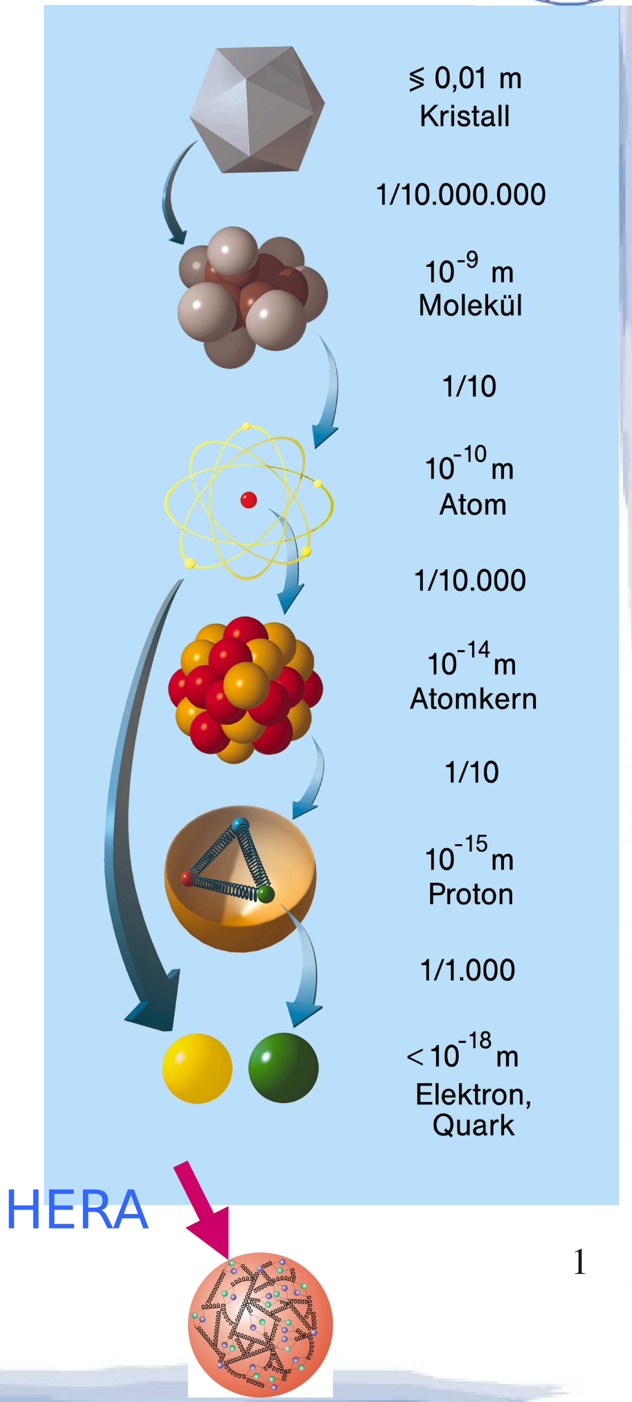
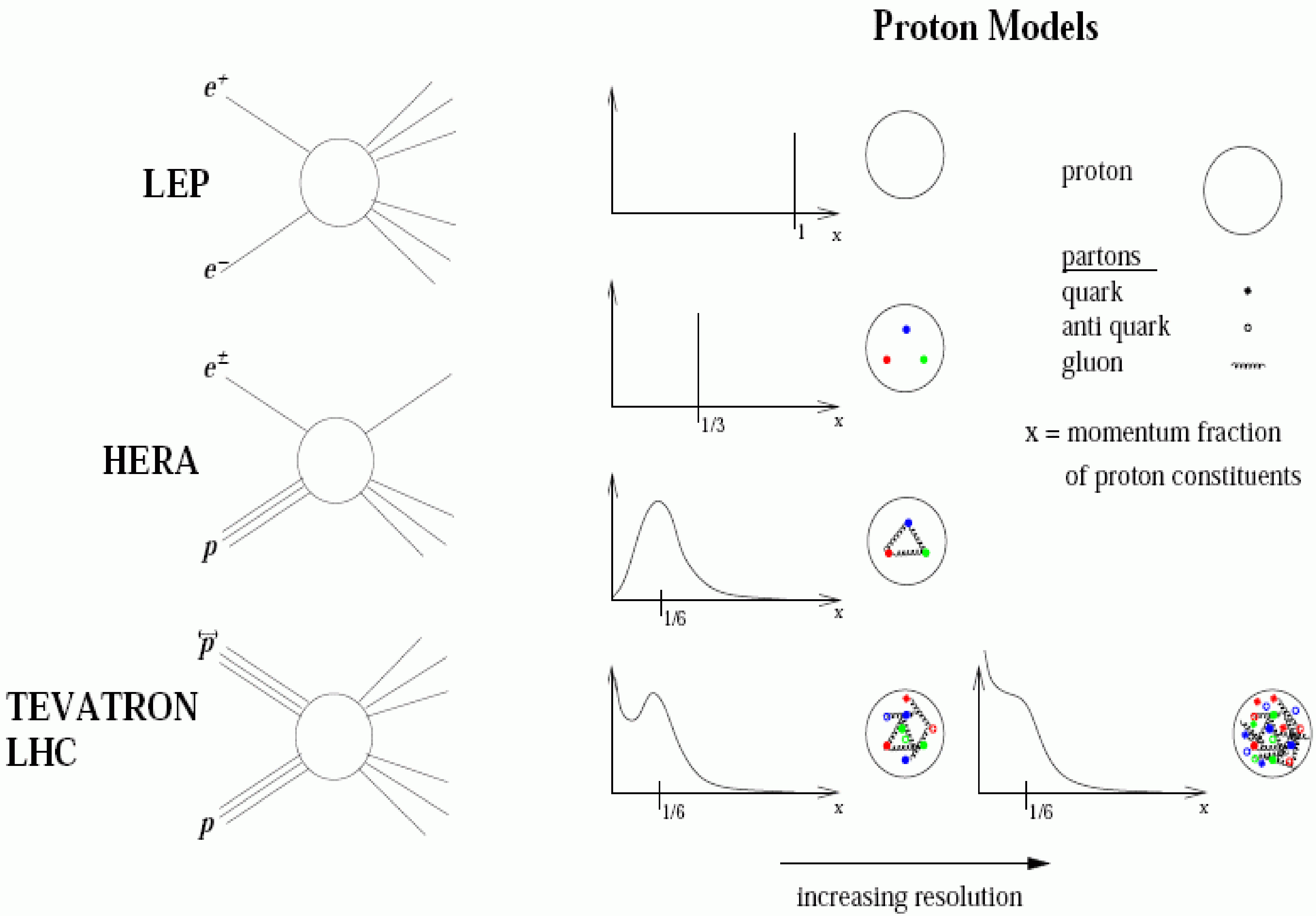
Study of NC cross sections using Zeus detector at HERA

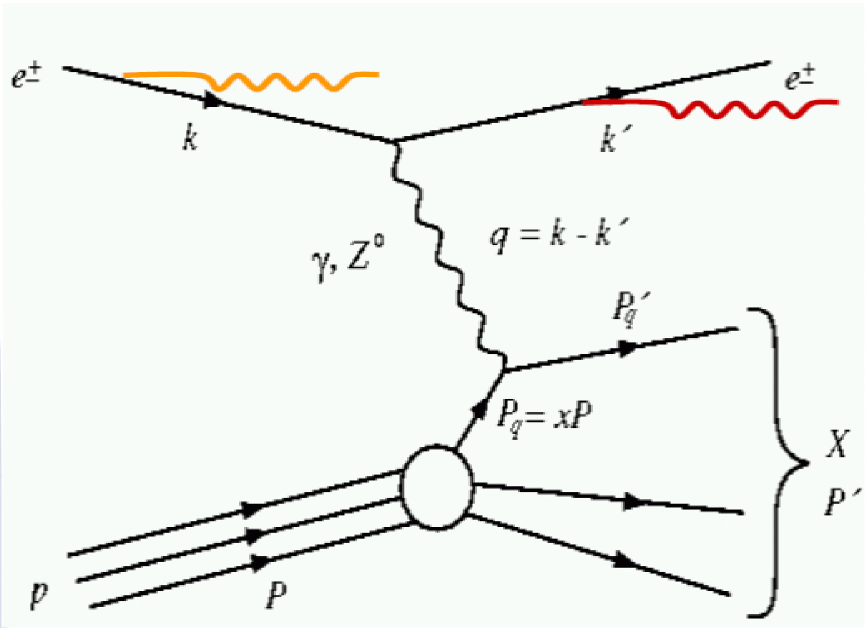
Ritu Aggarwal
Punjab Uni. India / MPI, Munich



Motivation : What's inside proton?



Deep Inelastic Scattering

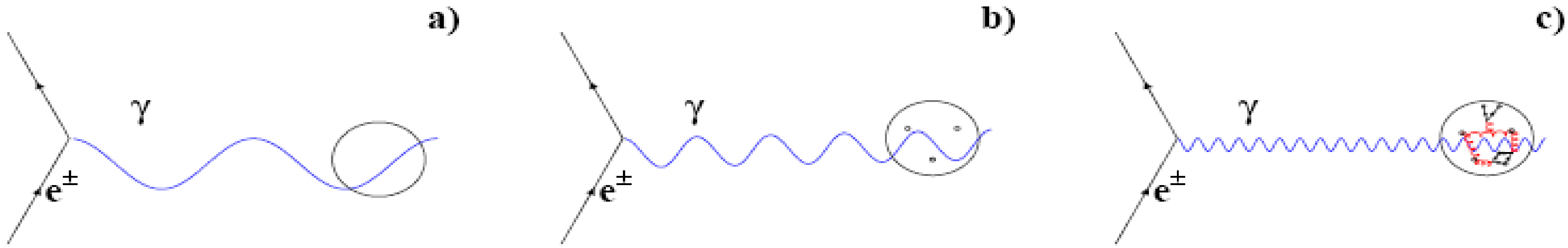


DIS cross-section can be described by :-

Q²: Four momentum transfer
(probing power)
x : Bjorken Scaling variable
(momentum fraction of struck quark)
y : inelasticity

√s = center of mass energy

$$\Delta p \cdot \Delta x \approx \hbar \Leftrightarrow \sqrt{Q^2} \approx \frac{\hbar}{\lambda}$$



DIS Cross-sections and Structure functions

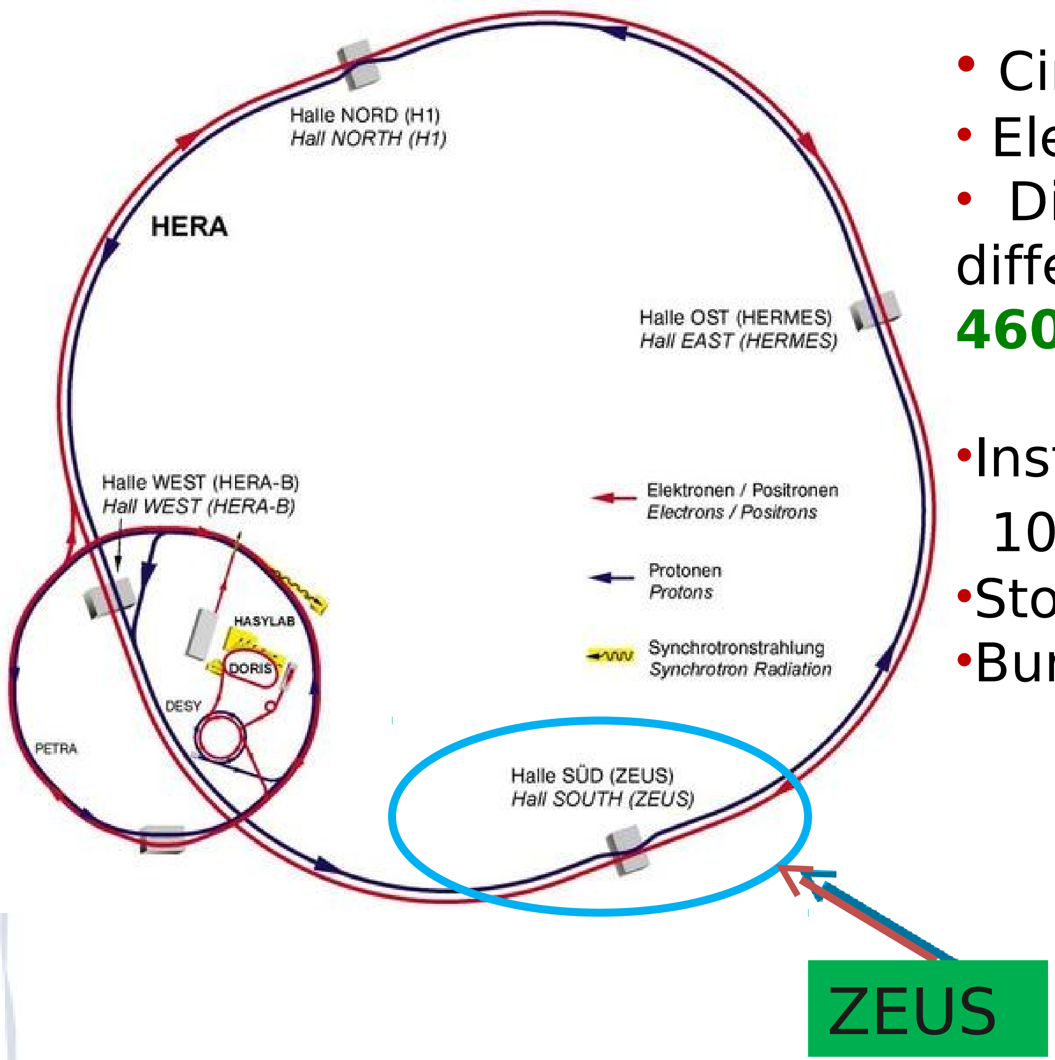
$$\frac{d^2\sigma(e^{\pm}p)}{dx\,dQ^2} = \frac{2\pi\alpha^2}{xQ^4}\left[Y_+ F_2(x,Q^2) \mp Y_- xF_3(x,Q^2) - y^2 F_L(x,Q^2)\right]$$

$$2xF_1^{NC}(x,Q^2) - F_2^{NC}(x,Q^2) = F_L^{NC}(x,Q^2)$$

Where $Y_{\pm} = 1 \pm (1-y)^2$

- $2xF_1^{NC}(x,Q)^2$ proportional to the transverse component of cross-section in which transverse boson is exchanged.
- $F_2^{NC}(x,Q^2)$ includes cross-section of both longitudinal and transversely polarized boson.
- $xF_3^{NC}(x,Q^2)$ contains parity violating part of cross-section which is negligible at low Q^2.

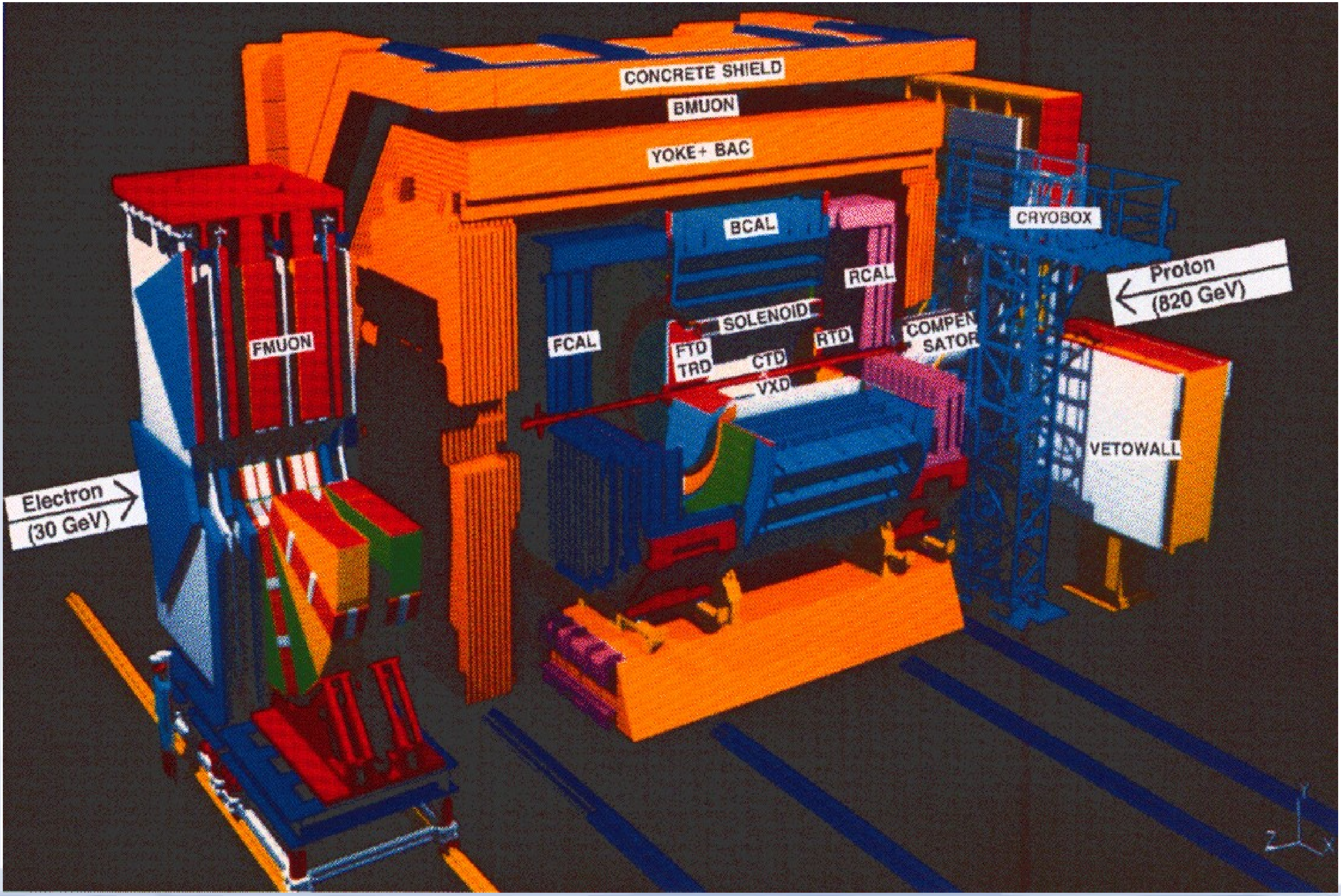
HERA (Hadron Electron Ring Accelerator)



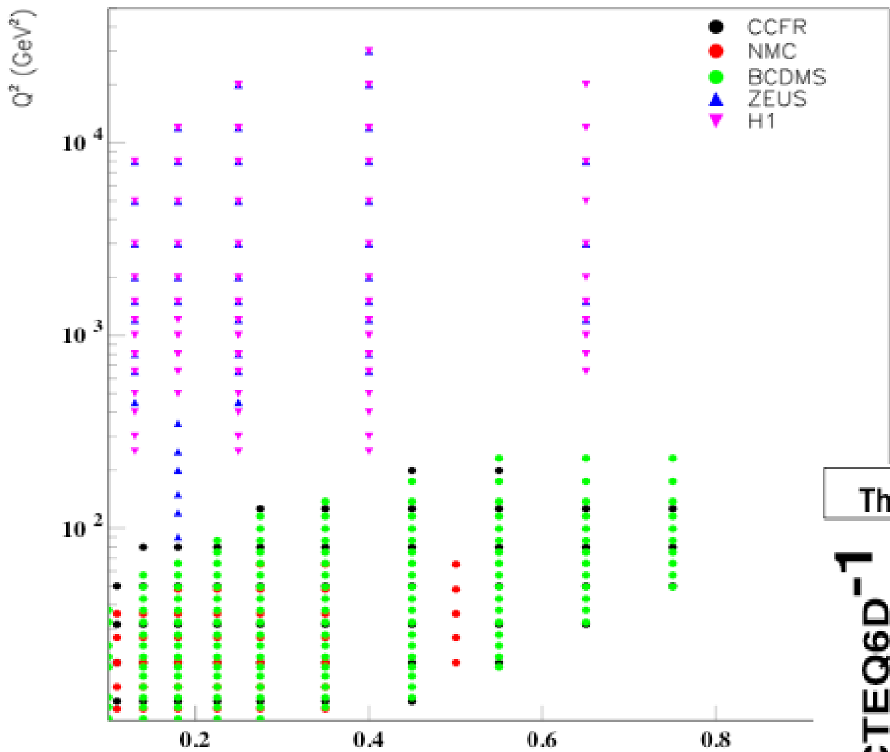
- Circumference 6.3 Km
- Electron Beam Energy **27.5 GeV**
- Different Proton Beam Energy for different time periods of running (**920, 460, 575) GeV** as (HER, LER, MER)

- Instantaneous luminosity 10^{32} $cm^{-2}sec^{-1}$
- Storage capacity of **210 bunches**
- Bunch spacing of **96 ns**

ZEUS Detector



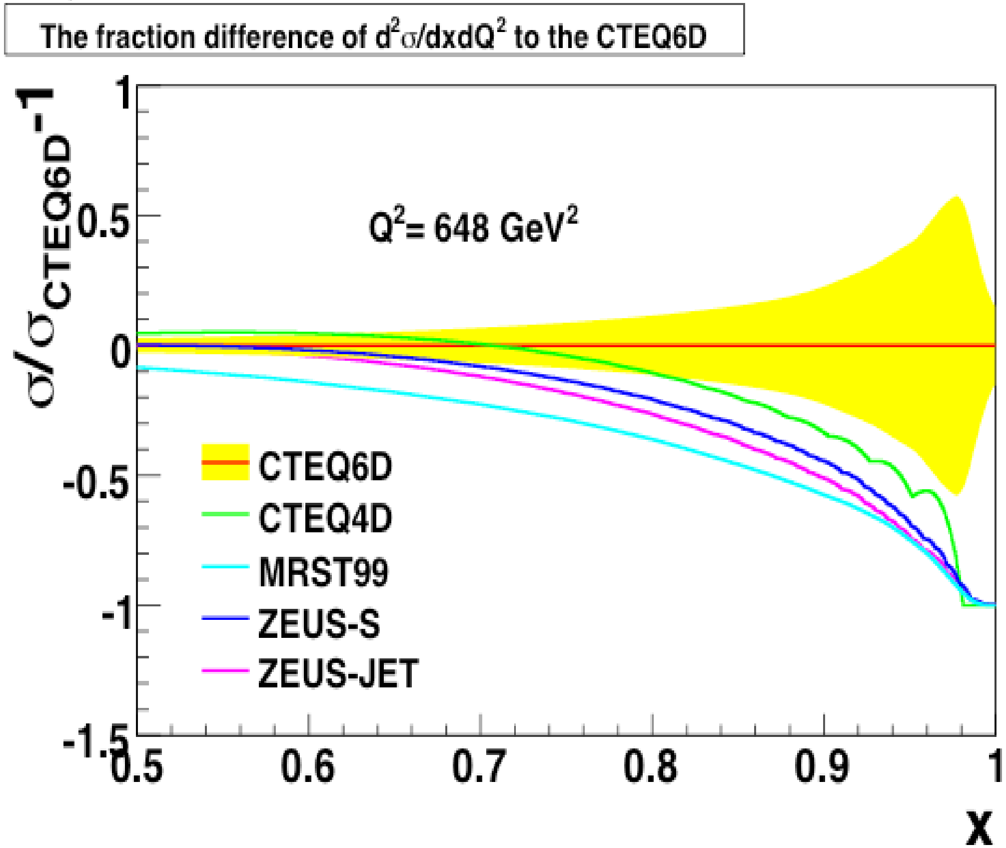
Motivation for high-x cross sections



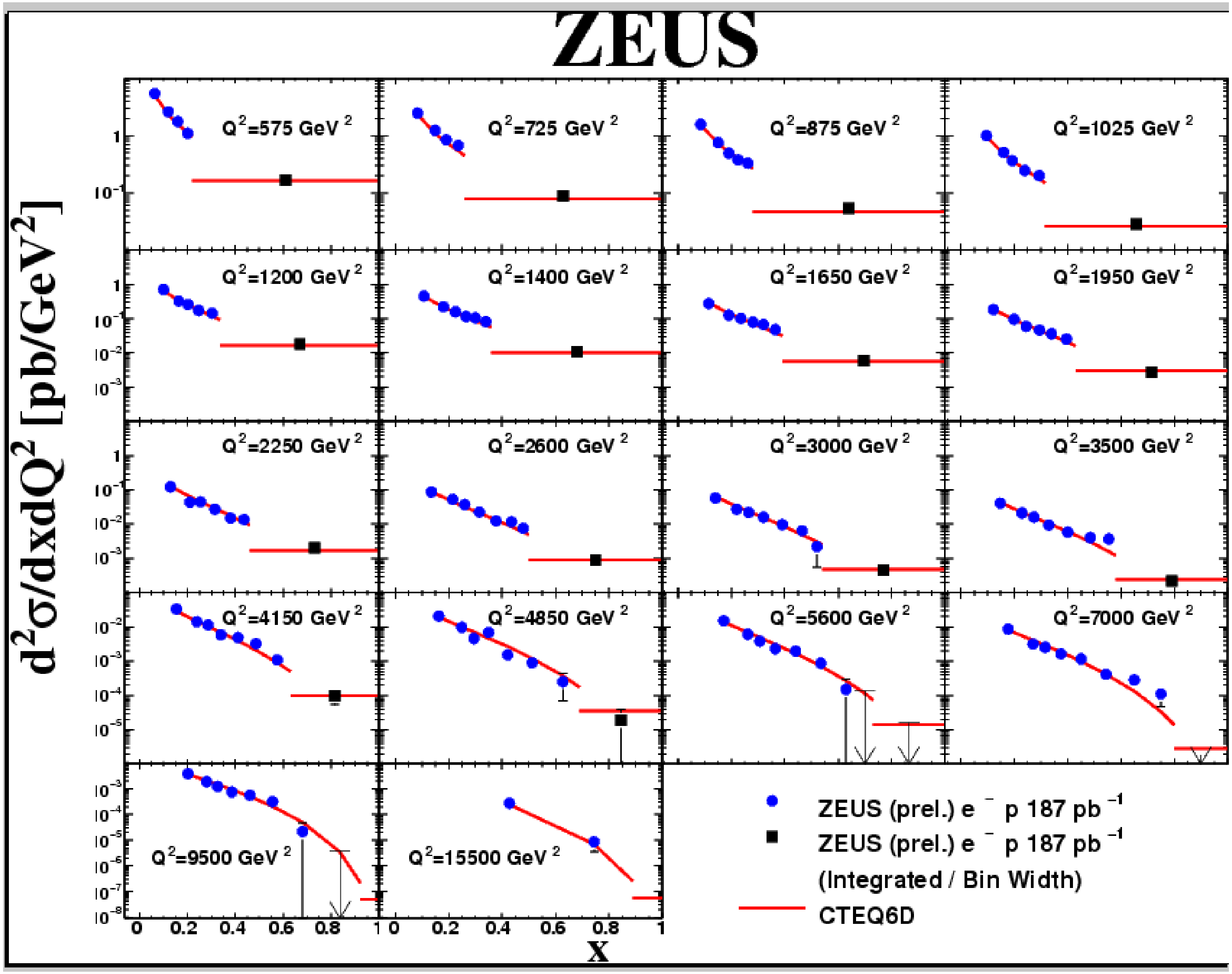
- The PDF's are poorly determined at high-x.
- parametrization $xq \propto (1-x)^{\eta}$.

BCDMS has measured F_2 up to x=0.75

H1, ZEUS have measured F_2 up to x=0.65

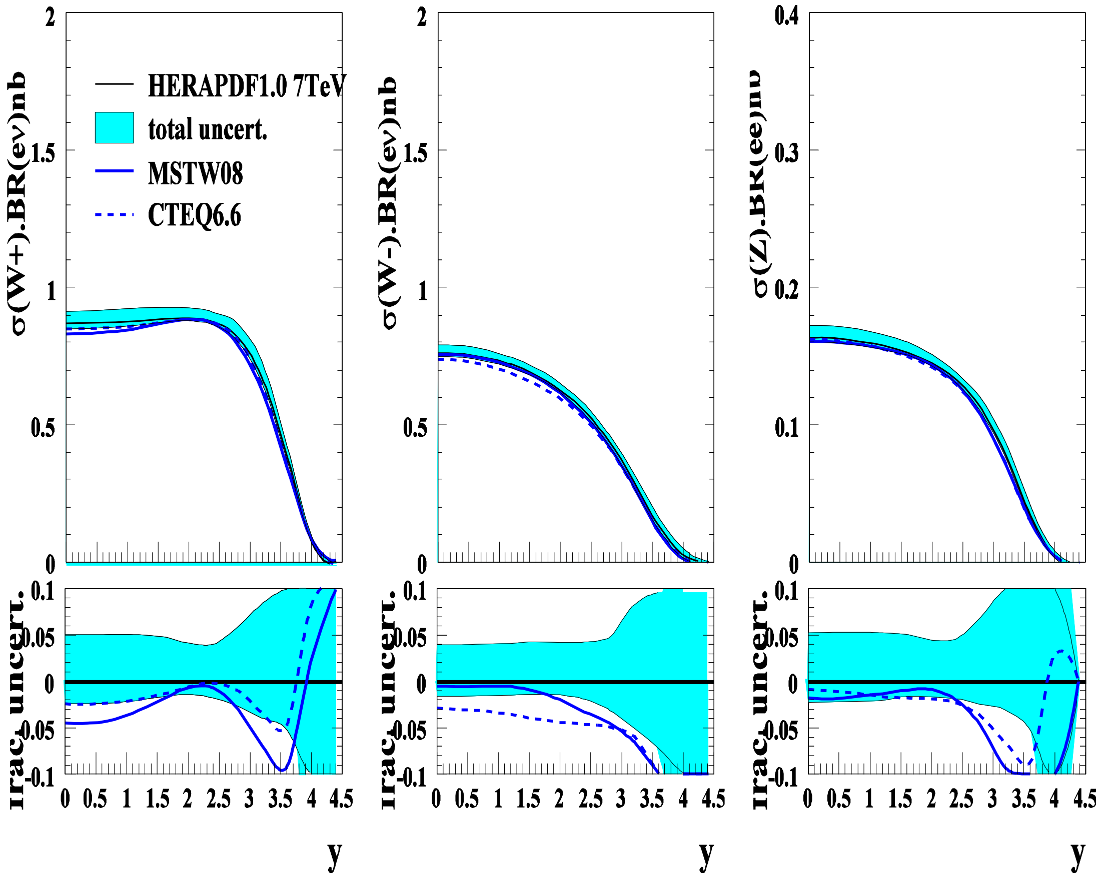


High-x NC e-p cross-section on the way to be fed to HERApdf's fit

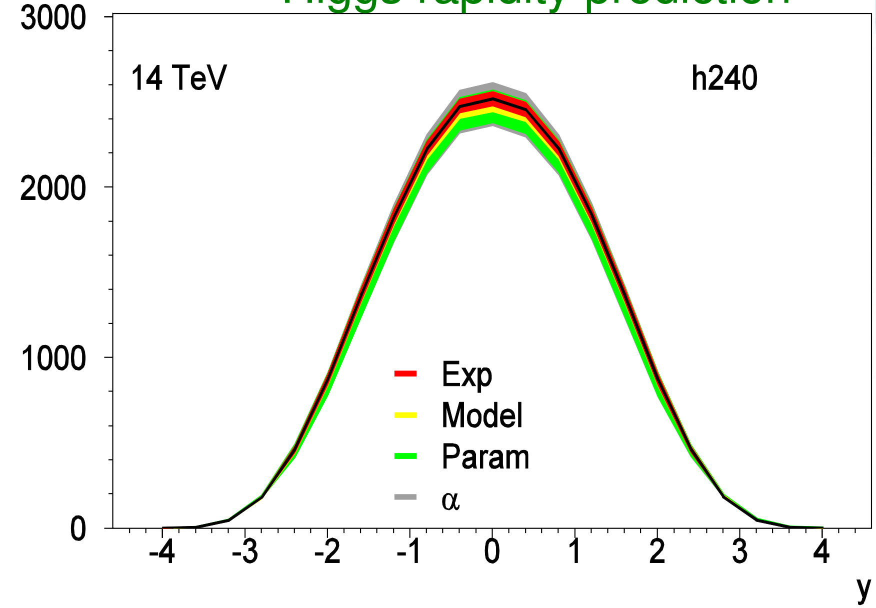


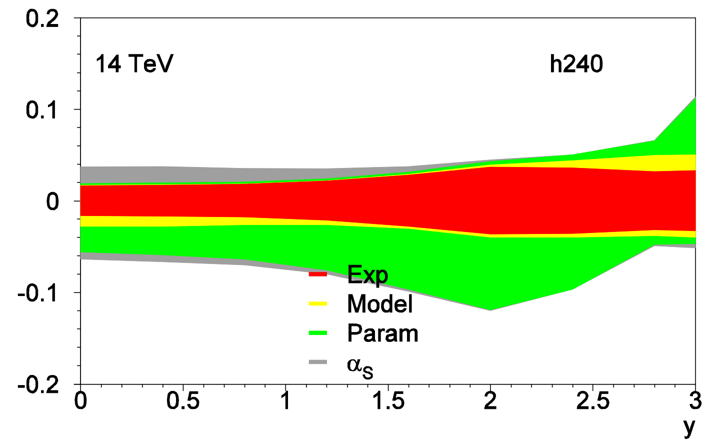
Plot from : Inderpal Singh

Why talk about HERA physics in LHC scenario..?



Higgs rapidity prediction

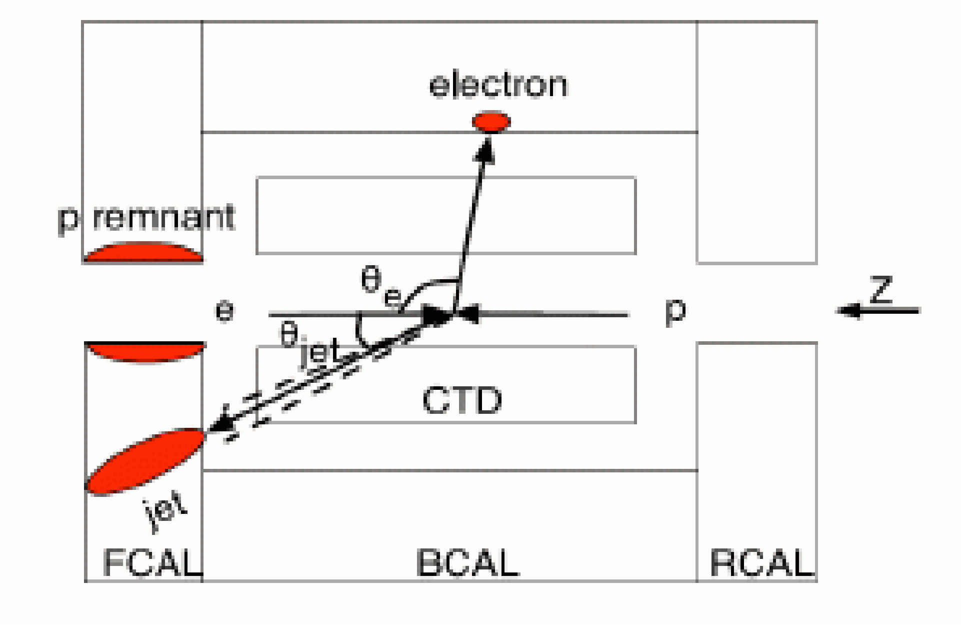




HERAPDF : W+,W-, Zo predictions at 7TeV

For more information :
https://www.desy.de/h1zeus/combined_results/benchmark/herapdf1.0.html

My focus : High-x cross section with Kinematic fit

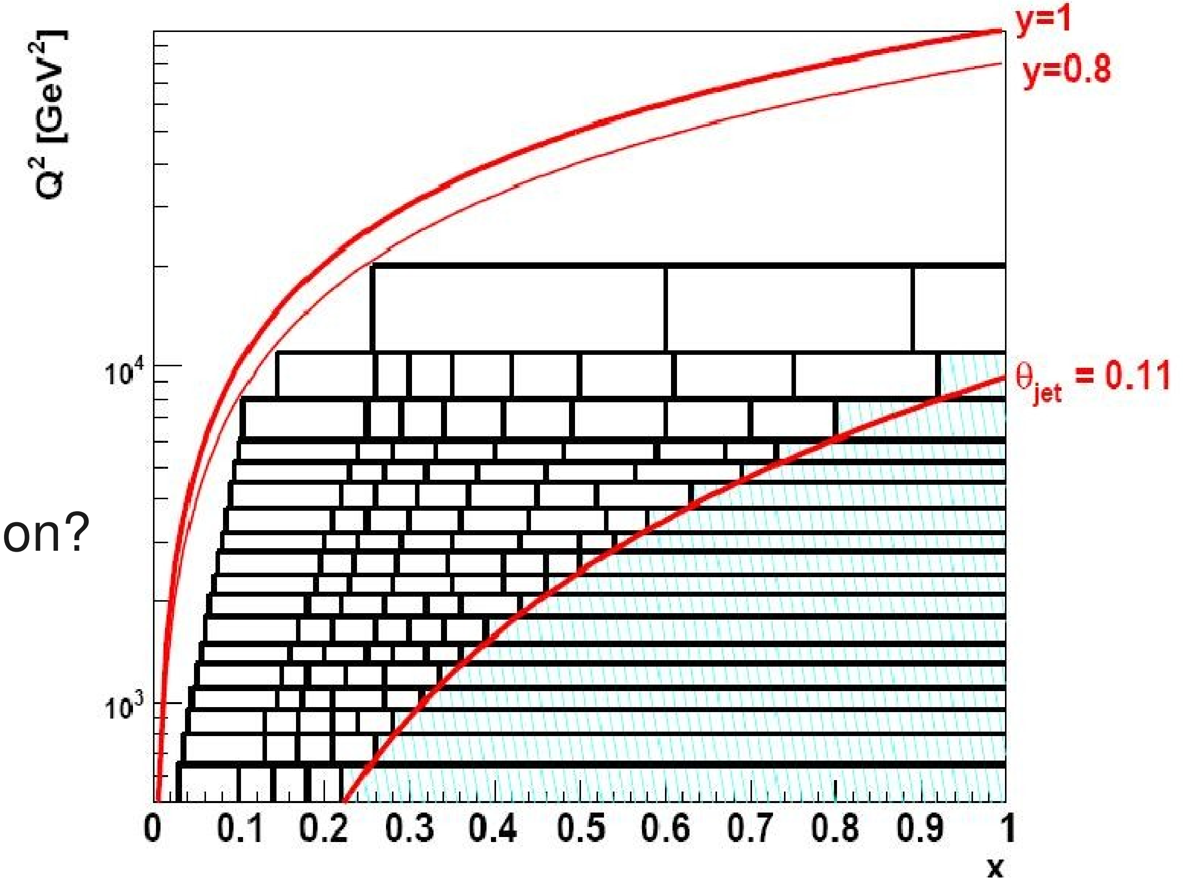


- Motivation
- Formulation & Parametrisation
- Obtaining KF using BAT
- Comparison to other methods
- Summary

x,Q² binning of the events

$$\frac{d\sigma(X_i)}{dX} = \frac{N_{i^{data}}}{N^{MC}_{rec,i}} \frac{d\sigma^{SM,Born}}{dX}(X_i)$$

How to recontruct
Kinematic variables
of an event
from the available information?



Motivation

Default Method (s)

Calculate x,y,Q^2 from
any of the two measured quantities $D = (E_e, \theta_e, E_j, \theta_{had})$

eg. Double Angle : (θ_e, θ_{had})

Electron Method : (E_e, θ_e)

Hadron Method : (E_j, θ_{had}) etc.

Results are expected to improve if we
use all the 4 quantities at a single time..

...Kinematic fitting

Principle : Use the **best available information** to find kinematic variables

Formulation

Aim : λ= (x,y,E_γ) from measured quantities D = (Ee,θe, Ej, θhad)

Choose a set of values for λ .

From λ, calculate E, θ,F, γ .

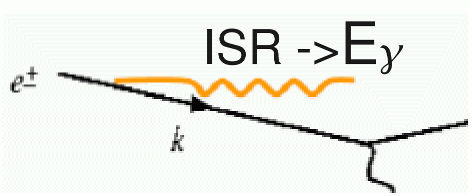
Compare these Quantities to D and calculate a probability.

$P(\lambda|D) \propto P(D|\lambda)Po(\lambda)$

Where $P(D|\lambda) = P(Ee|E)P(Ej|F)P(\theta e|\theta)P(\theta j|\gamma)$

and $Po(\lambda) = (1-x)^5 f(E_\gamma/Ee)/y^2/x^2$

Find λ **with highest probablity**



Where $f(a) = [1+(1-a)^2]/a$

Formulation...

The core of the method is to find P(Ee|E), P(Ej|F), $P(\theta e|\theta)$, $P(\theta had|\gamma)$

Simplest case : Expected for all of these is a gaussian of the measured quantities centered at the predicted quantities with some widths.

Next step

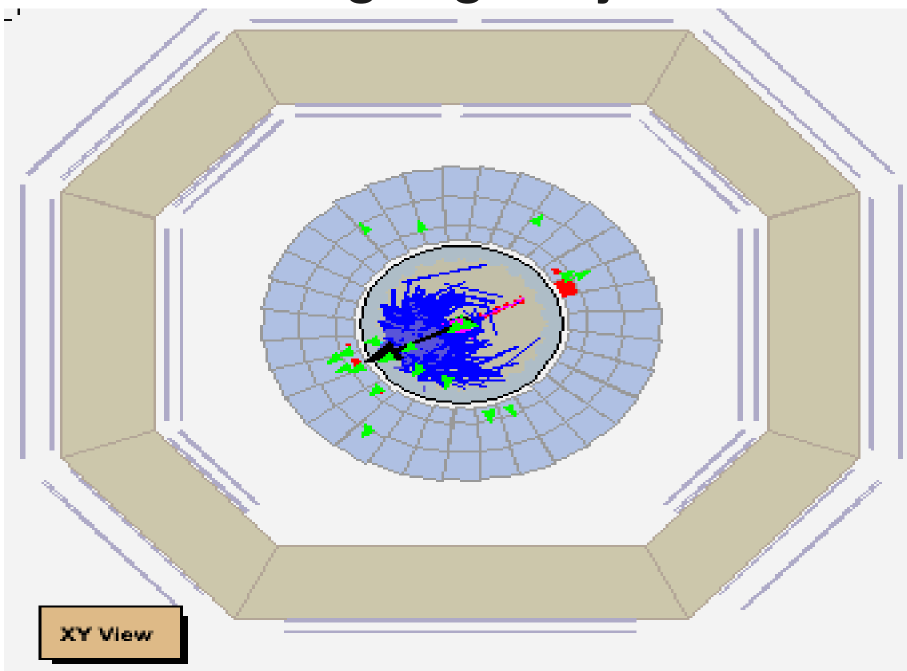
Find functional form of these probability distribution functions and parametrize the parameters of the PDF in terms of the predicted quantiies.

Study is done on MC comparing the measured quantities to the true quantites..

Parametrization

two category of events

Single good jets



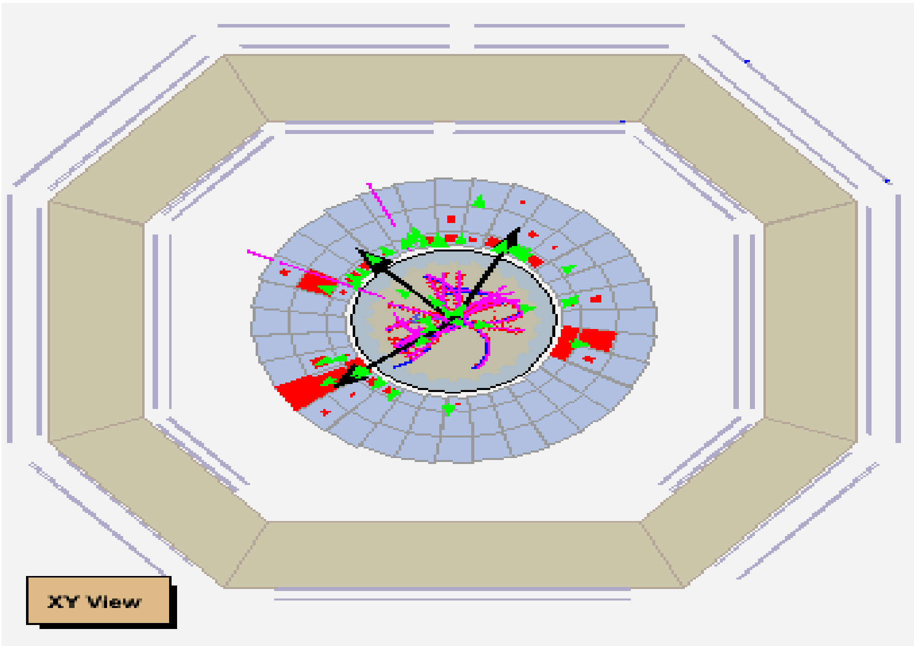
1 jet + Missimg Empz < 5 GeV

P(Ee|E), P(Ej|F), P(θe|θ)=> Gaussian

P(θhad|γ)

$$f(\gamma) = A/2\, e^{\frac{b^2}{4c^2}}\, e^{b(\gamma - m)}\, Erfc(c(\gamma - m))$$

Hadron system



1 jet + Missing Empz ≥ 5GeV
& multijet events

P(Ee|E), P(Ej|F), P(θe|θ)
P(θhad|γ) => Gaussian

Using BAT to get best λ

Choose a set of values for λ .

From λ, calculate E, F, θ, γ .

Compare these Quantities to D and calculate a probability.

$P(\lambda|D) \propto P(D|\lambda)Po(\lambda)$

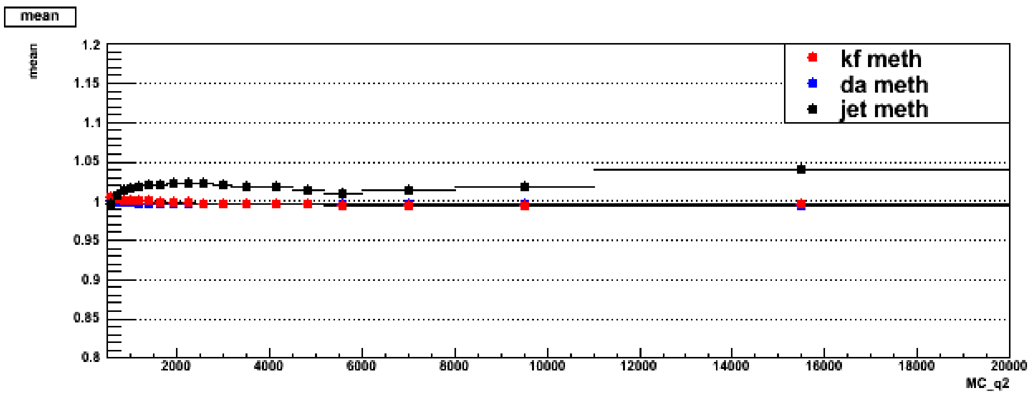
Find λ with highest probablity

Provide $P(D|\lambda)Po(\lambda)$

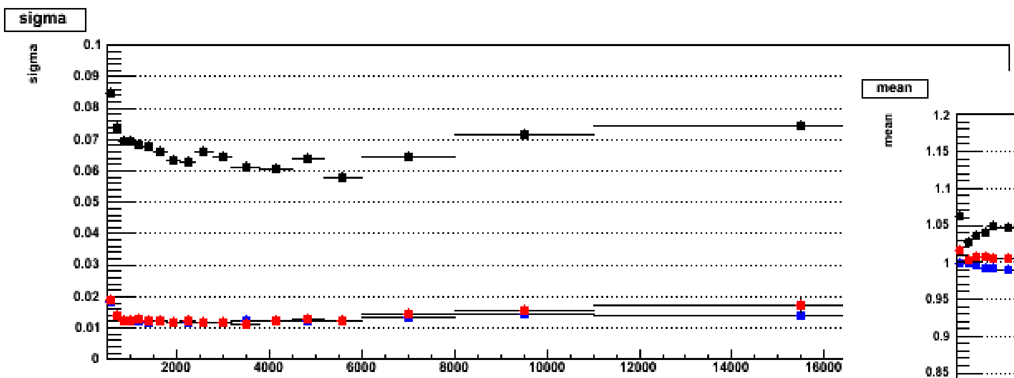
BAT does the job for you

BAT- More information:
http://www.mppmu.mpg.de/bat/

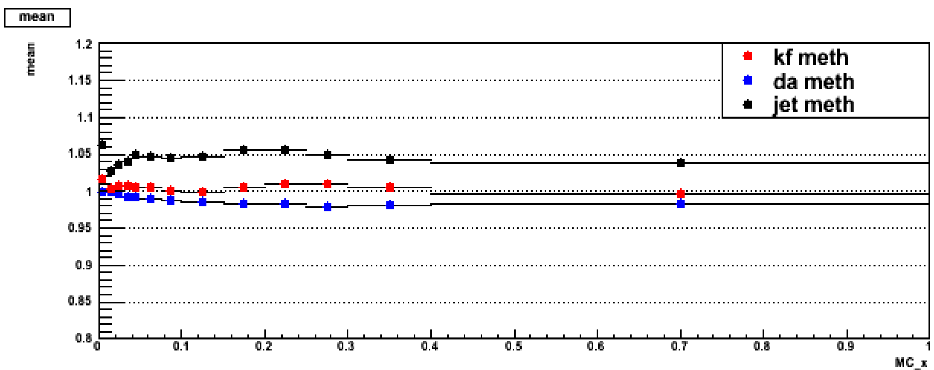
Comparing the resolution and bias for x & Q2 : 1jet good



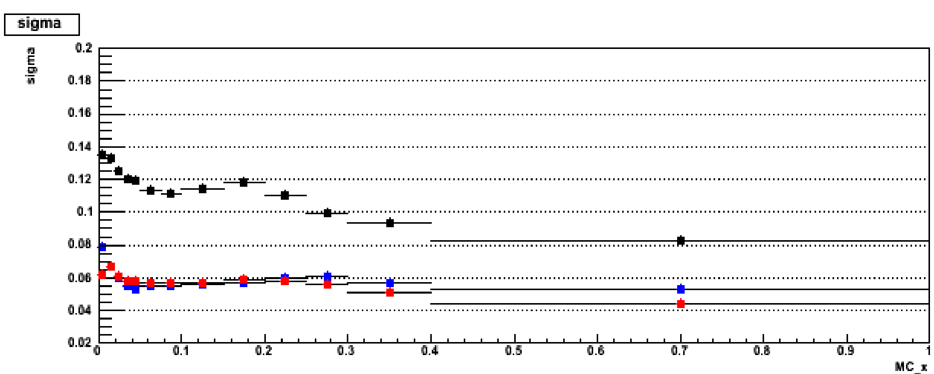
Bias in Q^2_{meth} / Q^2_{MC}



resolution Q^2_{meth} / Q^2_{MC}



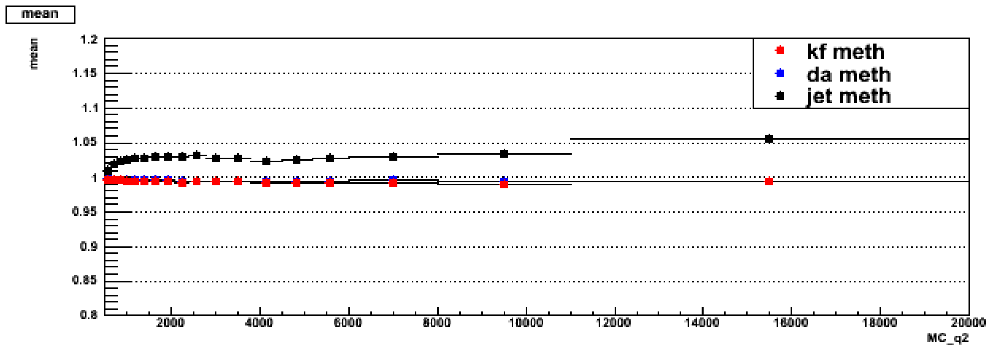
Bias in x_{meth} / x_{MC}



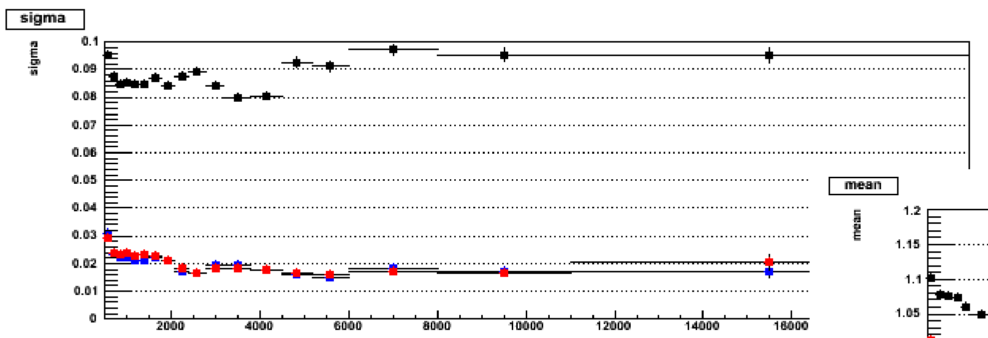
Resolution x_{meth} / x_{MC}

Kpf doing a good job!

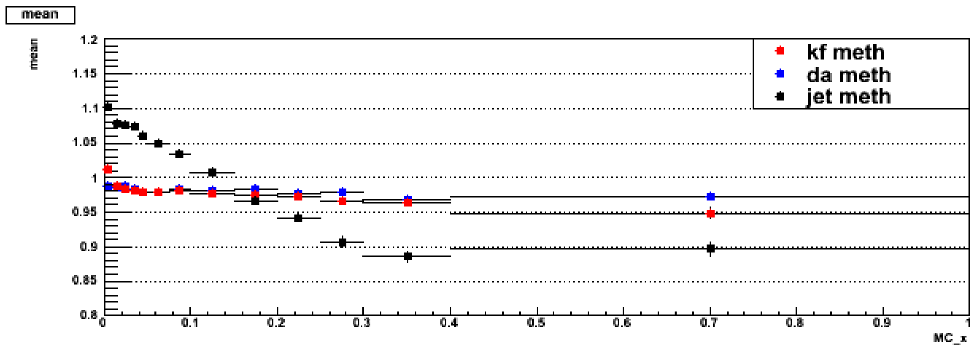
Comparing the resolution and bias for x & Q2 : hadsys



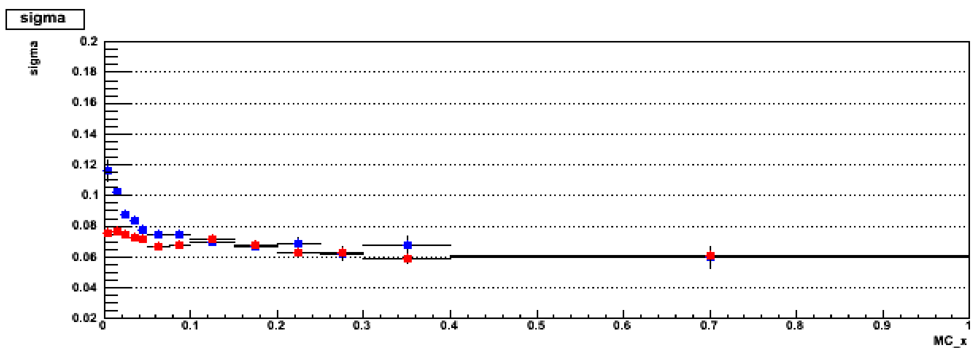
Bias in Q^2_{meth} / Q^2_{MC}



resolution Q^2_{meth} / Q^2_{MC}



Bias in x_{meth} / x_{MC}



Resolution x_{meth} / x_{MC}

Kpf doing a good job!

SUMMARY:

--Deep inelastic scattering and results from HERA.

--Reconstruction of Kinematic variables.

--Introduction of new method – Kinematic fit method.

--use whole information – expect better outcome.

--Usefulness of this method over other methods .

Thanks

Formulation..

$$E = xyP + Ar\,(1\text{-}y)$$

$$\cos\theta = \frac{xyP - Ar(1-y)}{xyP + Ar(1-y)}$$

$$F = x(1\text{-}y)P + yAr$$

$$\cos\gamma = \frac{x(1-y)P - Ary}{x(1-y)P + Ary}$$

Where :

A : Electron beam Energy

P : Proton beam Energy

Ar = Electron energy participating in scattering A - E_γ

Electron Method

$$Q_e^2 = 4E_eE'_e\cos^2\frac{\theta_e}{2},$$

$$y_e = 1 - \frac{E'_e}{2E_e}(1-\cos\theta_e),\ x_e = Q_e^2/y_es$$

DA Method

$$Q_{DA}^2 = \frac{4E_e^2\sin\gamma_h(1+\cos\theta_e)}{\sin\gamma_h + \sin\theta_e - \sin(\theta_e+\gamma_h)},$$

$$y_{DA} = \frac{\sin\theta_e(1-\cos\gamma_h)}{\sin\gamma_h + \sin\theta_e - \sin(\theta_e+\gamma_h)},\ x_{DA} = Q_{DA}^2/(sy_{DA})$$

Hadron Method

$$y_h = \frac{\sum_i(Ei - p_{z,i})}{2E_e},\quad Q_h^2 = \frac{P_{T,h}^2}{1-y_h},\quad x_h = \frac{Q_h^2}{sy_h}$$

Elpt-jet method

.

$$x_{pt_e} = \frac{(p_{t_e}/sin\theta_{jet})(1+cos\theta_{jet})}{2E_p(1-\frac{(p_{t_e}/sin\theta_{jet})(1-cos\theta}{2E_e}}\quad x = \frac{E_{\text{jet}}(1+\cos\theta_{\text{jet}})}{2E_p\left(1-\frac{E_{\text{jet}}(1-\cos\theta_{\text{jet}})}{2E_e}\right)}$$

MC sample:

04/05e- : DJANGOH 1.6, Ariadne 4.12, CTEQ-5D with Q2 > 400 GeV2

Selection:

Vertex:

Valid vertex && |Zvtx| < 50. cm

Electron:

1 e- candidate (Ee>15GeV)

Fiducial volume cuts:

BCAL+FCAL e-s

no cracks, no RCAL

|DME| > 1.4 cm && | DCE| > 0.5 cm

In CTD Acceptance

DCA < 10 cm

Superlayers > 4

TrkP > 5. GeV

Not in Acc. Of CTD

Pt elec > 30. GeV

Kinematics:

45<Empz<65

Pt/SqrtEt < 5 GeV

y_el < 0.95

Jets

"good jets"

1 jet events in FCAL/BCAL

Box cut 40.40 cm2

Avoid FBCAL crack

Missing Empz < 5 GeV

Et > 10 GeV

"hadsys_jets"

1,2,3(<4) jet events in FBCAL

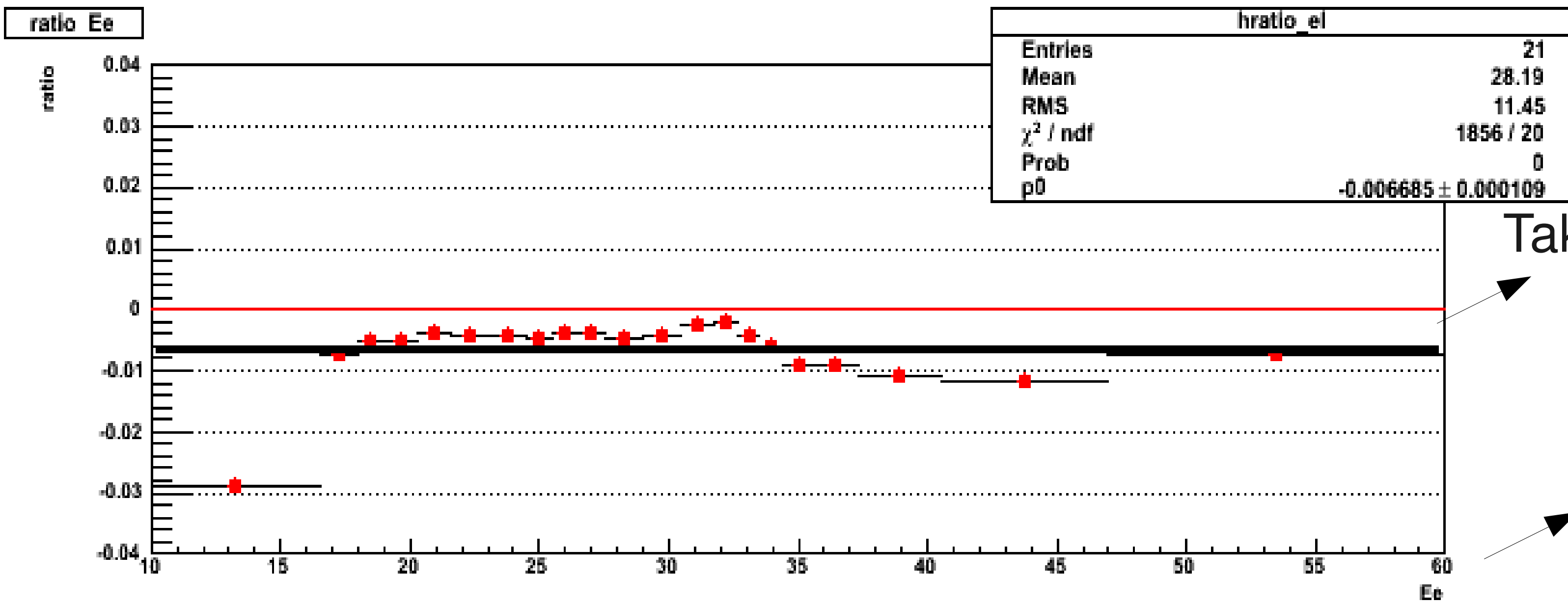
Box cut

None of the jets in FBCAL crack

Missing Empz >= 5GeV for 1jet events

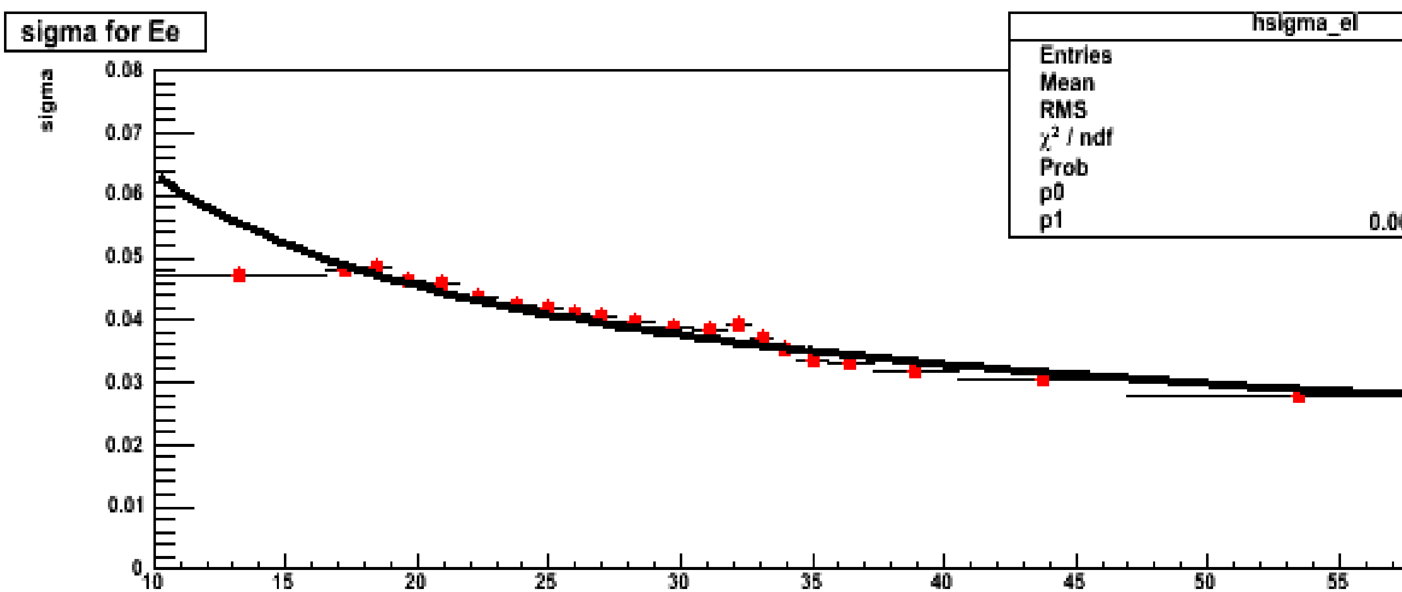
Et of first jet > 10 GeV

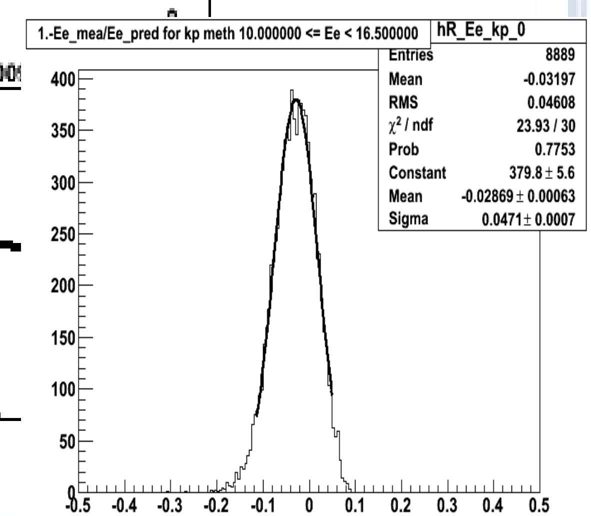
P(Ee|E): 1-Ee/E in bins of E => a gaussian



Taking Offset = 0

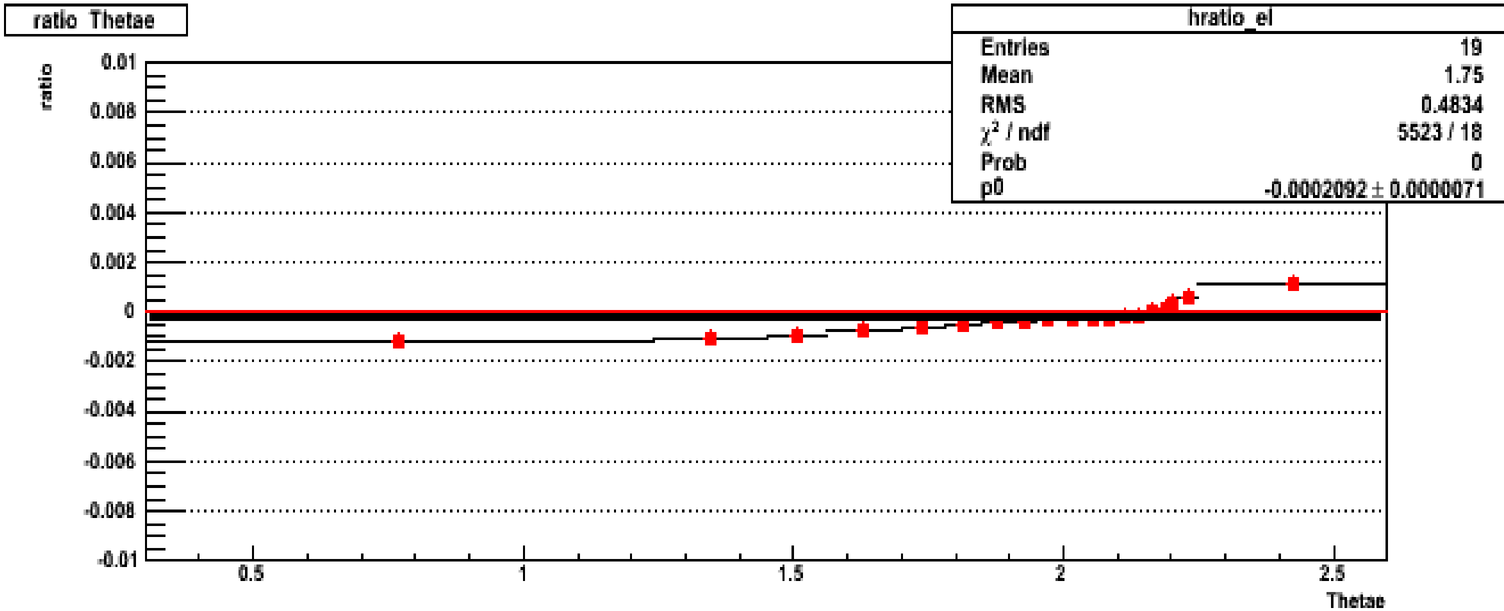
$\sigma = a/\sqrt{E} \oplus b$





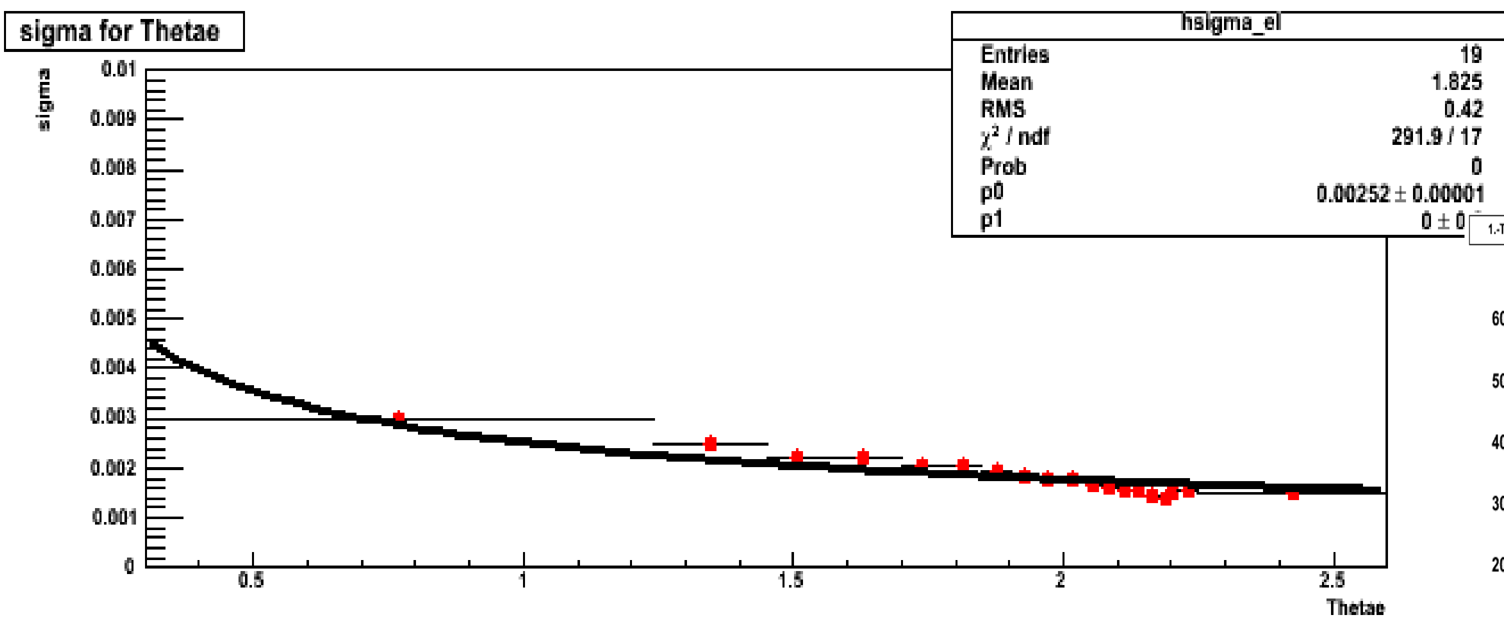
As an example

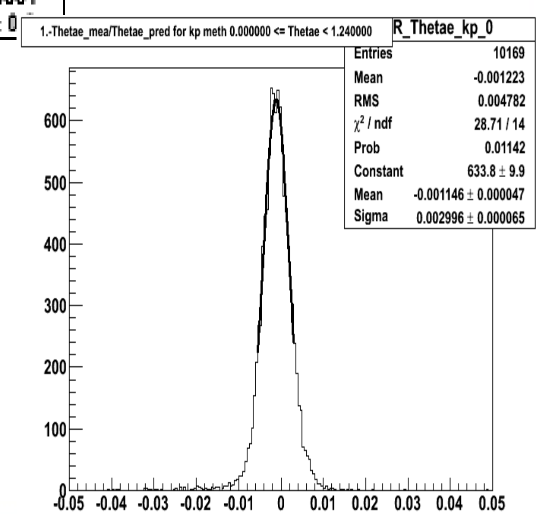
P(θe|θ): 1-θe/θ in bins of θ => a gaussian



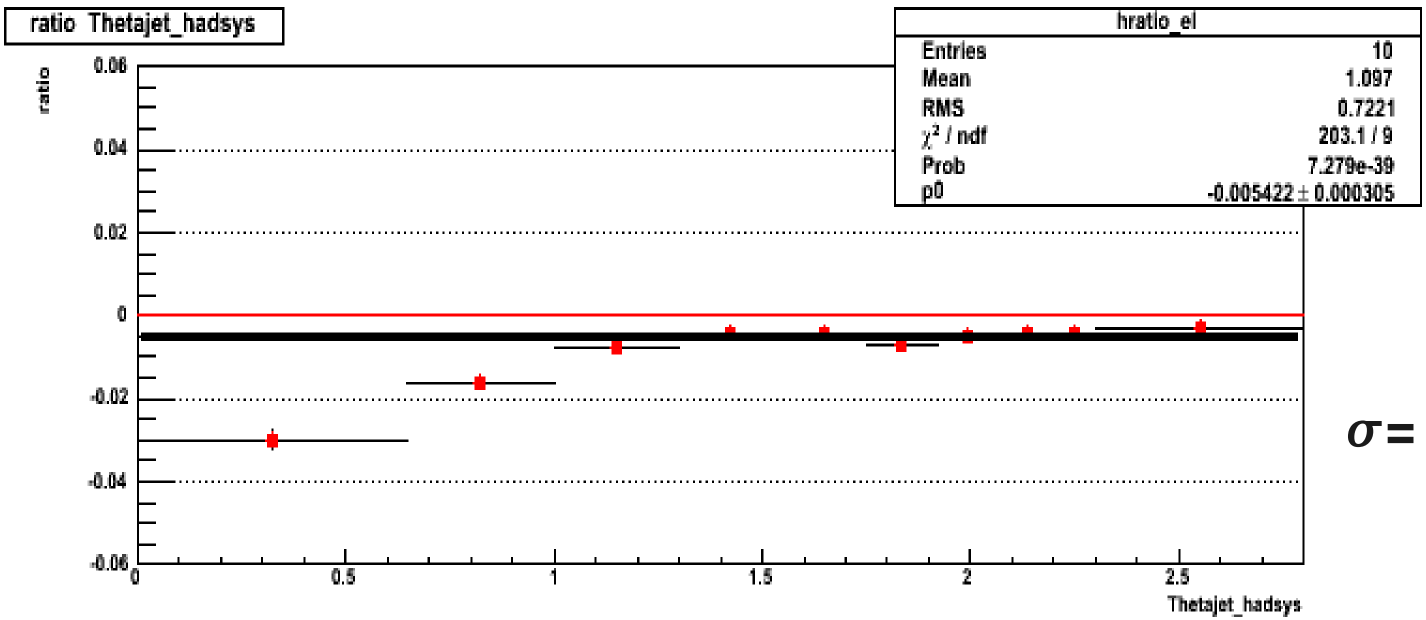
Taking Offset = 0

$\sigma = a/\sqrt{\theta} \oplus b$



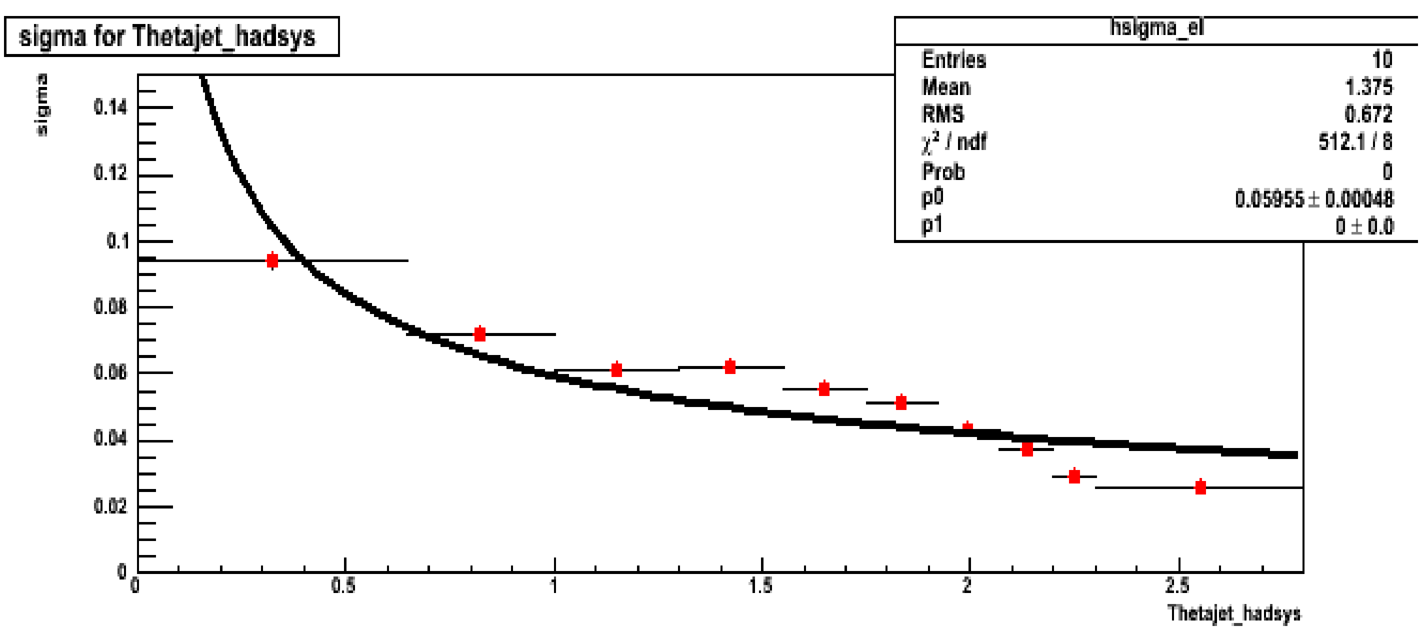


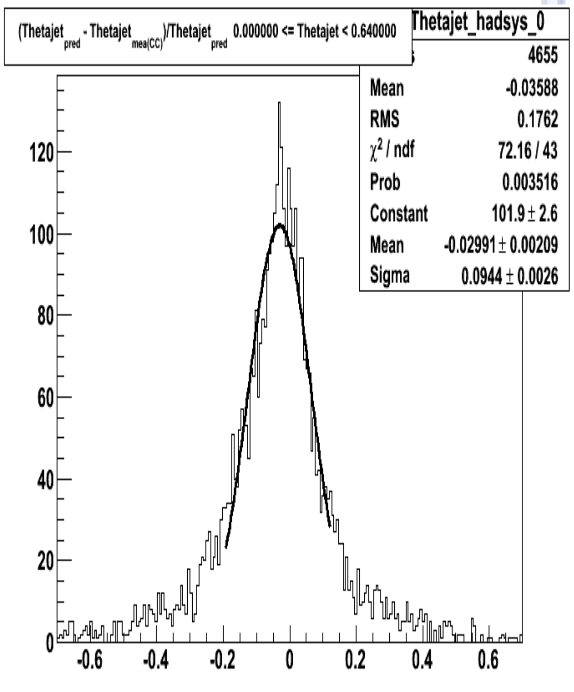
P(θj_had|γ_had): 1-θj_had/γ_had in bins of γ_had => a gaussian



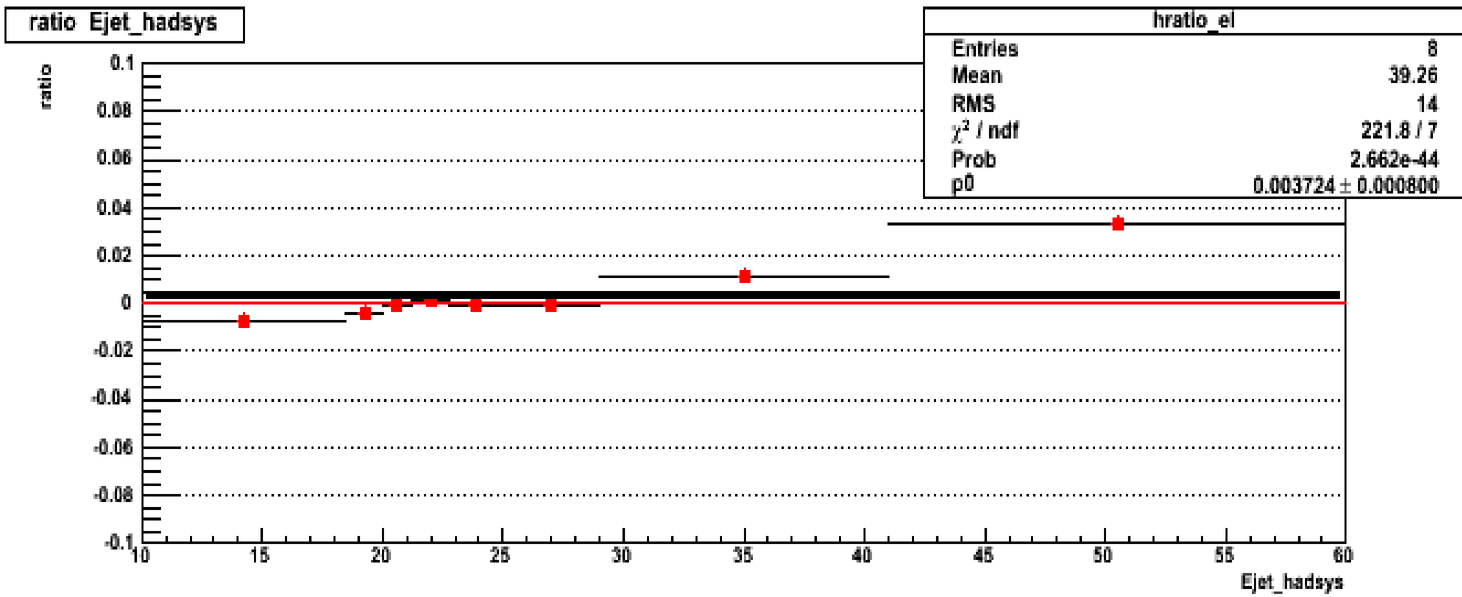
Taking Offset = 0

σ= a/$\sqrt{\gamma}$_had$\oplus$ b



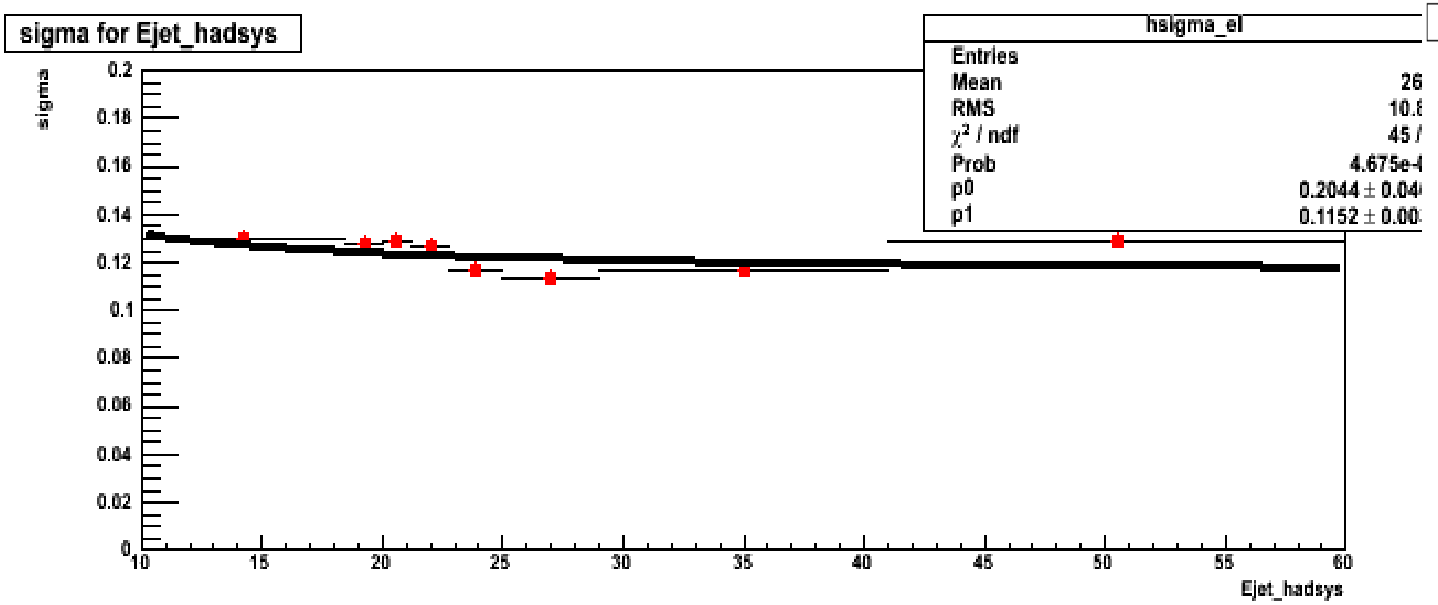


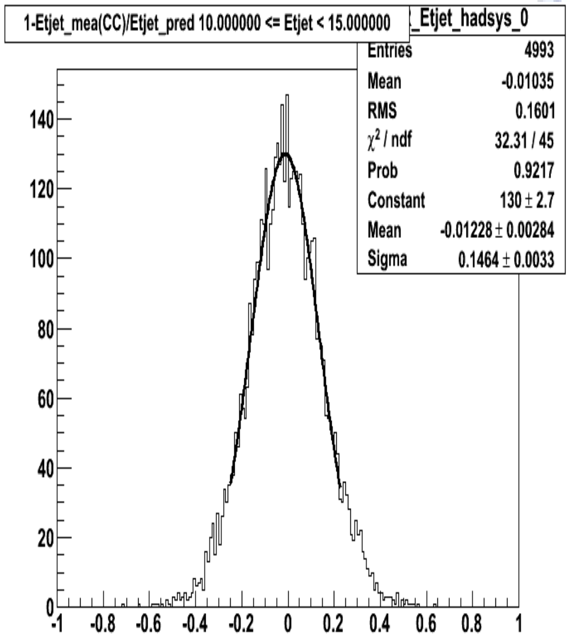
P(Ej_had|F_had): 1-Ej_had/F_had in bins of F_had =>a gaussian



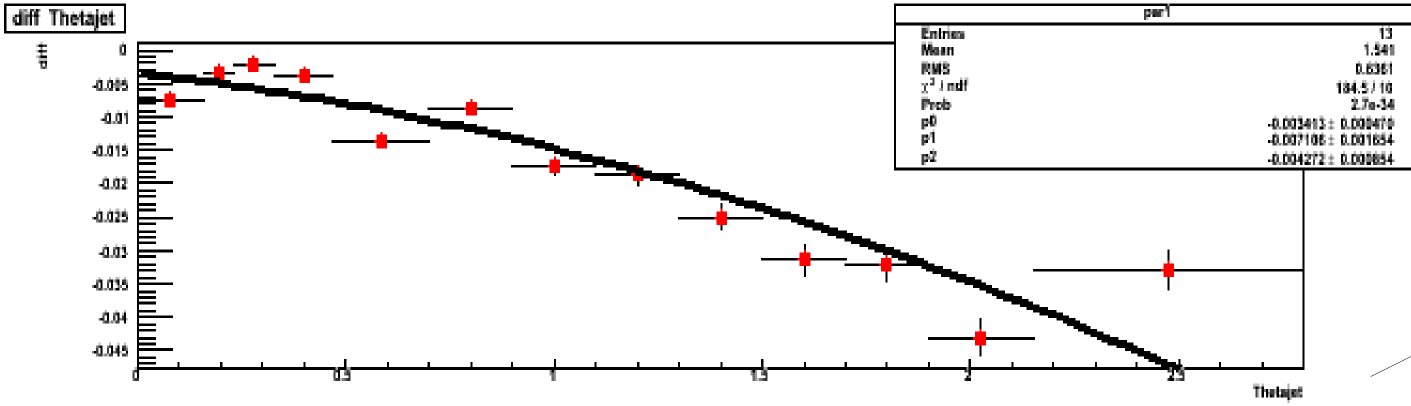
Taking Offset = 0

σ= a/√F_had⊕ b

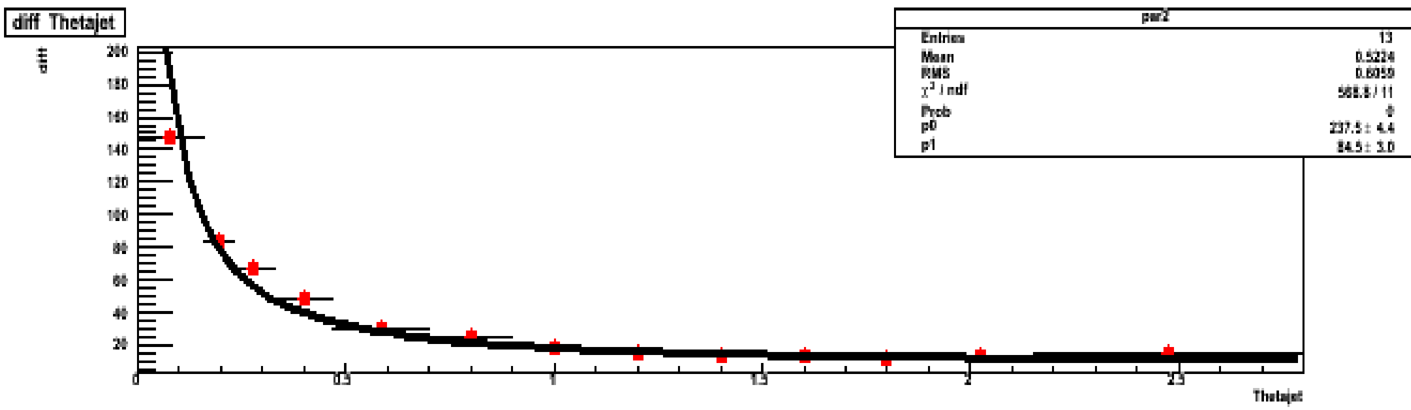




P(θj|γ): 1-θj/γ in bins of γ => $f(\gamma)=A/2\, e^{\frac{b^2}{4c^2}}\, e^{b(\gamma-m)}\, Erfc(c(\gamma-m))$

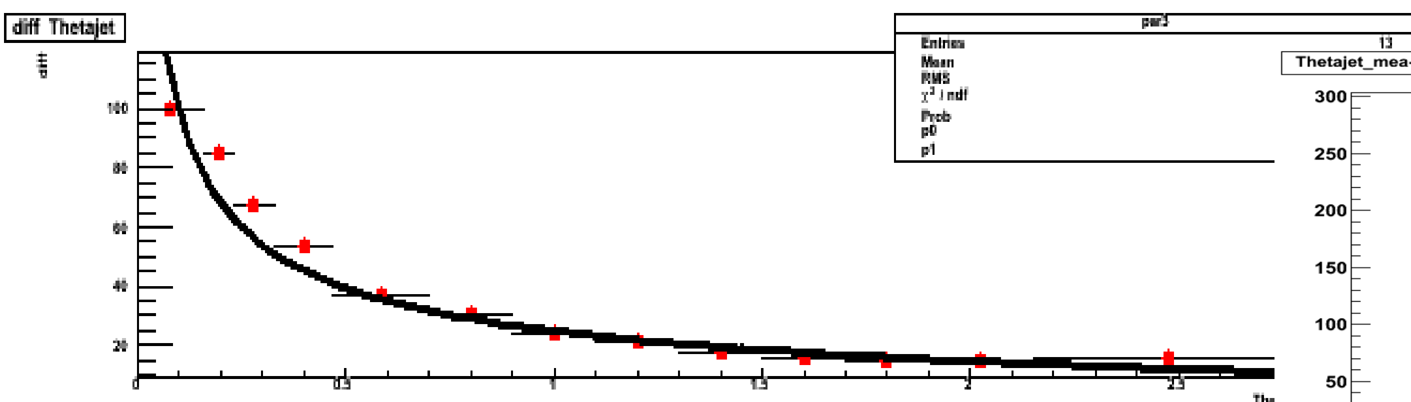


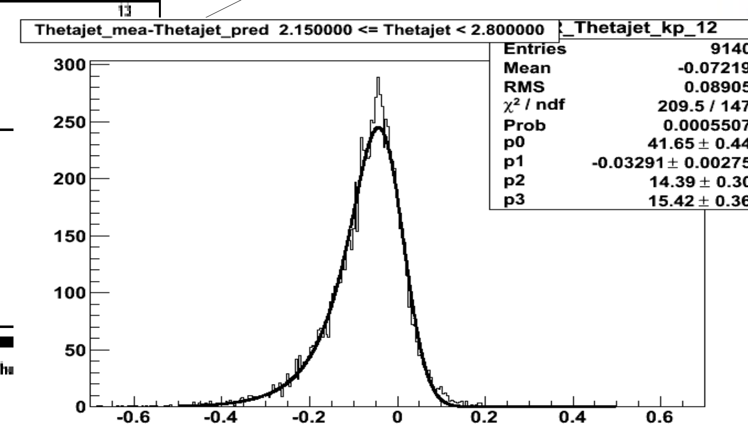
m : II order pol in γ



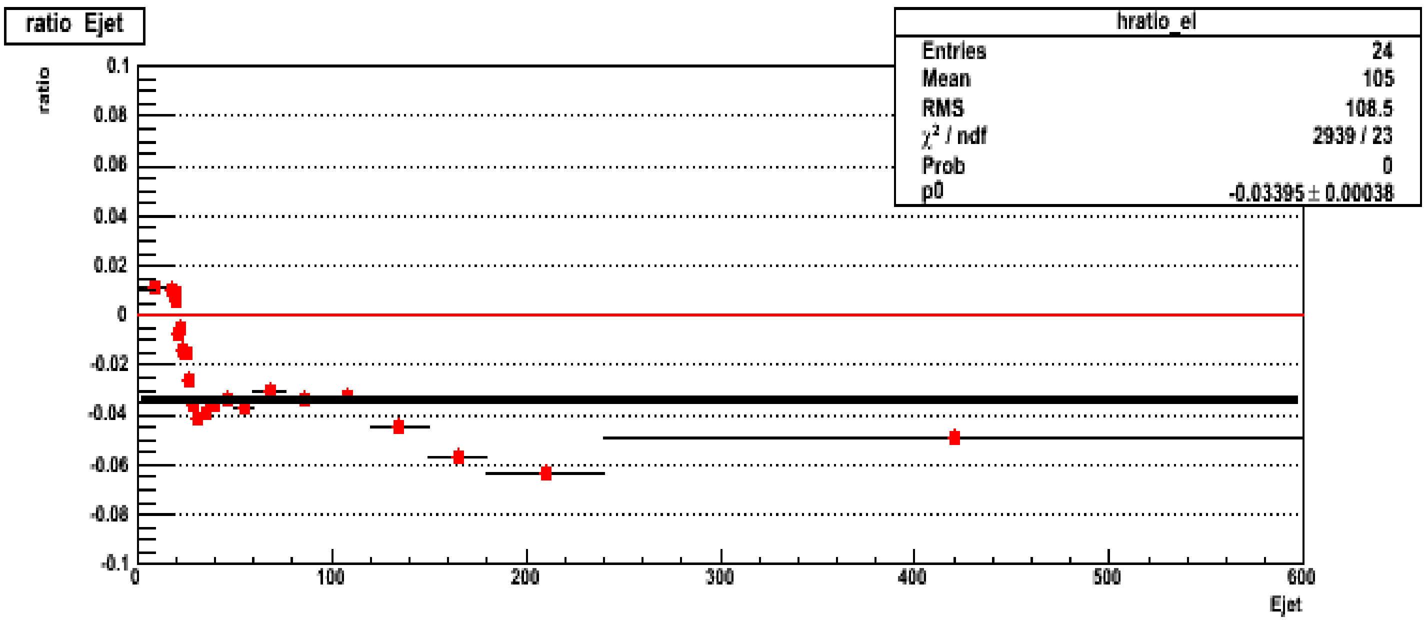
b=√(a/ γ + b)

C= a/ √γ + b





P(Ej|F): 1-Ej/F in bins of F=> a gaussian



Taking Offset = -0.034

σ= a/√F⊕ b