = 1.5 \pm 0.5$ (GeV/c)^2 and $x_{Bj} = 0.06 \pm 0.005$
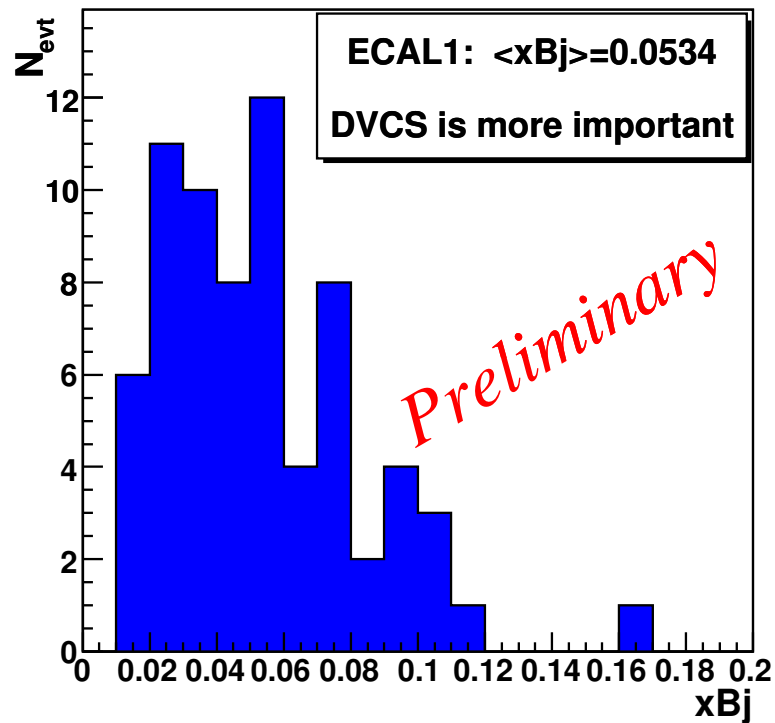
2009 beam test : DVCS signal observed at $X_{Bj} > 0.03$

- excess (~ 44) of events for $X_{Bj} > 0.03$ is a clear sign for DVCS
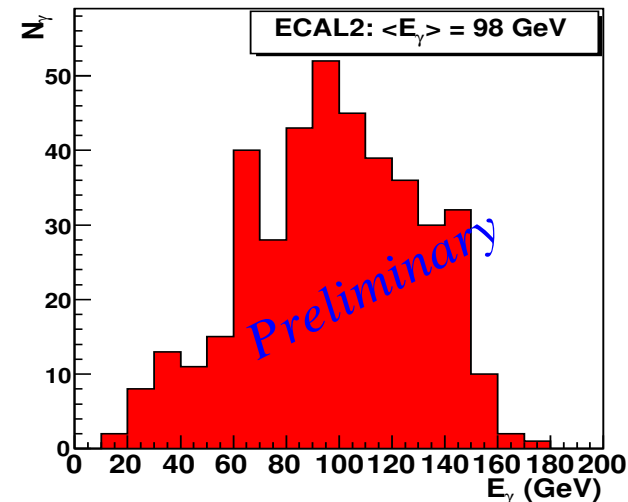- evaluation of exclusive π^0 background is in progress

x_{Bj} for exclusive single-photon events detected in ECAL1 and ECAL2

ECAL1: $\langle xBj \rangle = 0.0534$

DVCS is more important

Preliminary

ECAL2: $\langle xBj \rangle = 0.0098$

BH strongly dominates

Preliminary

ECAL0 will cover the region $X_{Bj} \sim 0.1\text{-}0.2$ where DVCS process dominates

θ_γ & E_γ from the detected exclusive single-photon events
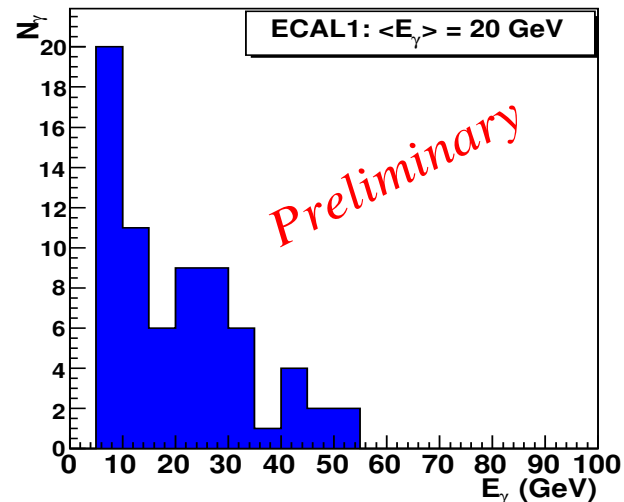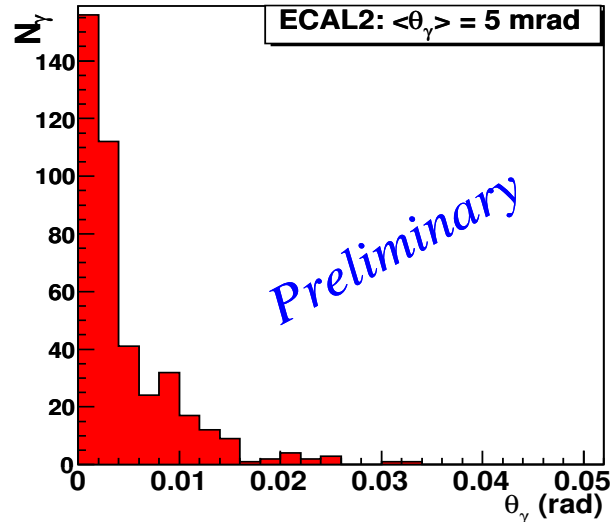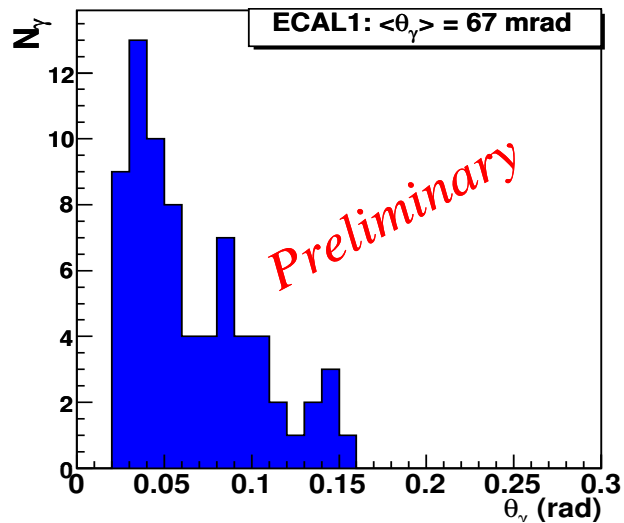
Up to ~30 GeV the photons are detected mainly in Ecal1

Kinematic ranges for DVCS photons in ECAL1 and ECAL2

MC by Andrzej Sandacz

ECAL1

$<\theta_\gamma>$ = **63 mrad** (DVCS)

56 mrad (DVCS/BH)

67 mrad (DATA)

ECAL2

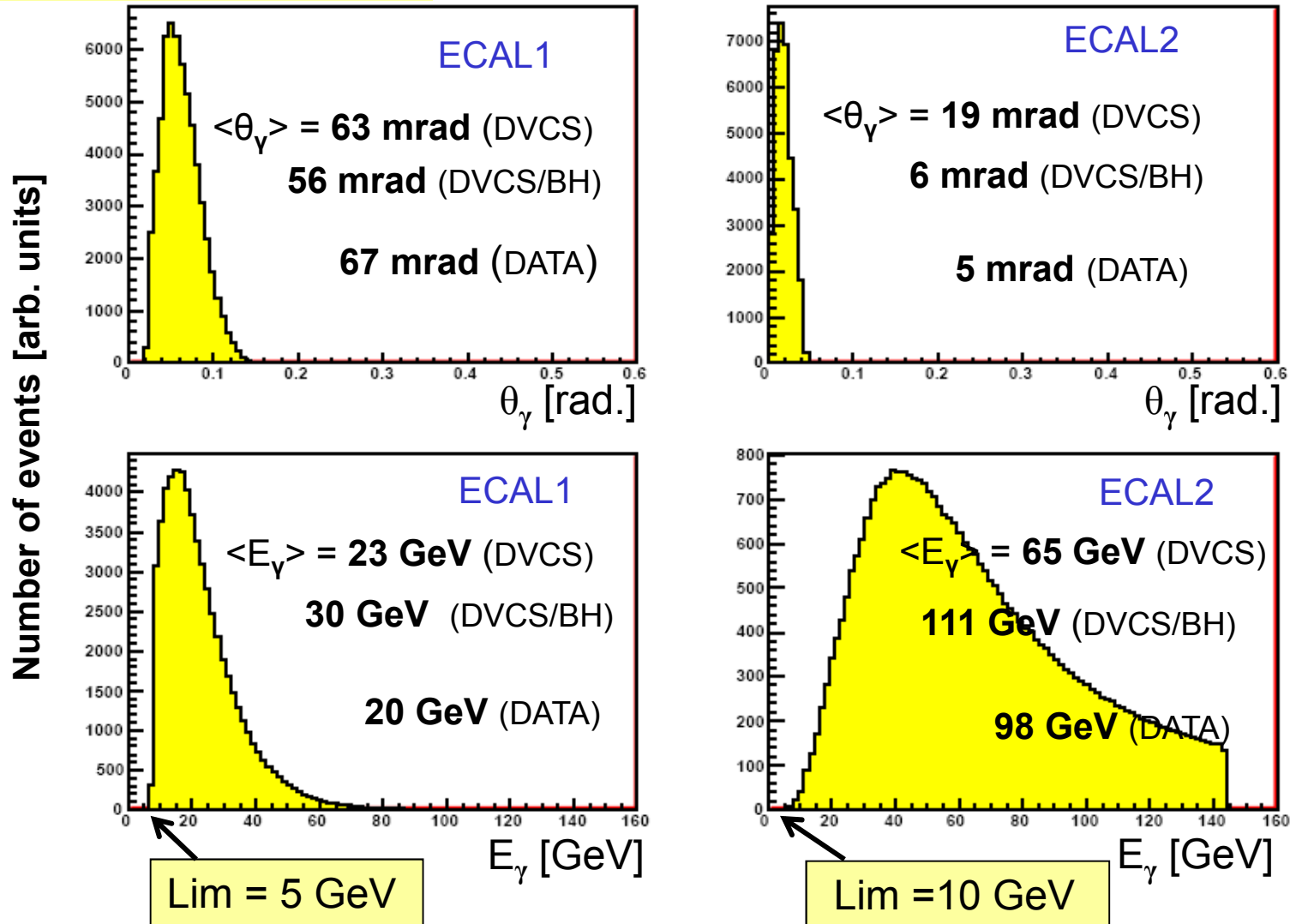$<\theta_\gamma>$ = **19 mrad** (DVCS)

6 mrad (DVCS/BH)

5 mrad (DATA)

θ_γ [rad.]

ECAL1

$<E_\gamma>$ = **23 GeV** (DVCS)

30 GeV (DVCS/BH)

20 GeV (DATA)

ECAL2

$<E_\gamma>$ = **65 GeV** (DVCS)

111 GeV (DVCS/BH)

98 GeV (DATA)

E_γ [GeV]

Number of events [arb. units]

Lim = 5 GeV

Lim = 10 GeV

π^0 and γ energies from MC (**S.Goloskokov and P.Kroll GPD model**)
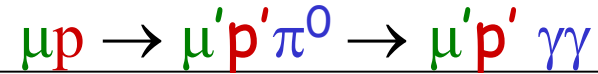
MC by Andrzej Sandacz
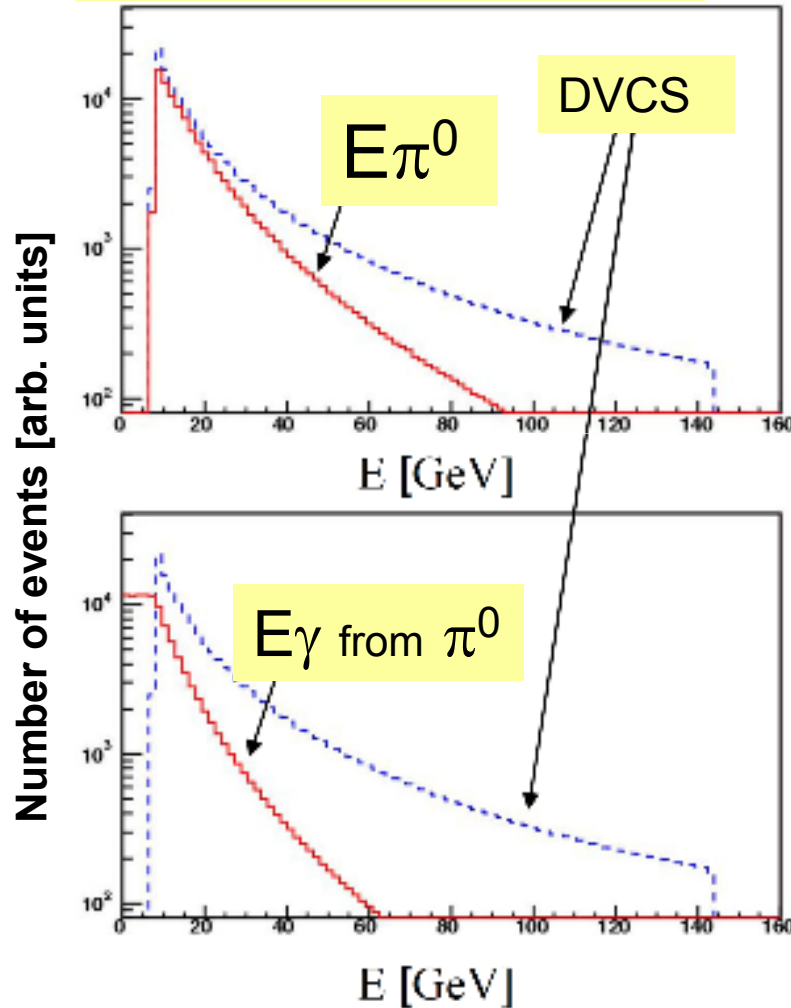
dist = distance between cluster's centers

- 2γ separation   dist>2 cm
- 100% efficiency   dist~4-5 cm
- Eπ^0 =100 GeV   dist ~8 cm
- Eπ^0 <100 GeV   from MC
- no bkg from 2γ non separated

$$\mu p \rightarrow \mu'p'\pi^0 \rightarrow \mu'p'\ \gamma\gamma$$

- only bkg if 1γ is non detected

$$\mu p \rightarrow \mu'p'\pi^0 \rightarrow \mu'p'\ \gamma$$

- The photons from π^0 should be mainly registered in ECAL1 ....what was confirmed by preliminary analysis ....

S.Goloskokov and P.Kroll GPD model for $\mu p \rightarrow \mu' p' \pi^0$

-- GPDs (DD using CTEQ6) for quarks and gluons

-- quark transverse degrees of freedom taken into account

-- both contributions of γ^*_L (asymptotically dominant) and γ^*_T calculated: $\gamma^* p \rightarrow p\, \pi^0$

cross section for 160 GeV

integrated over kinematic range

$\sigma_{\pi 0}$ = 10.7 pb   (GK model)

σ_{DVCS} = 97.2 pb   (FFS-S factorised model, α' = 0.8)

$1 < Q^2 < 12$ GeV²
$0.05 < y < 0.9$
$0.06 < |t| < 0.64$ GeV²

Results of the simulation for COMPASS (Andrzej Sandacz)

● Background from decay photons of exclusive π^0 to exclusive γ sample

< 1.0% in most of the kinematic range

higher 2% – 11% at small Q^2 and large x without ECAL0

π^0 analysis: goal and limitations

Goal==> estimation of background from exclusive π^0 to DVCS sample

1) analysis ==> take DVCS preselected sample

- only 2 tracks in the primary vertex μ & μ'

- at least 1 γ with $E\gamma$ > 5 GeV in ECAL1 or $E\gamma$ >10 GeV in ECAL2
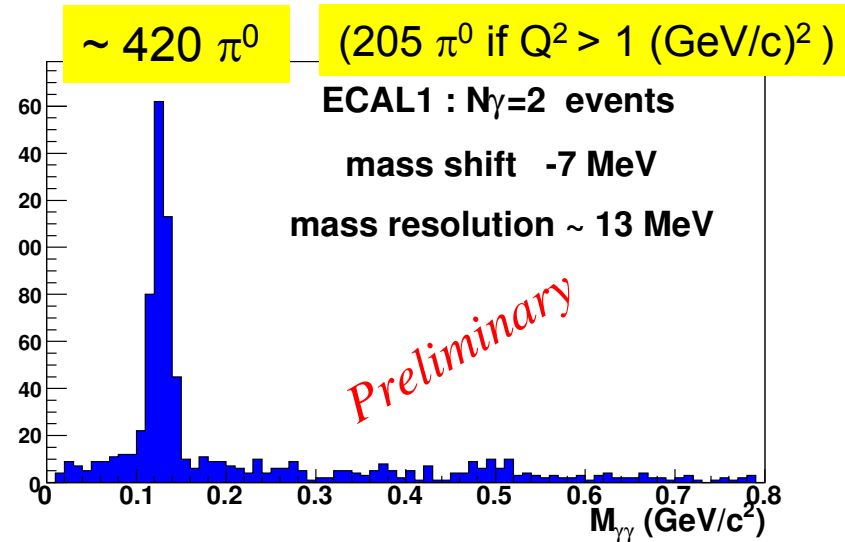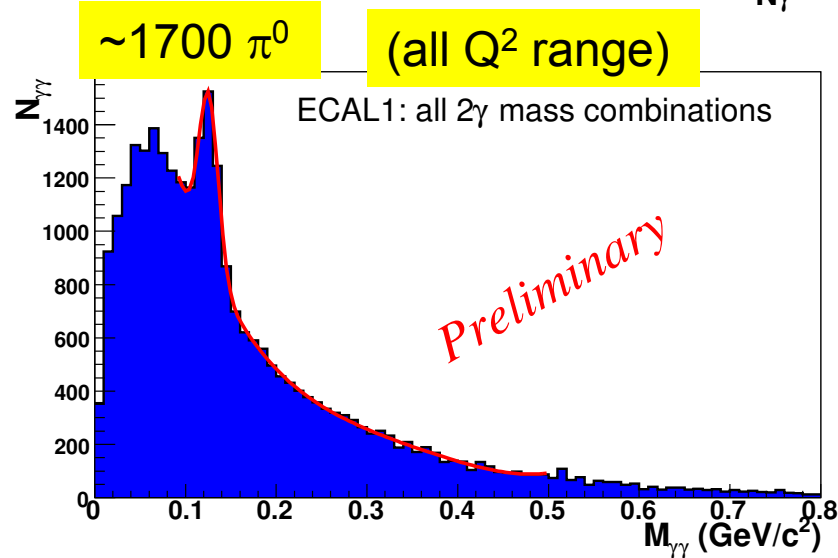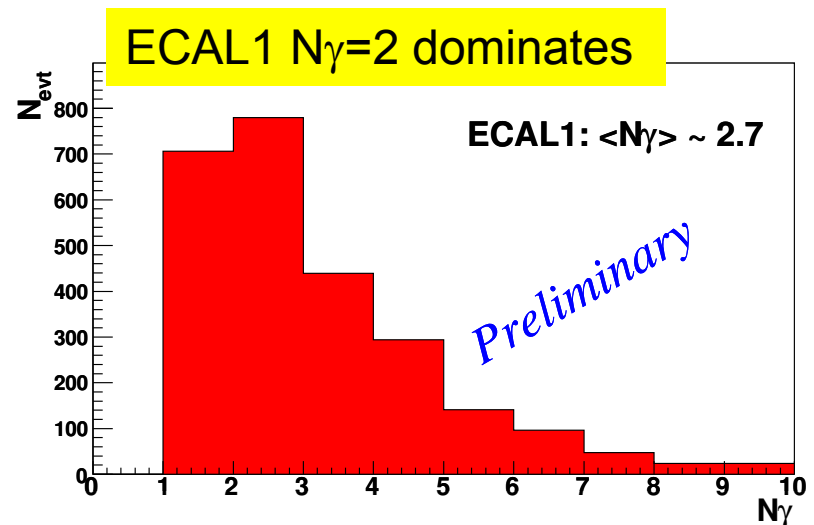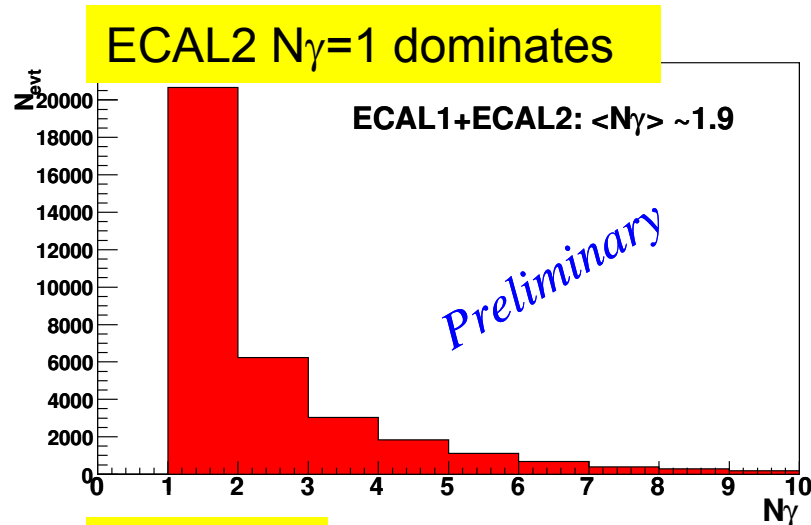
- only 1 RPD proton with E_p<1 GeV

2) keep photons detected in ECAL1;

3) full chain of ECALs calibrations is not yet done;

4) only "visible" ($2\gamma\gamma$) part of the exclusive π^0 was studied; the MC to extract "invisible" (1γ) part is in finalising stage;

A clear signal from exclusive π^0 is seen in x_{Bj}>0.03 region where the excess of DVCS candidates over BH ones was observed
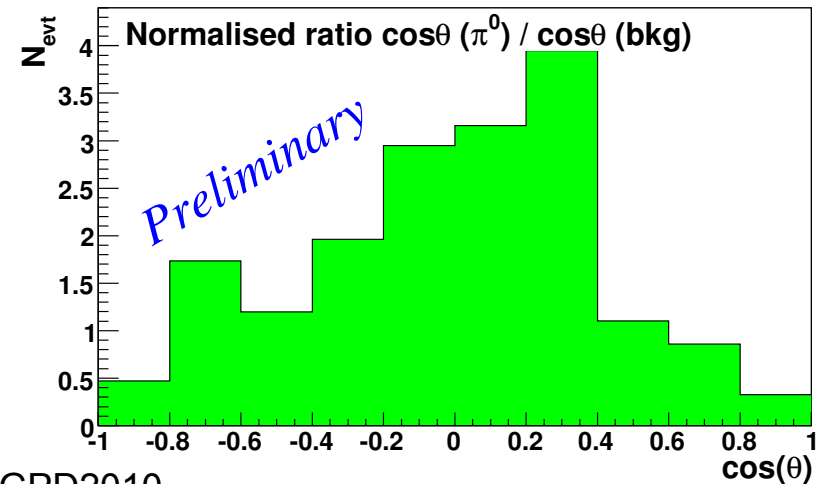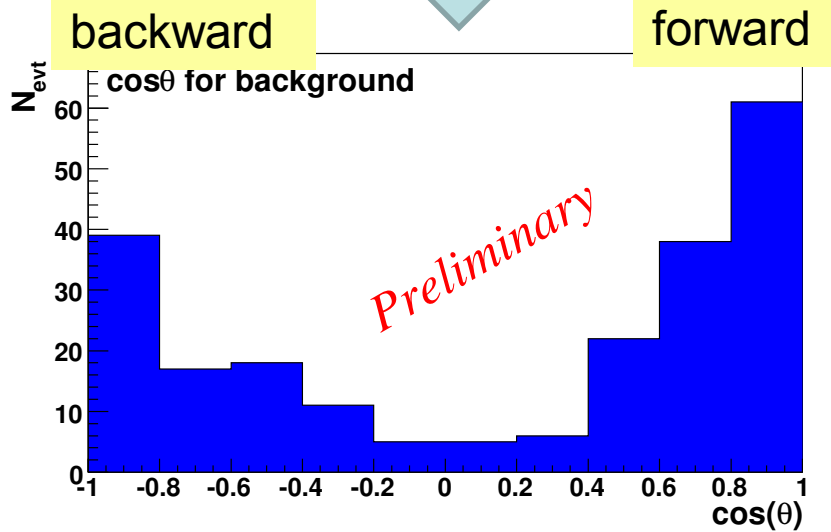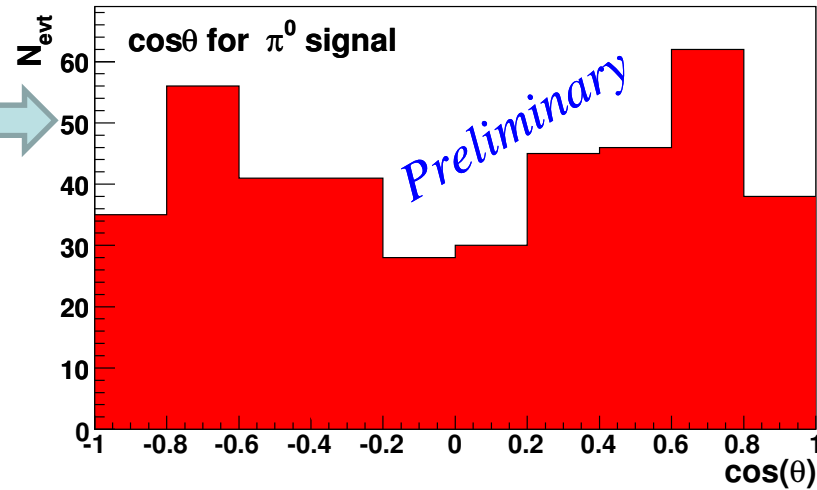
γ multiplicities and the π^0 signal ($\mu\, p \to \mu'\, p'\, \pi^0$ +X reaction)

ECAL2 Nγ=1 dominates

ECAL1+ECAL2: $\langle N\gamma \rangle$ ~1.9

Preliminary

ECAL1 Nγ=2 dominates

ECAL1: $\langle N\gamma \rangle$ ~ 2.7

Preliminary

~1700 π^0 (all Q^2 range)

ECAL1: all 2γ mass combinations

Preliminary

~ 420 π^0 (205 π^0 if $Q^2 > 1$ $(GeV/c)^2$)

ECAL1 : Nγ=2 events

mass shift   -7 MeV

mass resolution ~ 13 MeV

Preliminary

The angular distribution of the π^0 decay products

For true π^0 in c.m.s. this distribution is isotropic;

For fake π^0 it peaks in forward/backward direc-tions

backward · · · · · · · · · · · · · · · forward

cosθ for π^0 signal

Preliminary

cosθ for background

Preliminary

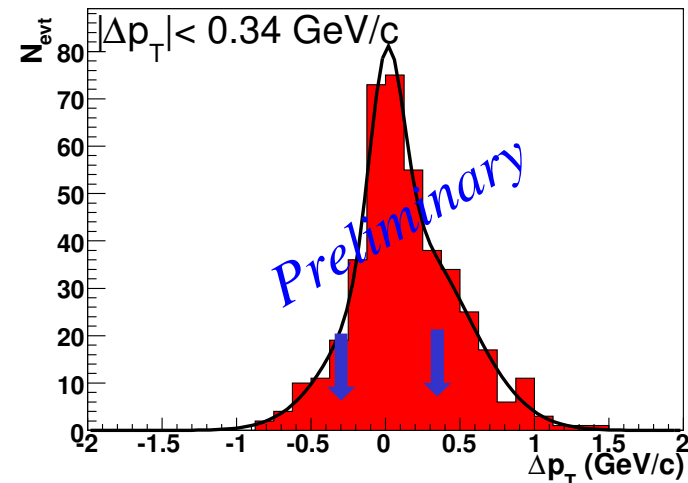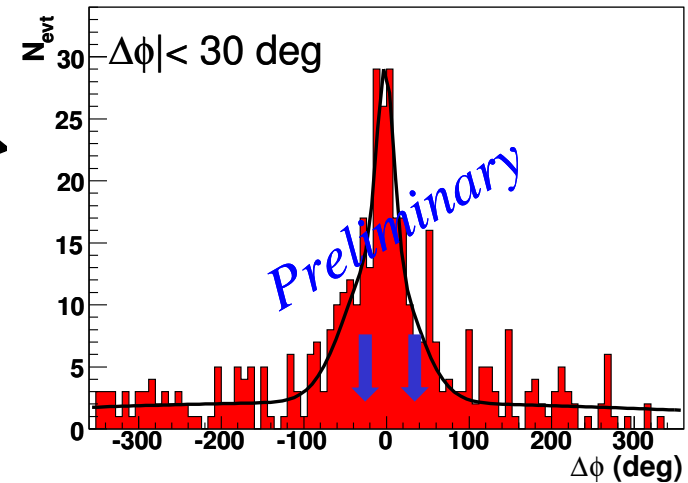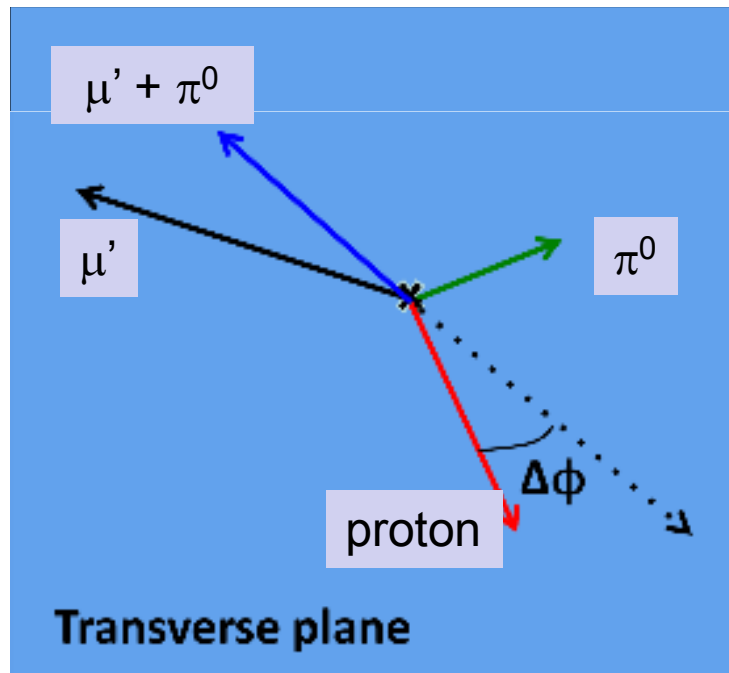Normalised ratio cosθ (π^0) / cosθ (bkg)

Preliminary

Towards the exclusive π^0 signal: $\mu\, p \rightarrow \mu'\, p'\, \pi^0$ (1)

First two exclusivity variables:

1) $$\Delta\phi = (\phi_{miss} - \phi_{rpd})$$

2) $$\Delta p_T = |p_{T\text{miss}}| - |p_{T\text{rpd}}|$$

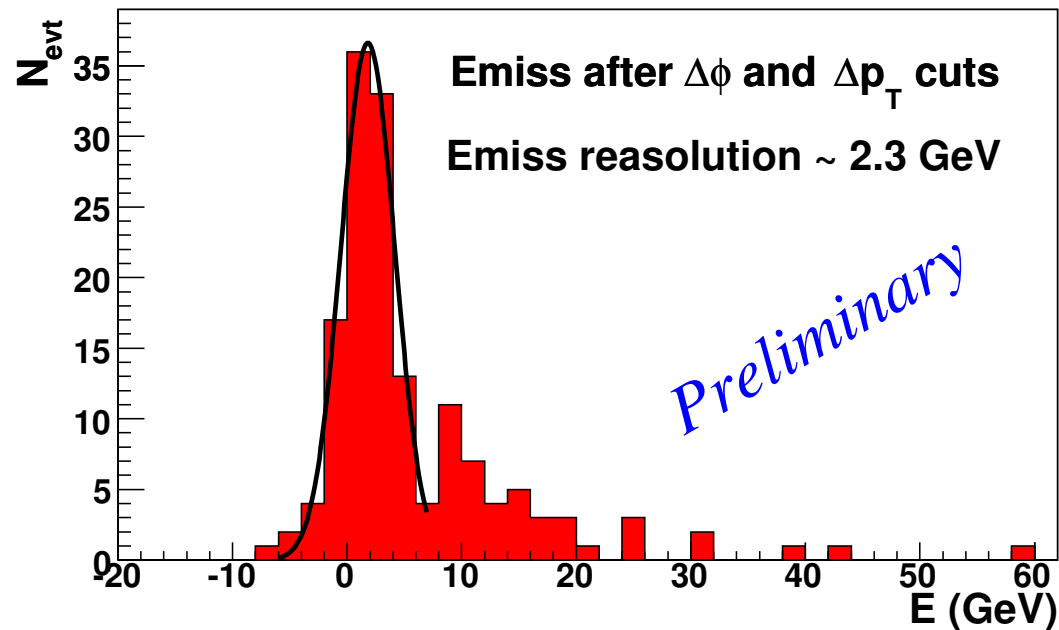# Towards the exclusive π^0 signal: $\mu\, p \rightarrow \mu'\, p'\, \pi^0$ (2)

Third exclusivity variable

3) $\quad$ Emiss = Eμ+Mp – (Eμ' + Ep +Eπ^0)

Exclusivity cuts
$\Delta\phi \qquad < \qquad 30$ deg
$\Delta p_T \qquad < \quad 0.34$ GeV
|Emiss-1.8|<7 GeV

Emiss after $\Delta\phi$ and Δp_T cuts

Emiss reasolution ~ 2.3 GeV

Preliminary

N$_{evt}$

E (GeV)

For exclusive π^0 sample keep the events with Q^2 > 1 (GeV/c)^2

Exclusive π^0 signal: $\mu\,p \rightarrow \mu'\,p'\,\pi^0$ ($Q^2 > 1$ (GeV/c)^2 range)

Trento GPD2010
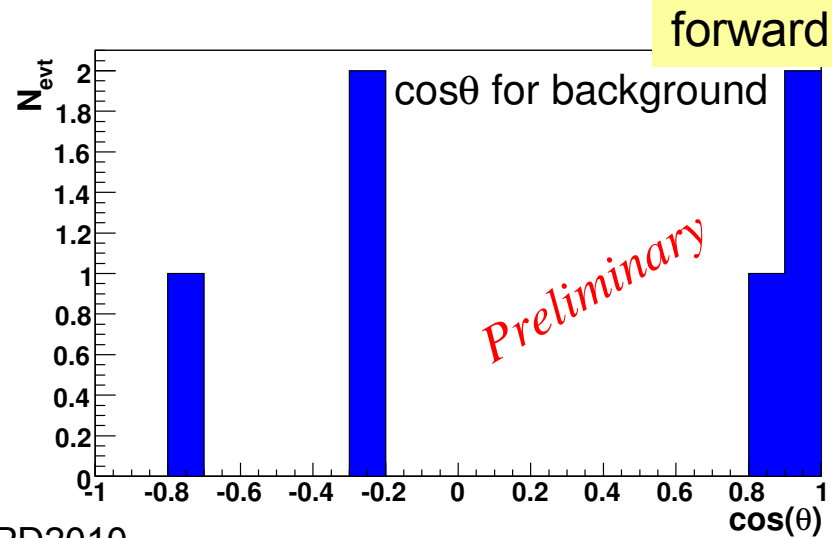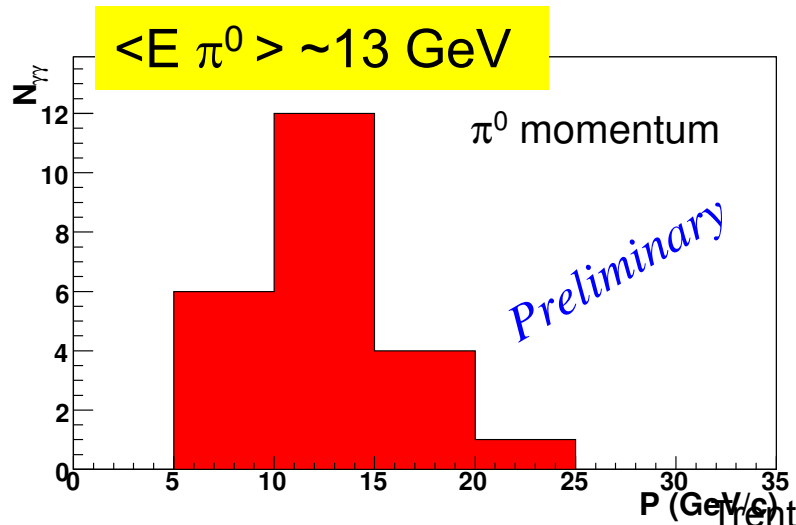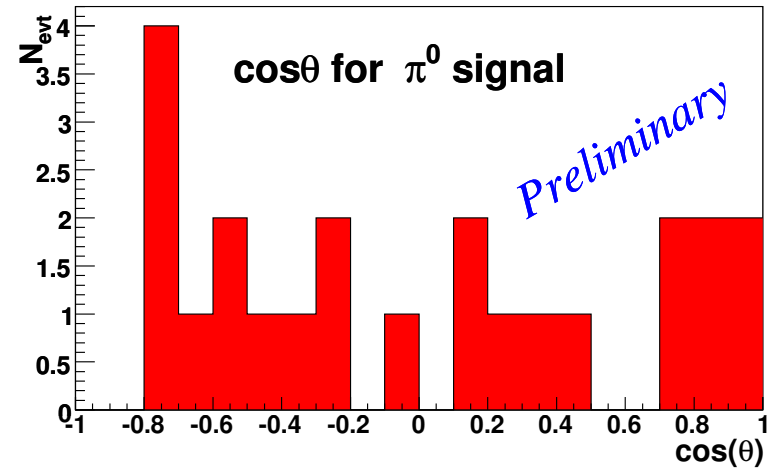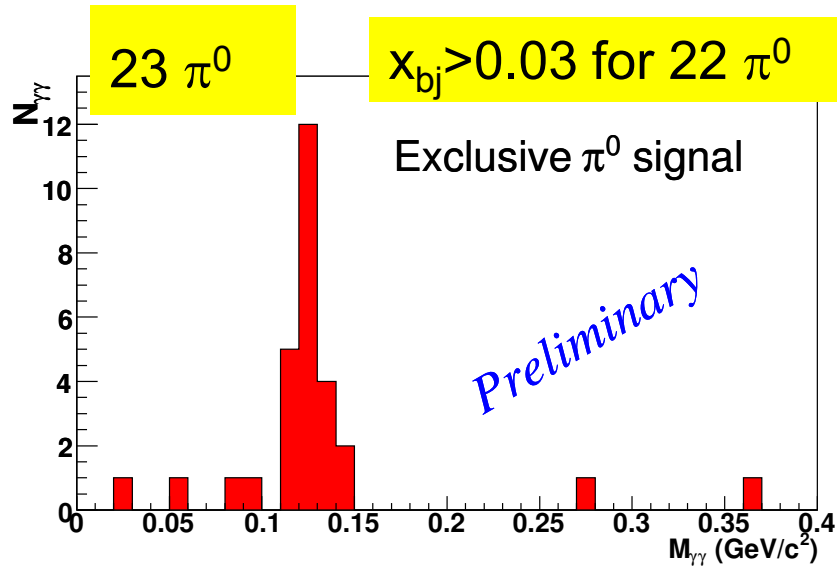
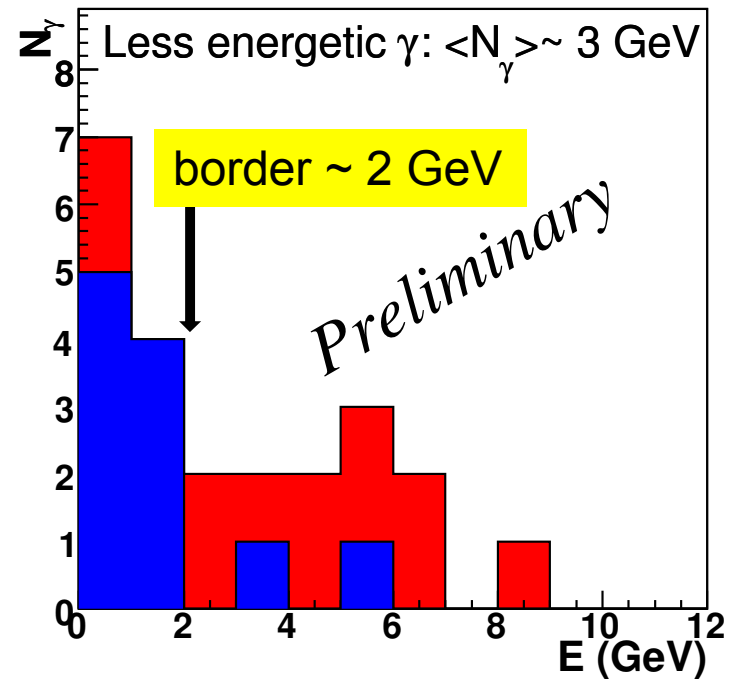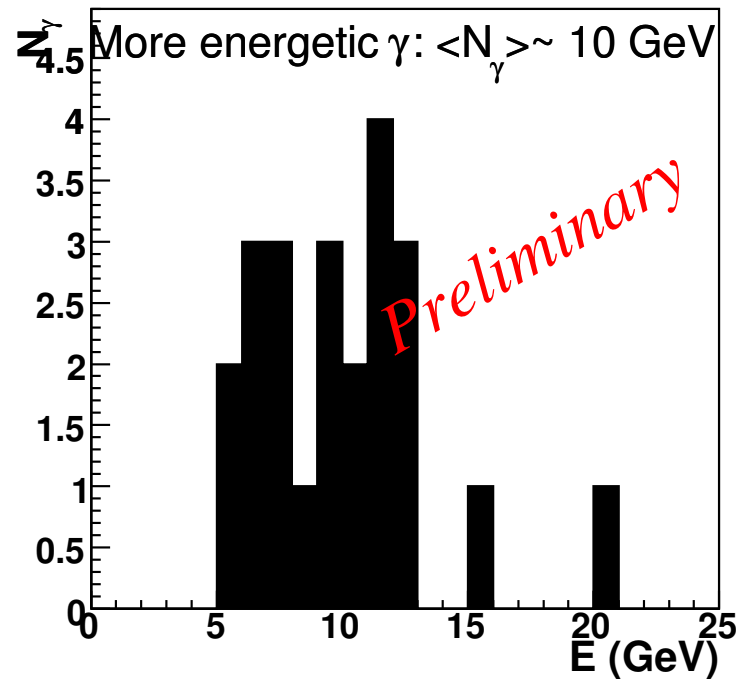## Analysis of the exclusive π^0's as single-photon candidates

Let's treat 23 π^0 events as single-photon candidates disregarding low energy γ ;

~50% can be DVCS/BH candidates

blue➔ accepted events (11) as DVCS/BH candidates
red ➔ rejected events (12)

More energetic γ: $<N_\gamma>\sim$ 10 GeV

Preliminary

Less energetic γ: $<N_\gamma>\sim$ 3 GeV

border ~ 2 GeV

Preliminary

π^0 background to DVCS (1)

A. The "visible" (2γ) part of the exclusive π^0 is estimated
… the exclusive π^0 signal is extremely sensitive to the ECALs calibration which is still not perfect (clearly seen shifts in the π^0 mass, Emiss …)

B. Evaluation of "invisible" (1γ) part needs MC
…. for the moment generated samples of the exclusive π^0 events cannot be analysed at the same way as Real Data applying $\Delta\phi$ and Δp_T exclusivity cuts..
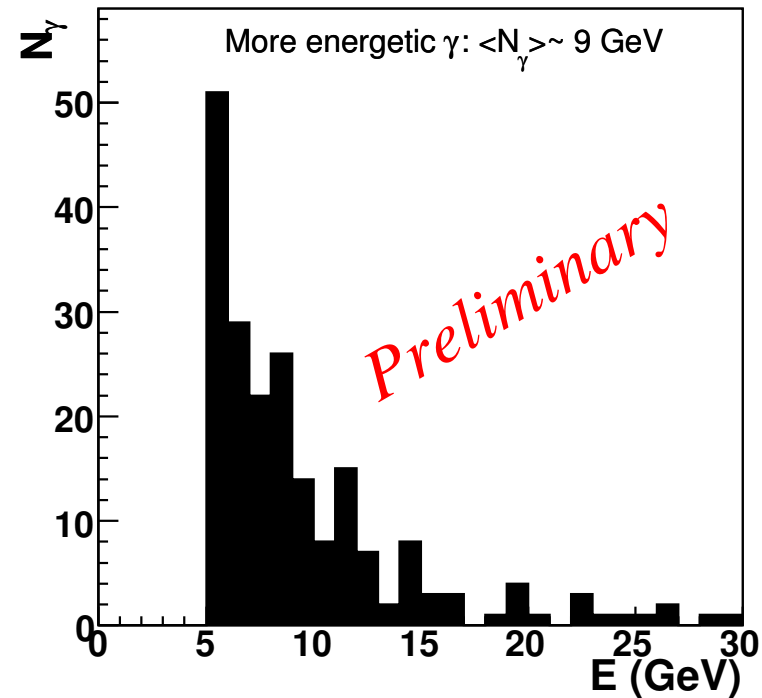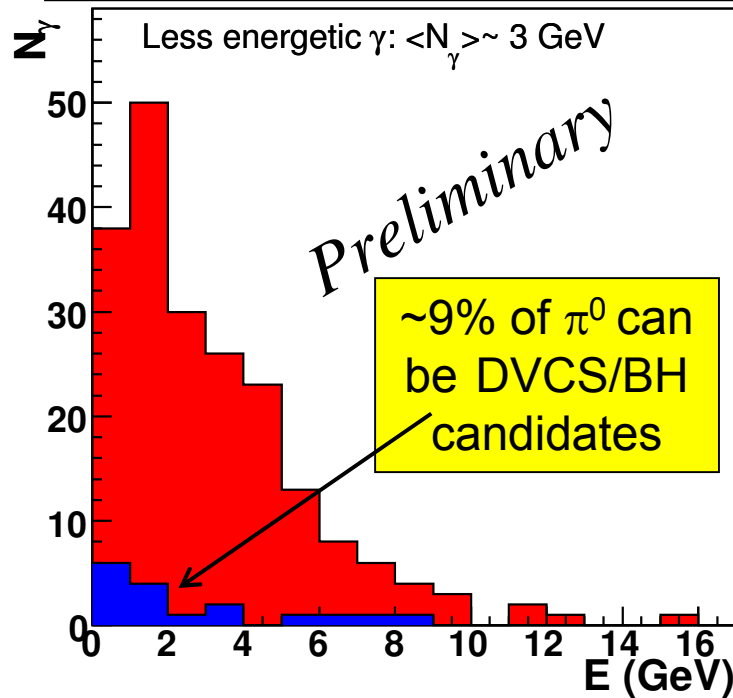
C. The upper limit of π^0 background to DVCS was extracted analysing the $\pi^{0,}$s in $\mu\, p \rightarrow \mu'\, p'\, \pi^0$ +X reaction as single-photon candidates

π^0 background to DVCS (2)

π^0 sample in $Q^2 > 1$ (GeV/c)^2 range ➔ 205 π^0

blue ➔ accepted events (17) as DVCS/BH candidate
red ➔ rejected events (188)
N.B. 17 events contain all 11 events from exclusive sample.

π^0 MC: yields of $1\gamma/2\gamma$ events is about 0.8. An upper limit of the π^0 background to DVCS can be estimated as 17x0.8 = 14 evts (or ~30%)

Less energetic γ: $<N_\gamma> \sim 3$ GeV

Preliminary

~9% of π^0 can be DVCS/BH candidates

More energetic γ: $<N_\gamma> \sim 9$ GeV

Preliminary

Summary

- First analysis of π^0 production using the same preselected sample as for DVCS study has been performed

- Exclusive π^0 signal is observed - size of the signal is "surprising"

- a very rough estimation of background from π^0 to DVCS is shown

- a new analysis with improved EC calibration (including stability control and calibration using real physics process) is in preparation.

BACKUP SLIDES

Δφ and Δp$_T$ exclusivity for the events M$_{\gamma\gamma}$∈(0.1-0.15) GeV/c^2, after |Emiss|<9 GeV and Q^2>1 (GeV/c)^2 cuts