Monte Carlo study of the DVCS process on nuclear target

Student report from the HERMES experiment
DESY Summer School 2005

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Outline

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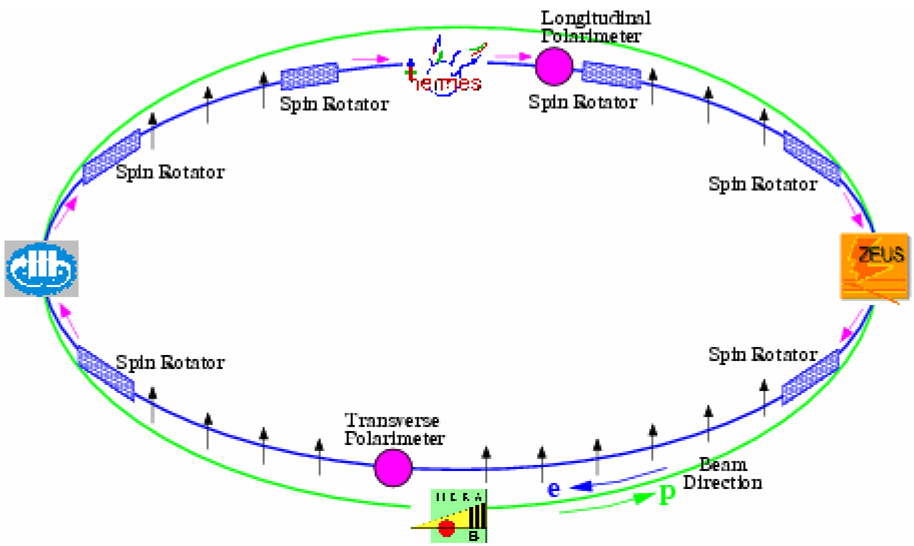
- Kinematics
- Scattering processes
- Results
- Summary
- Other HERMES projects

HERMES

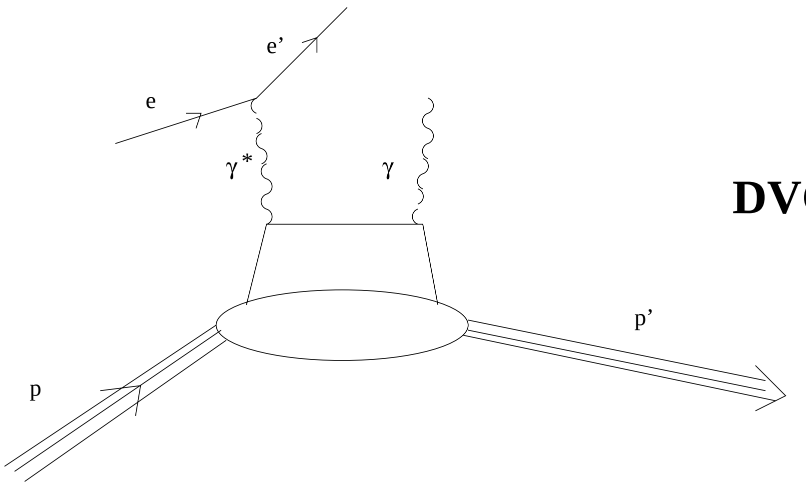
HERMES (HERa MEasurement of Spin) is one of three currently running experiments at the HERA accelerator.

Contrary to H1 and ZEUS it is a fixed target experiment. The 27.6 GeV lepton beam collides with a nuclear target H, Ne, Kr,…

At HERMES, not only the beam, but also the target is polarized.
→ We can study spin physics and may contribute to solve the puzzling spin structure of the nucleon.



DVCS – Introduction

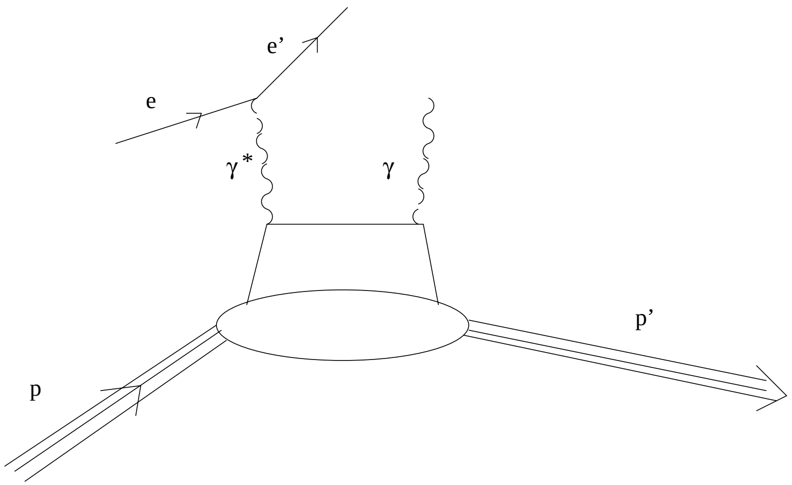


DVCS = **D**eeply **V**irtual **C**ompton **S**cattering

DVCS is the cleanest way to access General Parton Distributions (GPDs).

The motivation for studies of DVCS on heavy nucleous is that it can provide better understanding of the nuclear force and of the distribution of energy, pressure and shear force.

Kinematics



$$Q^2 \equiv -q^2 = (k - k')^2 \approx \{\text{lab}\} \approx 4EE'\sin^2\left(\frac{\theta}{2}\right)$$

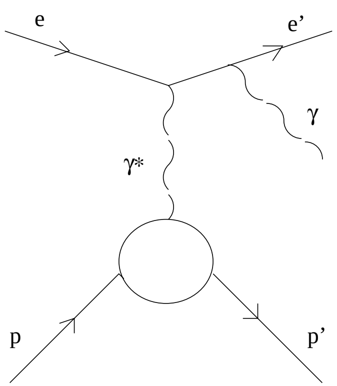
$$x_{Bj} \equiv \frac{Q^2}{2pq} = \frac{Q^2}{2M_p\upsilon}$$

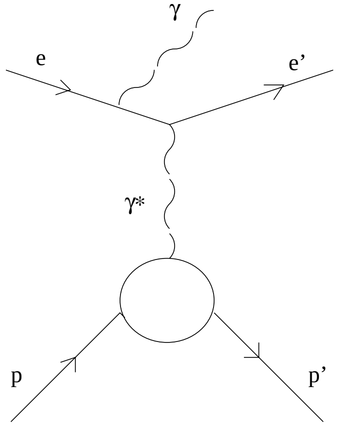
$$\upsilon \equiv \frac{pq}{M_p} = \{\text{lab}\} = E - E'$$

$$W^2 = (p+q)^2 = M_p^2 + 2M_p\upsilon - Q^2$$

$$t = (p - p')^2 = (q - q')^2$$

Final states identical with the Bethe-Heitler process.



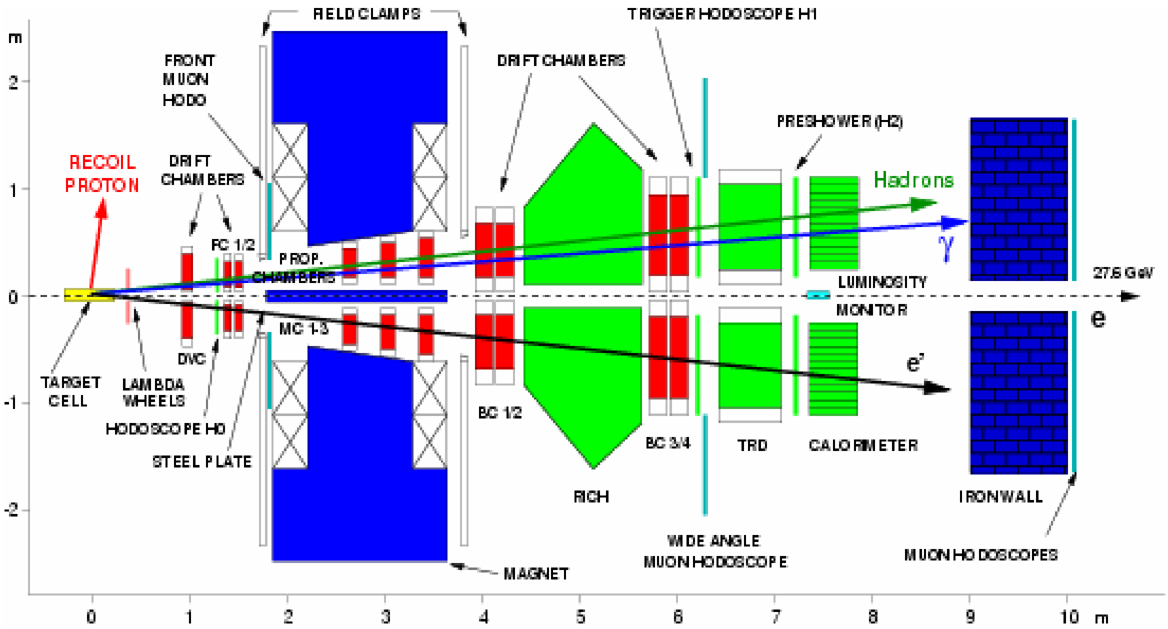


$$|\tau(ep \rightarrow e'p\gamma)|^2 = |\tau_{BH} + \tau_{DVCS}|^2 =$$

$$|\tau_{BH}|^2 + |\tau_{DVCS}|^2 + \tau_{DVCS}\,\tau_{BH}^* + \tau_{DVCS}^*\,\tau_{BH}$$

Interference!

DVCS at HERMES



calorimeter → γ

tracking chambers → e

PID: TRD, preshower,

calorimeter → e/hadron

HERMES: $\sigma_{BH} >> \sigma_{DVCS}$

→ τ_{DVCS} accessed through asymmetries

$$A_{LU} = \frac{d\vec{\sigma} - d\overleftarrow{\sigma}}{d\vec{\sigma} + d\overleftarrow{\sigma}} \qquad A_C = \frac{d\sigma^+ - d\sigma^-}{d\sigma^+ + d\sigma^-}$$

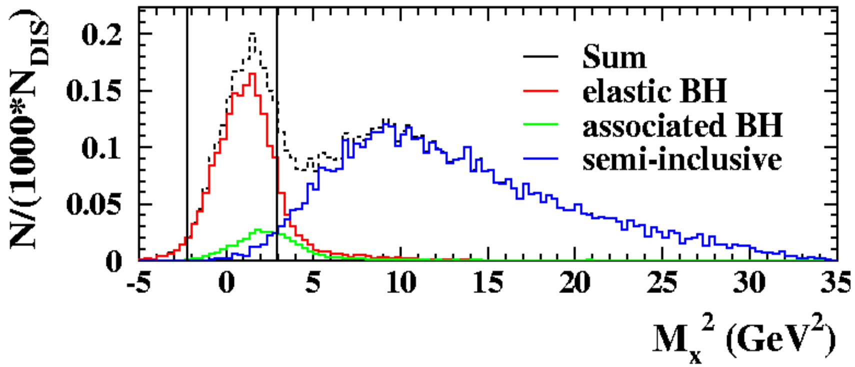
Scattering processes

Three different processes contribute to the total cross section:

- Elastic (DVCS and BH) $e + p \rightarrow e' + p + \gamma$
- Associated process $e + p \rightarrow e' + \Delta + \gamma$
- Semi-inclusive background $e + p \rightarrow e' + \pi^0 + X$

At HERMES only the photon and the electron are detected. The exclusivity is insured through the method of missing mass.

$$M_x^2 = (p + q - q')^2$$

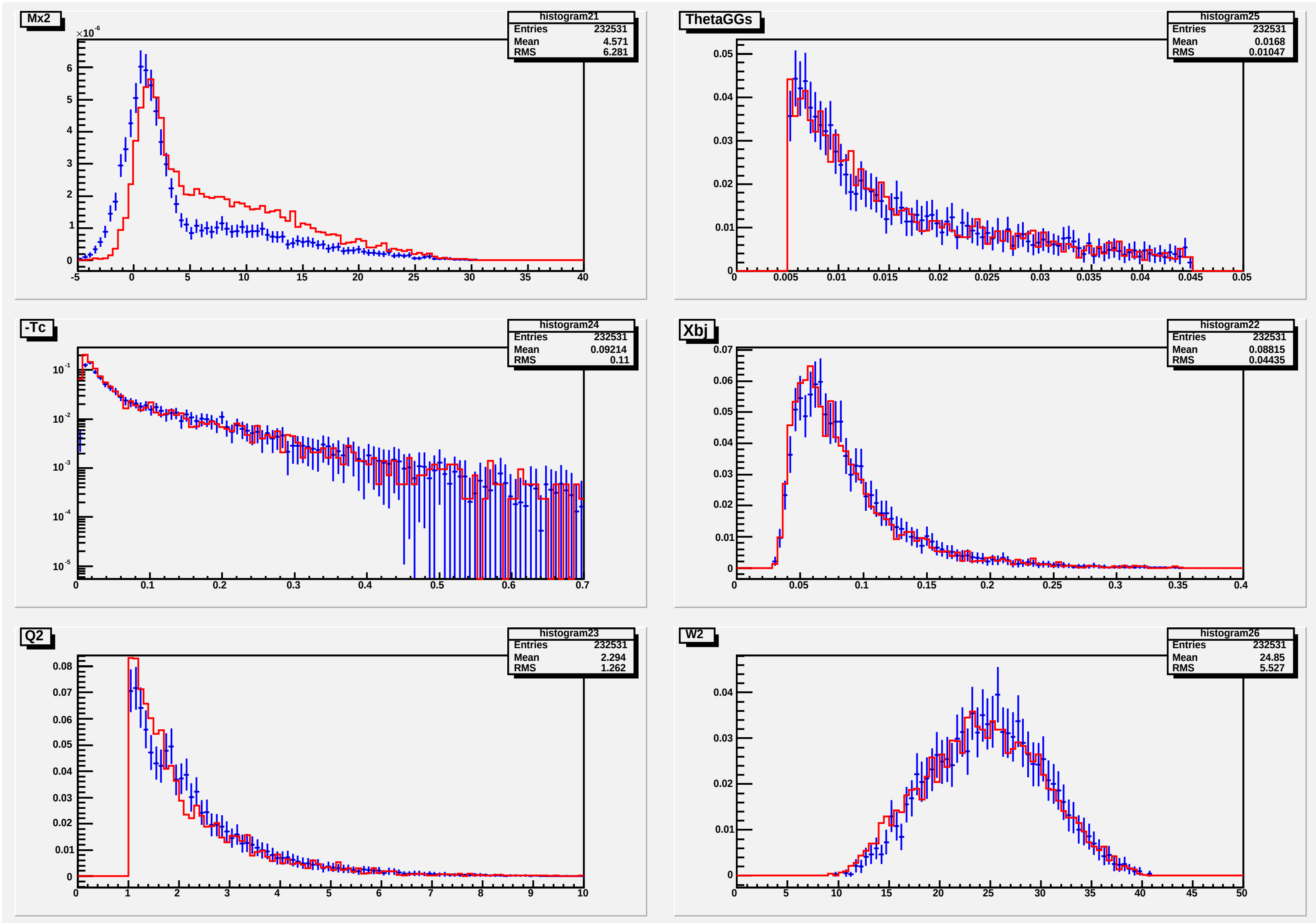


For nuclear target we also separate the coherent from the incoherent contribution.

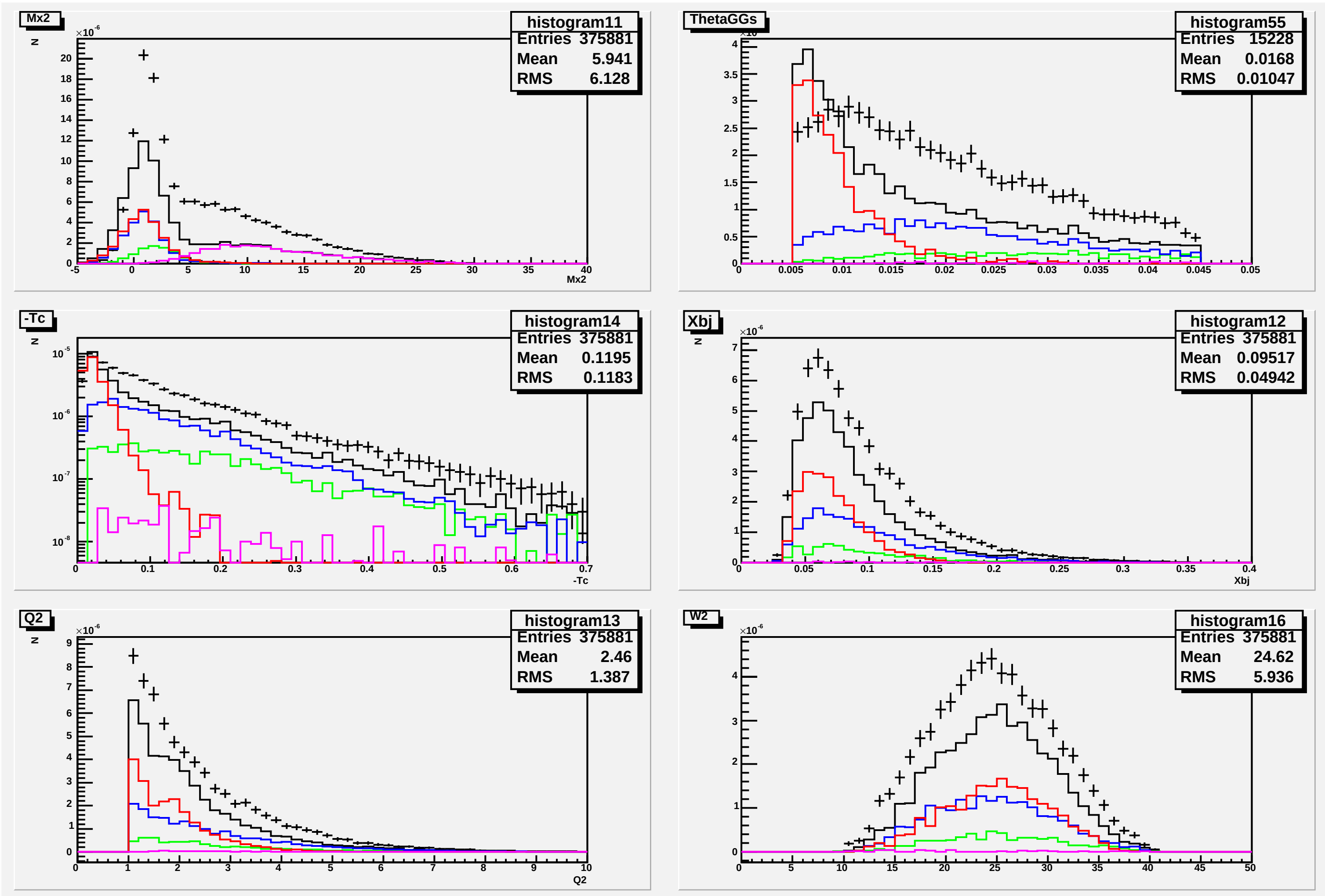
coherent → The whole nuclei acts as a scatterer.

incoherent → Scattering on separate nucleons.

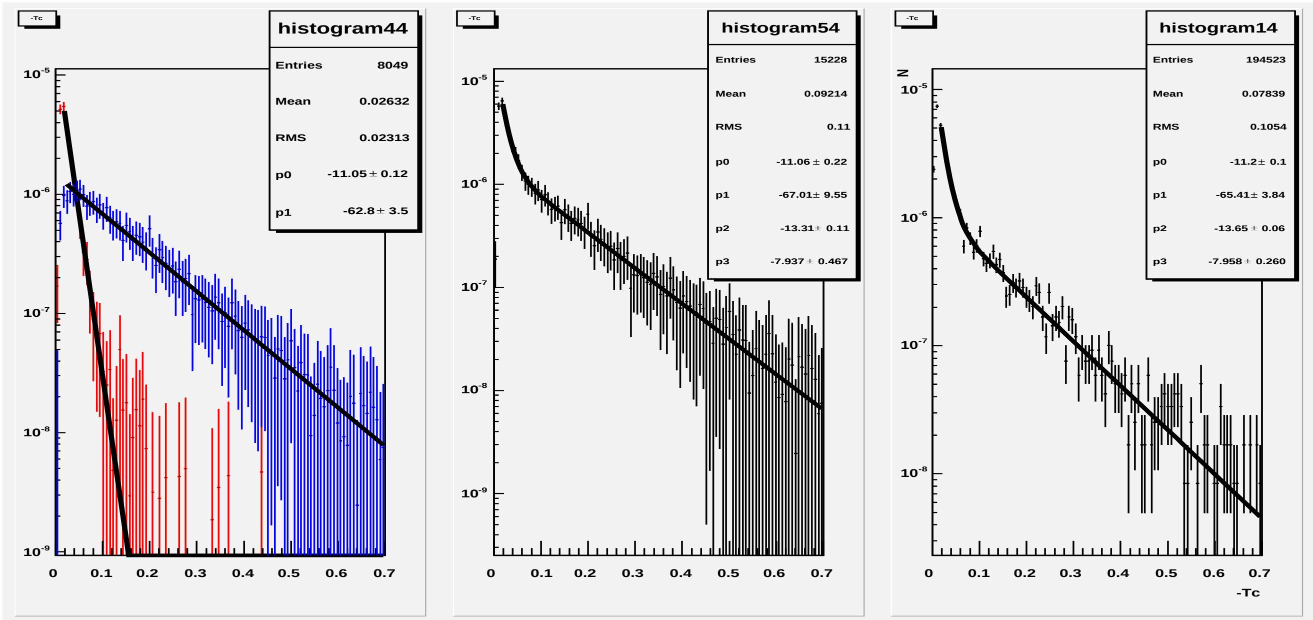
Result (1): MC and data comparsion



Result (2): H and Ne comparsion



Result (3): Coherent region



fitting performed with $f(x) = \exp(p_0+p_1x)+\exp(p_2+p_3x)$

	MC Coherent	MC Background	MC Total	Data
P_0	-11.05 ±0.12	-	-11.06 ± 0.22	-11.2 ± 0.1
p_1	-62.8 ± 3.5	-	-67.01 ± 9.55	-65.41 ± 3.84
p_2	-	-13.45 ± 0.07	-13.31 ± 0.11	-13.65 ± 0.06
p_3	-	-7.48 ± 0.33	-7.937 ± 0.47	-7.958 ± 0.26
$-t_c$	0.043 ± 0.004		0.038 ± 0.007	0.043 ± 0.004

Summary

- DVCS processes on different targets were analyzed.
- Comparsion of kinematics between
  - hydrogen and neon MC data
  - neon MC and neon real data
- By applying different cuts, the coherent contribution for neon was separated from the background.
- The critical $-t_c$ value for neon was determined
  Monte Carlo $\rightarrow$ 0.043 ± 0.004 GeV^2
  Data $\rightarrow$ 0.043 ± 0.004 GeV^2
- The contribution of the coherent process was calculated. $\rightarrow$ 72.4 %

Particle Reconstruction

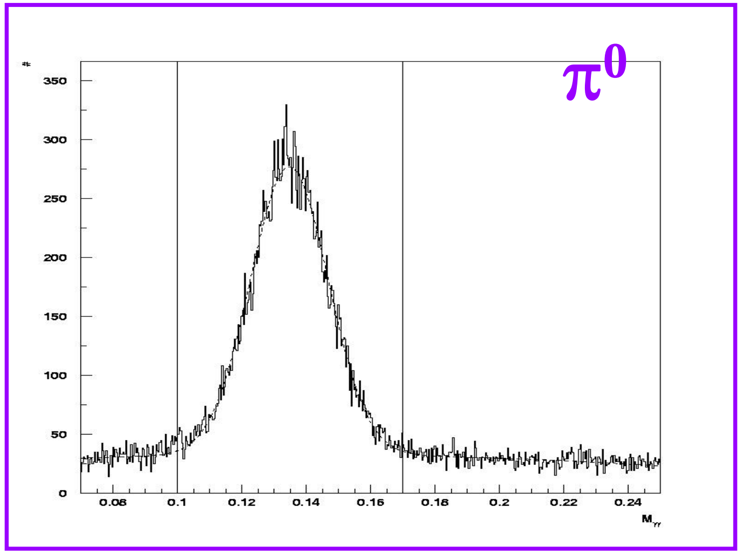
- Particle **X** is produced and decays instantaneously:

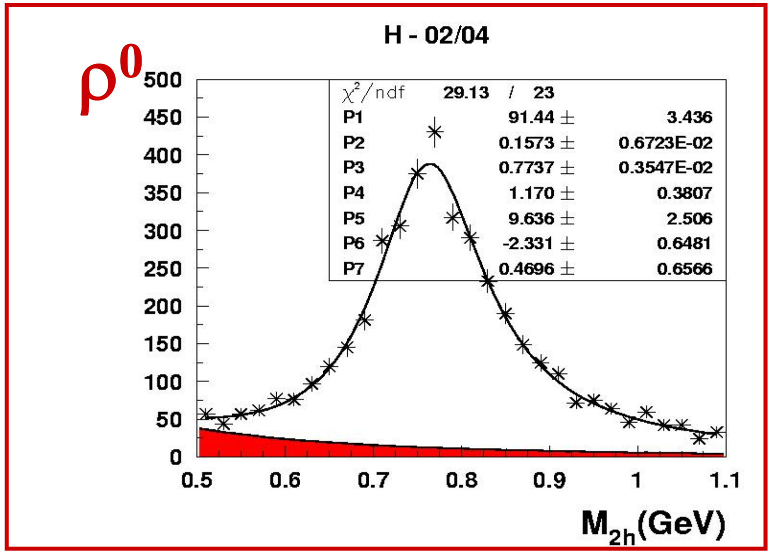
$$\mathbf{X} \rightarrow \mathbf{Y} + \mathbf{Z}$$

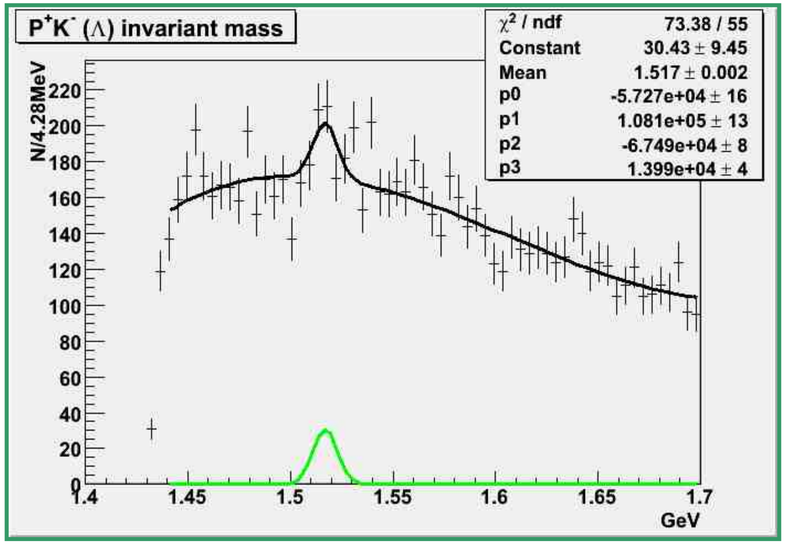
- **Y** and **Z** can be observed in the detector.
- We measure their energies and opening angle θ.
- We reconstruct **X** by building up its invariant mass:

$$M_X^2 = (P_Y + P_Z)^2 = 2\, E_Y E_Z (1 - \cos(\theta))$$

… after six weeks of event selection and cuts







$\Lambda(1520)$

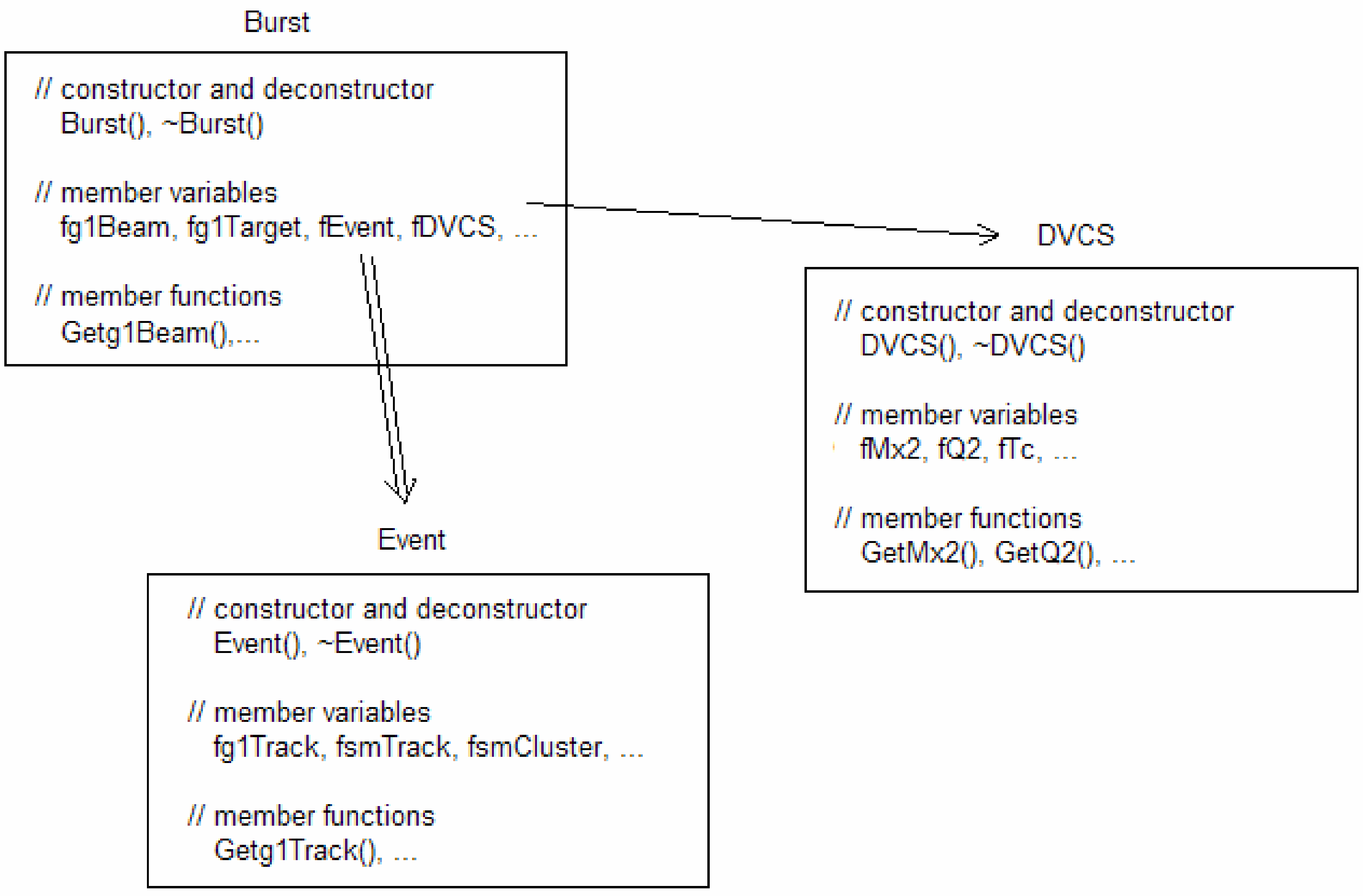
At last…

On behalf of all the HERMES summer students I would like to thank for a great time here at DESY.

Backup slides…

Data analysis (1)

ROOT was used to perform the analysis.



Data analysis (2)

Histograms were...

…created

```
TH1F *histMx2=new TH1F("histMx2", "Histogram for Mx2", 100, -5, 40);
```

…filled

```
histMx2->Fill(dvcs->GetMx2(), x2->GetWeight()*
(dvcs->GetThetaGGs()>0.005 && … && dvcs->GetQ2()<10));
```

…and finally plotted

```
histMx2->Sumw2();
histMx2->Scale(1/normalization);
histMx2->Draw();
```