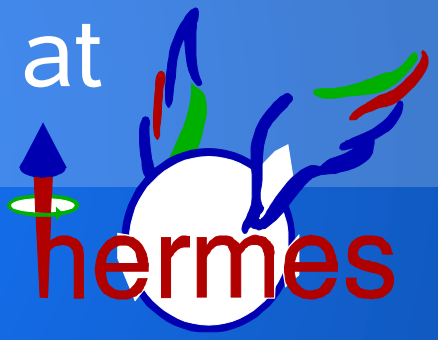
First measurement of the structure functions F_2^p, F_2^d and the DIS cross section ratio σ^d/σ^p at



◊

Dominik D. Gabbert

On the behalf of the HERMES collaboration

DIS 2009

April 27, 2009

DIS cross section and structure functions

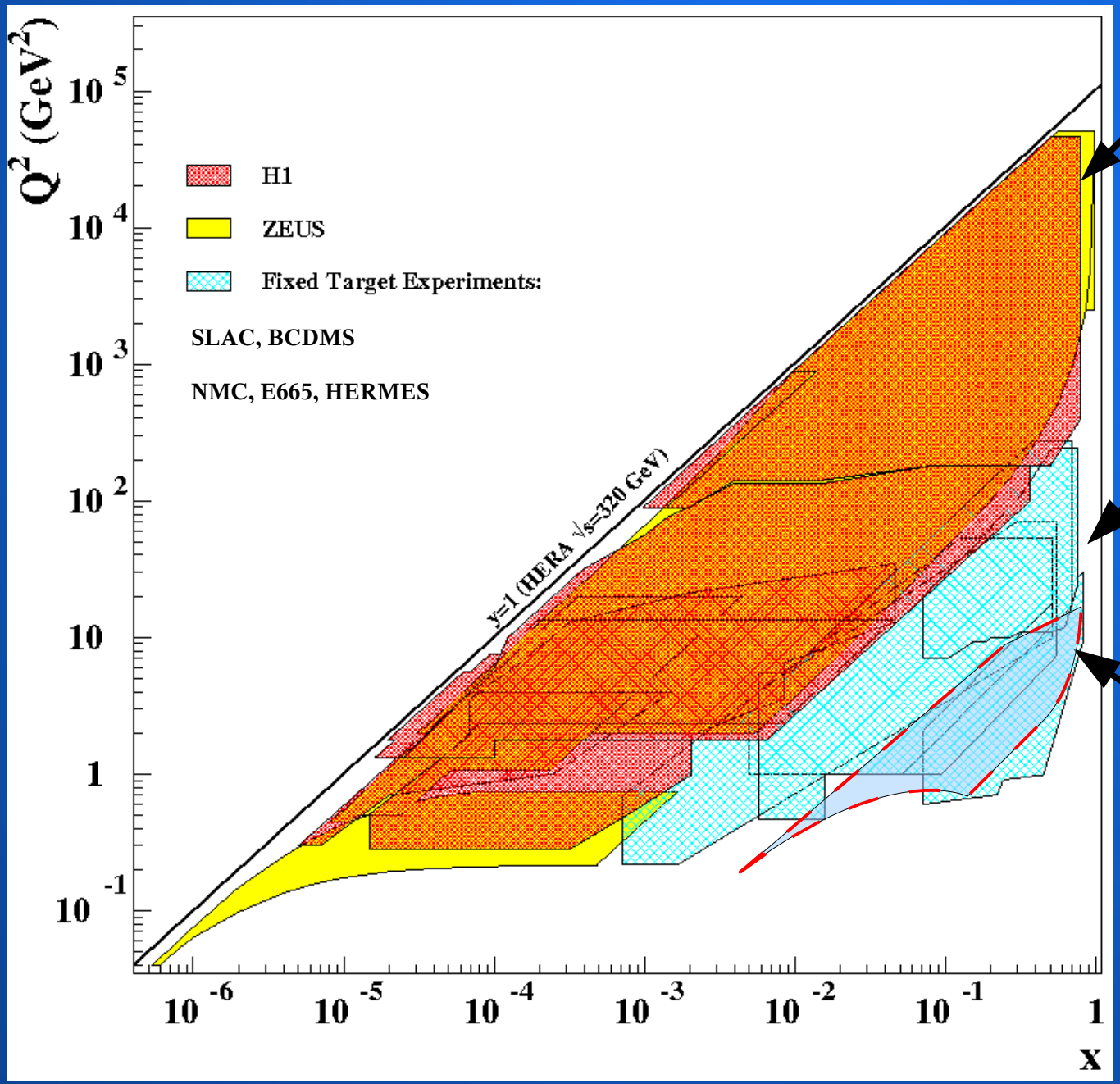
$$\frac{d^2\sigma}{d\Omega\, dE'} = \Gamma[\sigma_T(x,Q^2)+\epsilon\sigma_L(x,Q^2)]$$

Define ratio **R** and re-parameterize cross section

$$R=\frac{\sigma_L}{\sigma_T}$$

$$\frac{d^2\sigma}{dx\, dQ^2} = \frac{4\pi\alpha_{em}^2}{Q^4}\frac{F_2}{x}\times\left[\,1-y-\frac{Q^2}{4E^2}+\frac{y^2+Q^2/E^2}{2(1+R(x,Q^2))}\,\right]$$

Kinematic Plane in x-Q^2



Collider experiments

Fixed target experiments

Hermes

Why measuring *inclusive DIS cross sections* at Hermes?

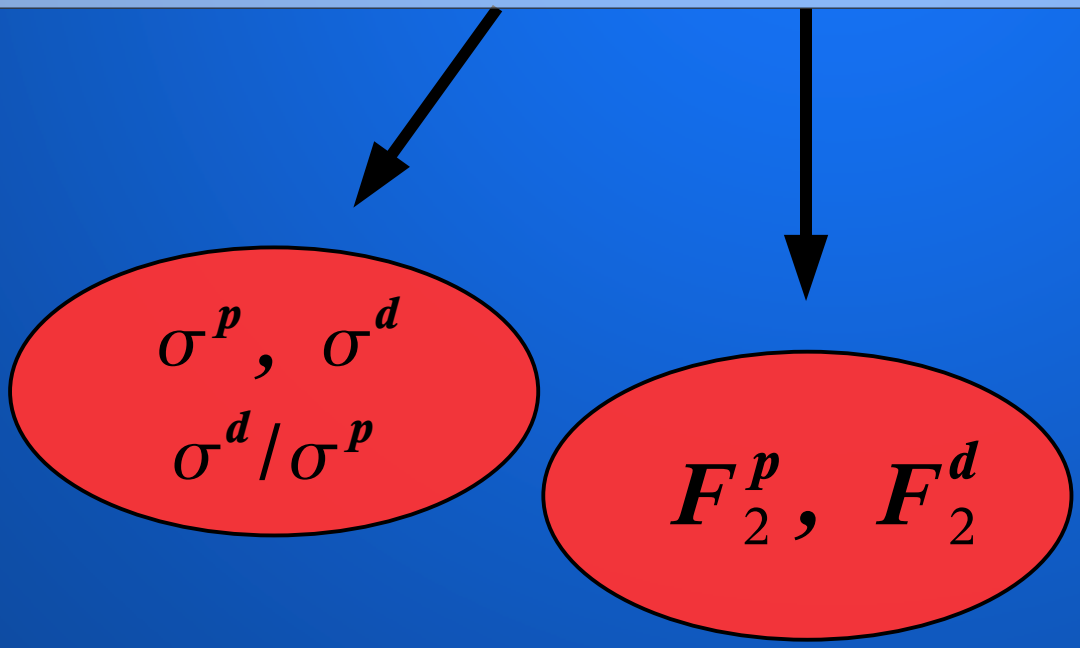
Hermes (1996-2005)

30 M proton + 28 M deuteron

~450 pb^{-1} **~460 pb^{-1}**

e. g. : compared to NMC

3 M proton + 6 M deuteron



Future plans

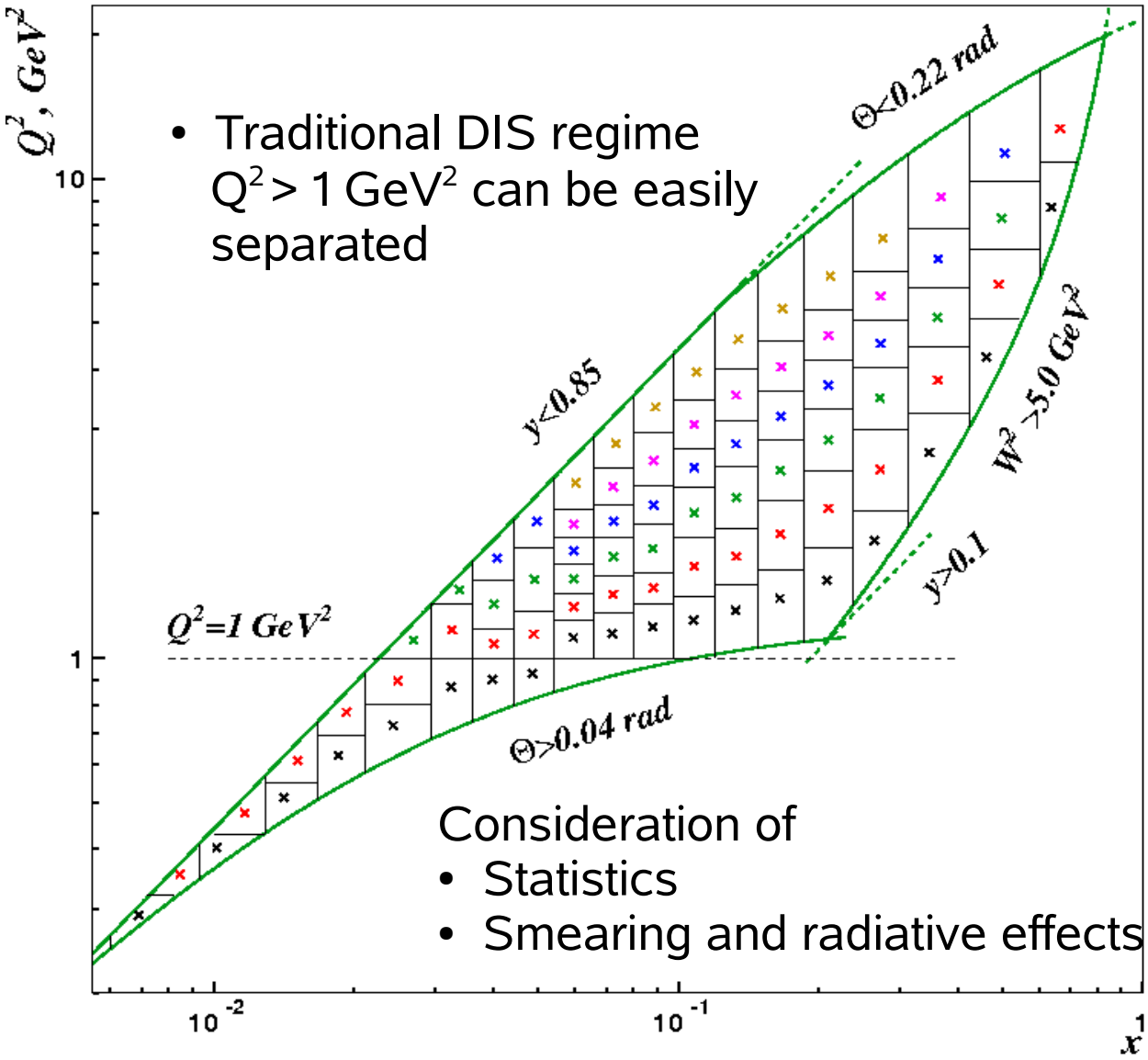
Gottfried Sum

$$\int \frac{dx}{x}\left(F_2^p - F_2^n\right)$$

valence quark ratio

$$\mathbf{d_V/u_V}$$

Binning in x and Q^2



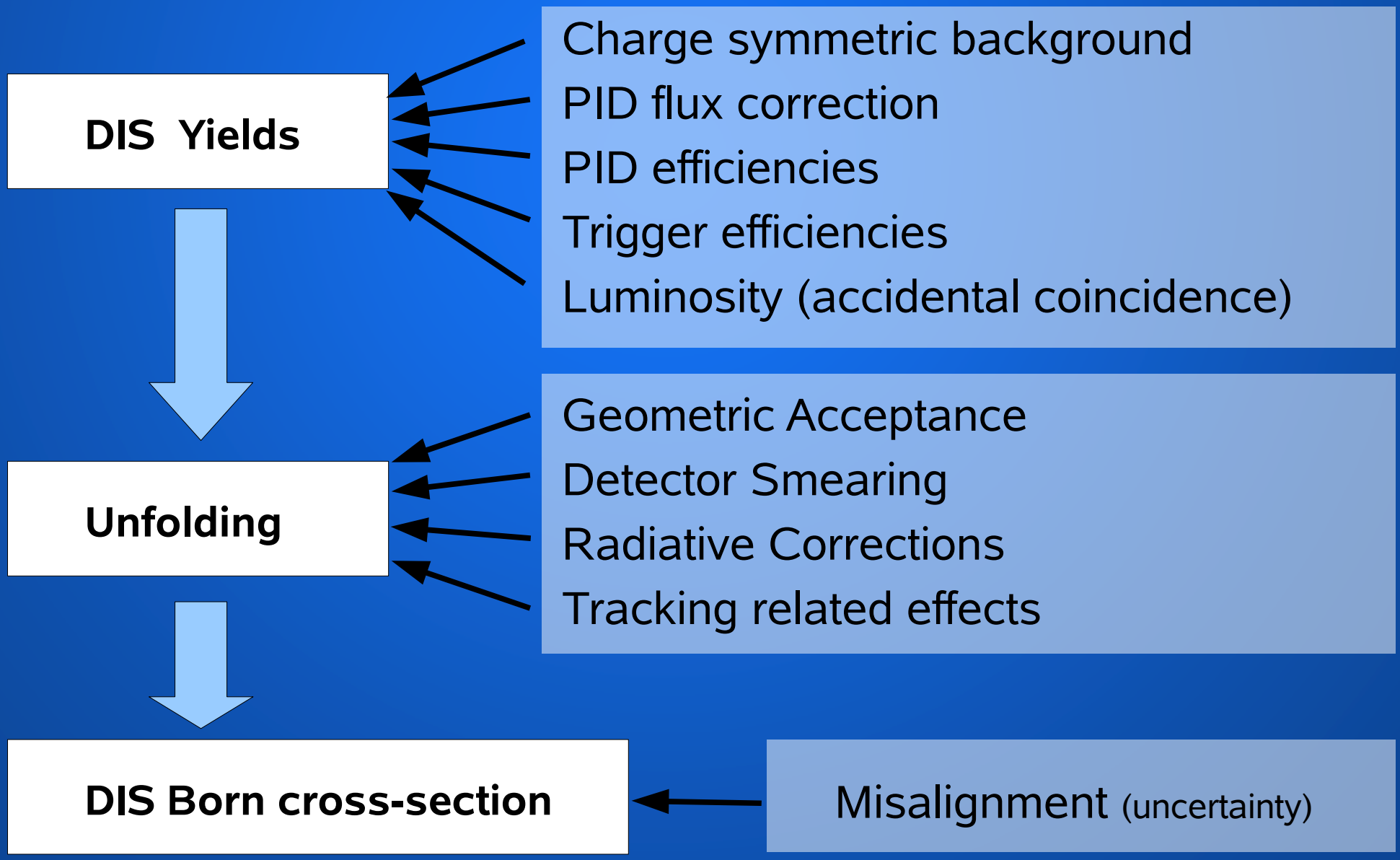
kinematic region

- $0.006 < x < 0.9$
- $0.1 < y < 0.85$
- $0.2\ \text{GeV}^2 < Q^2 < 20\ \text{GeV}^2$
- $W^2 > 5\ \text{GeV}^2$
- $0.04\ rad < \Theta < 0.22\ rad$

binning

- 19 x bins
- up to 6 Q^2 bins
- Total: 81 bins

Extraction of cross sections



Luminosity

- Elastic reference process: Interaction of beam with shell electrons
  - Electron Beam: Møller scattering $e^- e^- \rightarrow e^- e^-$
  - Positron Beam: Bhabha scattering $e^+ e^- \rightarrow e^+ e^-$, annihilation $e^+ e^- \rightarrow \gamma\gamma$

Luminosity

Corr. for acciden-tal coincidence

Trigger life time

Time interval

$$L = \int_b \mathcal{L}\, dt = (R_{LR} - \Delta t \cdot R_L \cdot R_R) \cdot C_{Lumi} \frac{A}{Z} \cdot l \cdot \Delta b$$

Coincidence rate

Luminosity constant

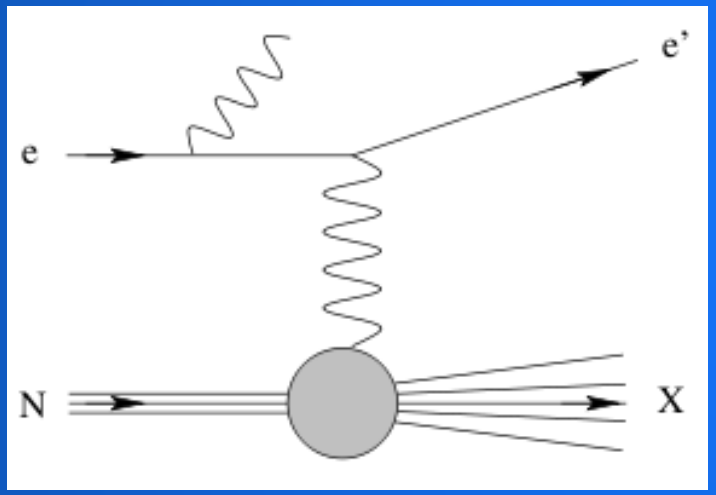
A: nucleons
Z: shell electrons

$$\sigma_{DIS} = \frac{N_{DIS}}{\int \mathcal{L}\, dt}$$

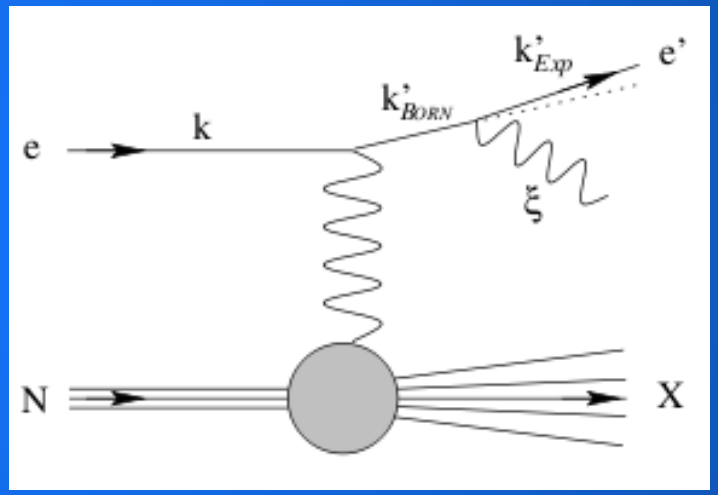
DIS yield

QED radiative effects

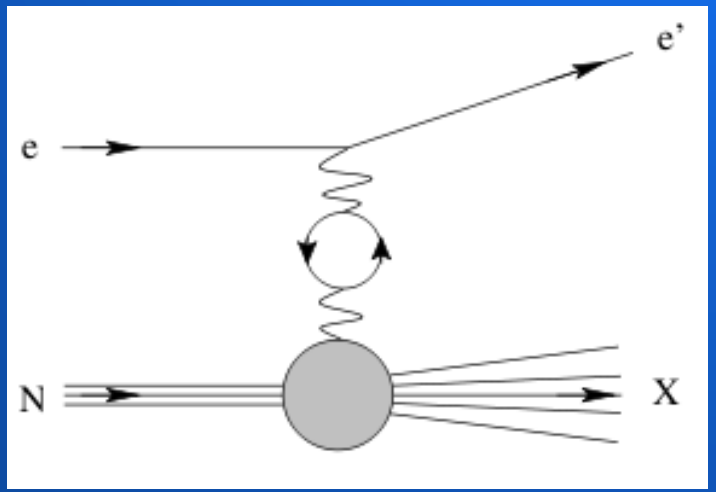
Feynman diagrams of processes contributing to radiative corrections:



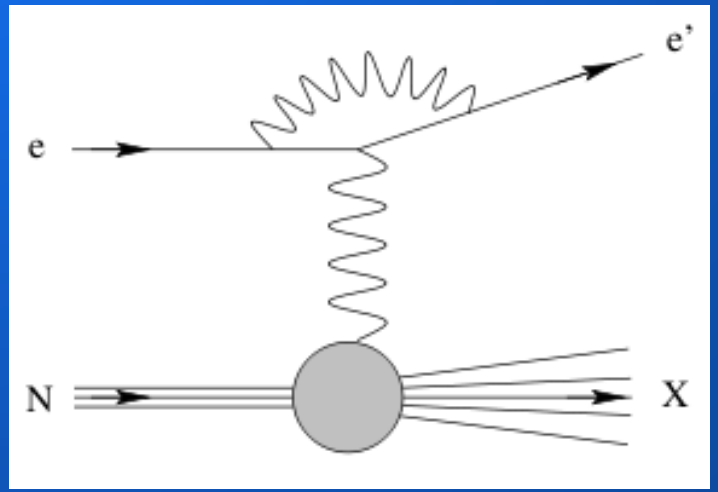
initial state radiation



final state radiation



vacuum polarization

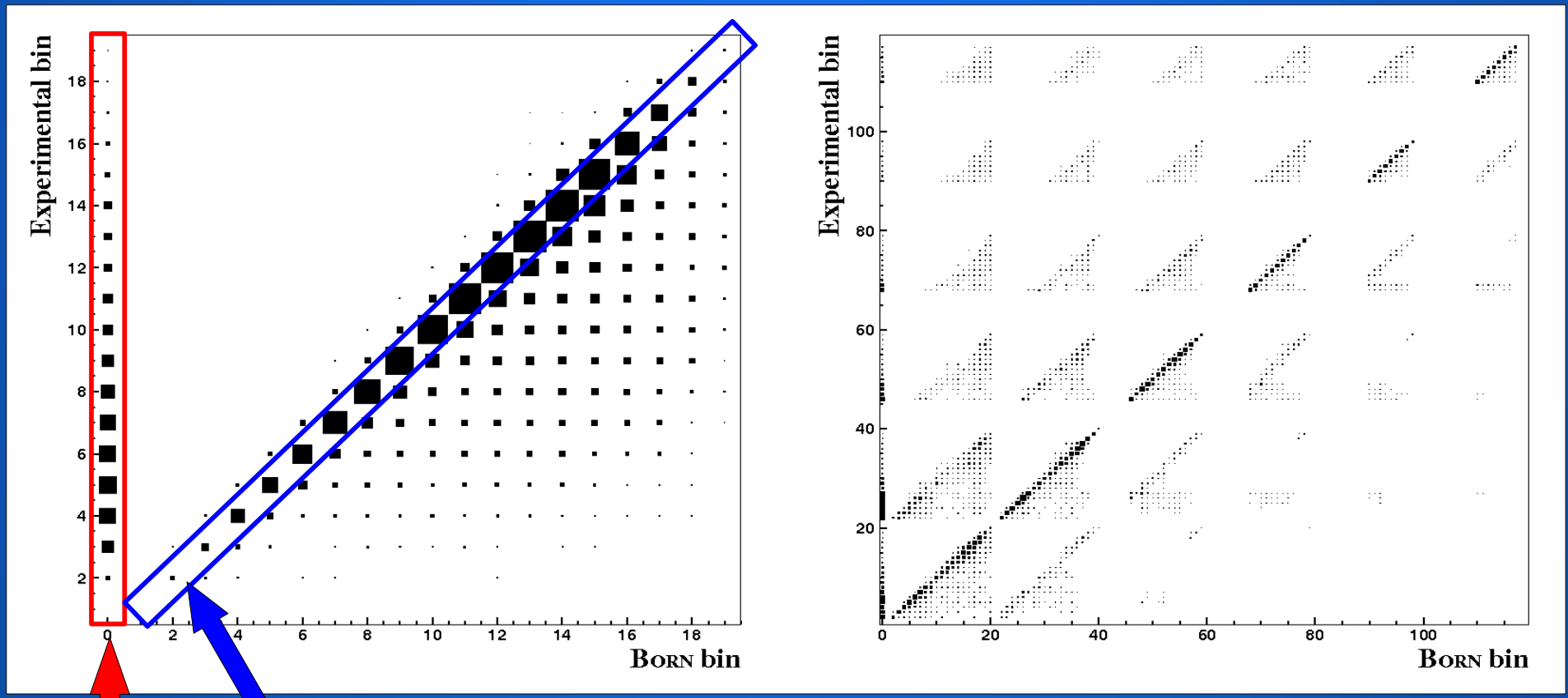


vertex correction

Migration matrix

Binning in x

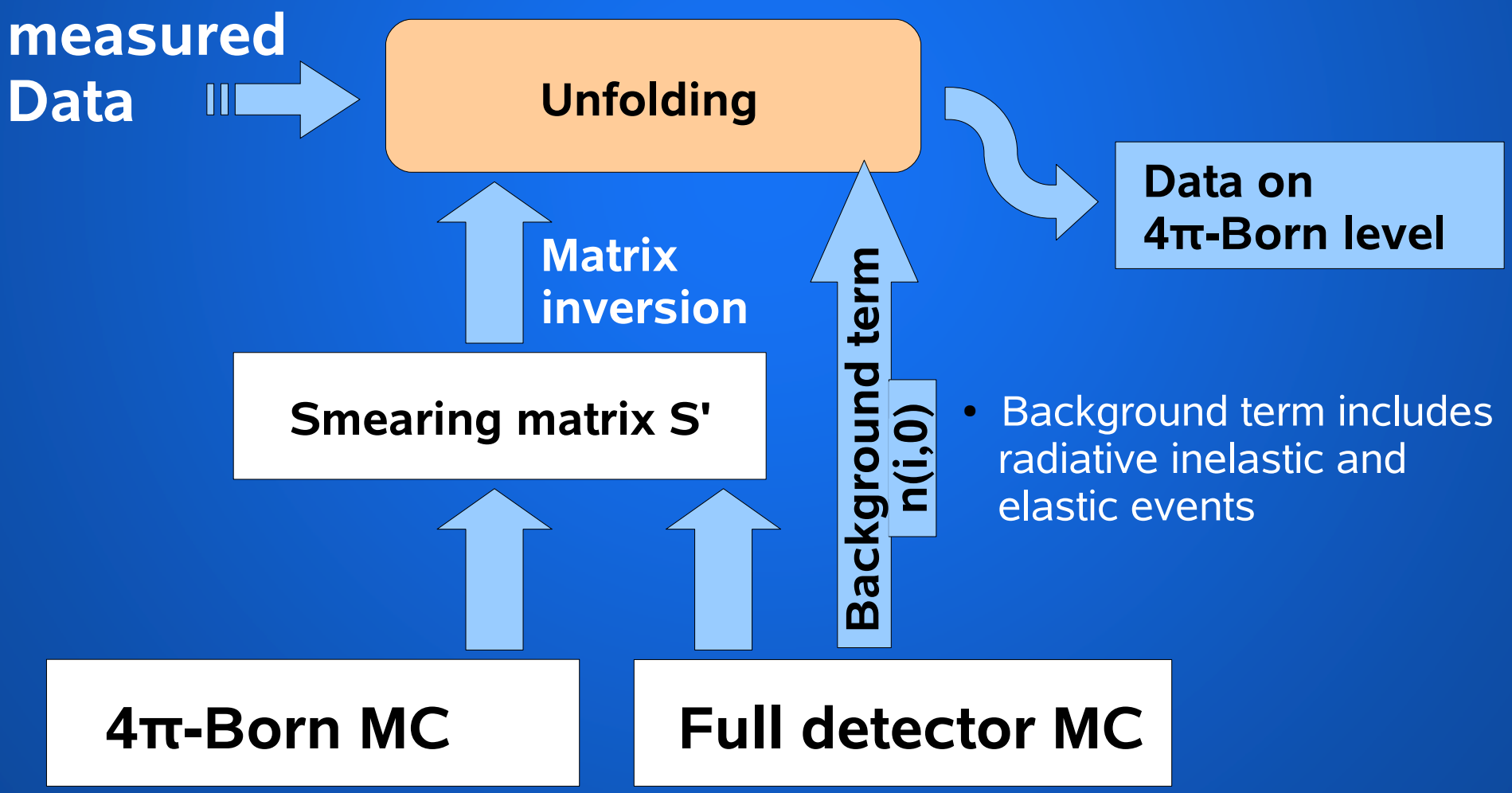
Binning in x-Q^2



Diagonal elements on migration matrix, measured bin = Born level bin

Migration into acceptance from outside n(i,0), i>0

Unfolding of kinematic bin migration



- Background term includes radiative inelastic and elastic events

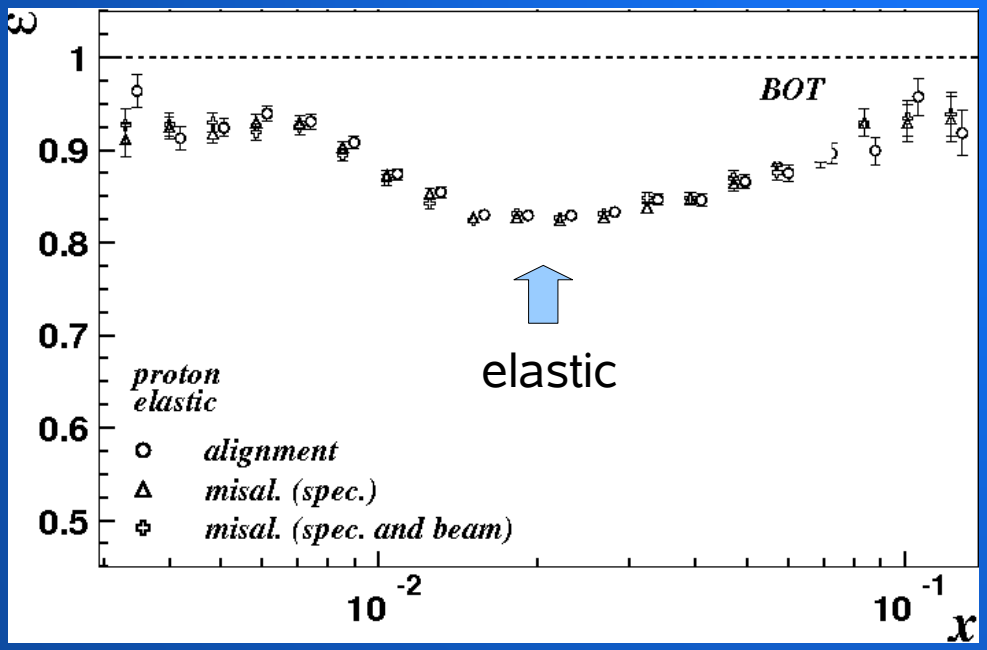
Simulation of true cross section
No radiative effects
No tracking

Detector material (GEANT4)
Radiative effects
Tracking

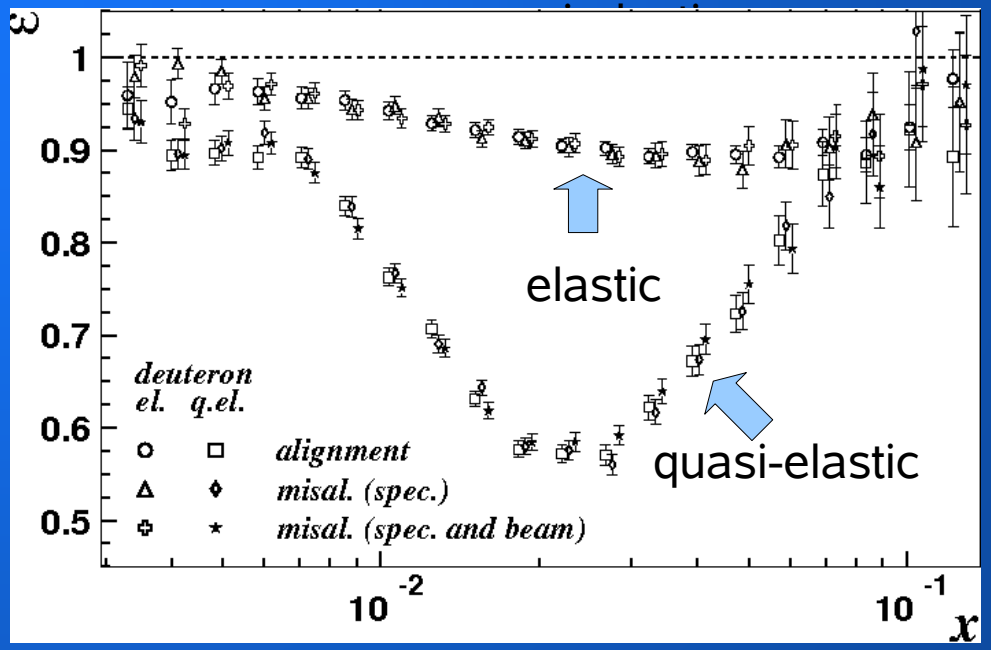
Bethe-Heitler efficiencies

- Bethe-Heitler efficiencies **extracted from MC** for proton and deuteron

Proton

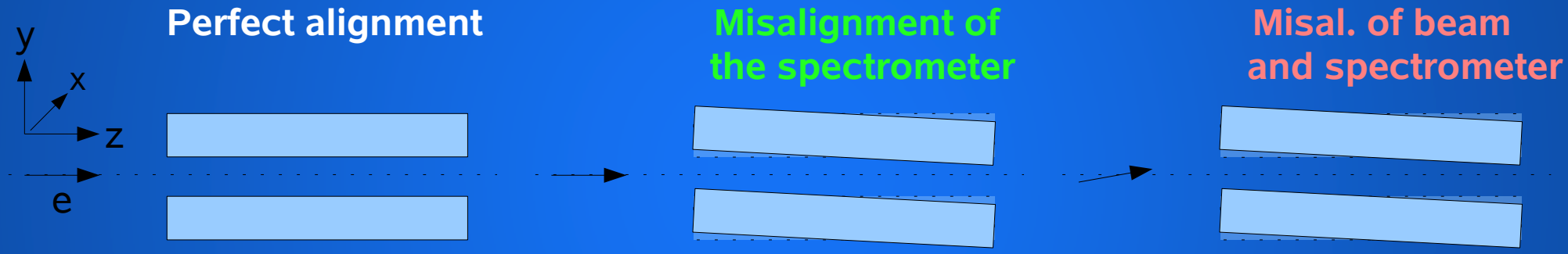


Deuteron



- Bethe-Heitler efficiencies are relevant for unfolding

Misalignment



- **Ideal situation**: Perfect alignment of beam and spectrometer
- In practice:
  - Top and bottom parts of **spectrometer** displaced
  - **Beam position** differs from nominal position

Simulation of misalignment in Monte Carlo

- Assignment of uncertainty according to MC predictions

$$\left| \frac{\sigma_{misaligned}}{\sigma_{aligned}} - 1 \right|$$

Systematic uncertainties on σ^p,σ^d

- Which systematic uncertainties are assigned.

δ_{PID} : PID misidentification
typically ~ 1%

$\delta_{rad.}$: Unc. of BH efficiencies due to misalignment
$\lesssim$ 1%

δ_{mis} : Misalignment effect on DIS events
~ 7%

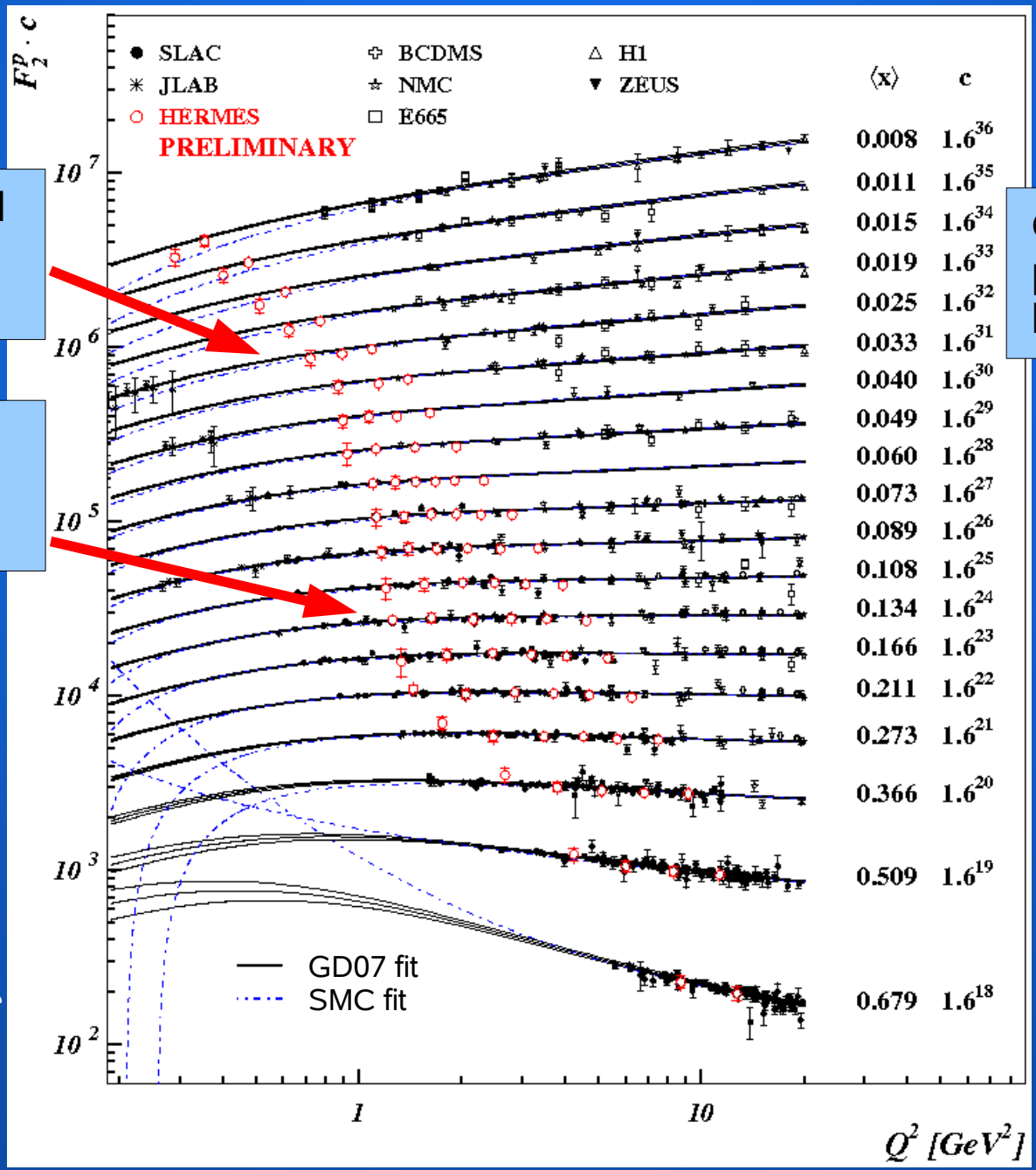
δ_{nor} : Overall normalization unc.: Luminosity
δ^p_{nor} = 6.4 % δ^d_{nor} = 6.6 %

Results on F_2^p

Proton

New region covered by HERMES

Agreement with world data in the overlap region



GD07 fit hep-ph 0708.3196
SMC fit Phys. Rev. D, Vol. 58, 112001

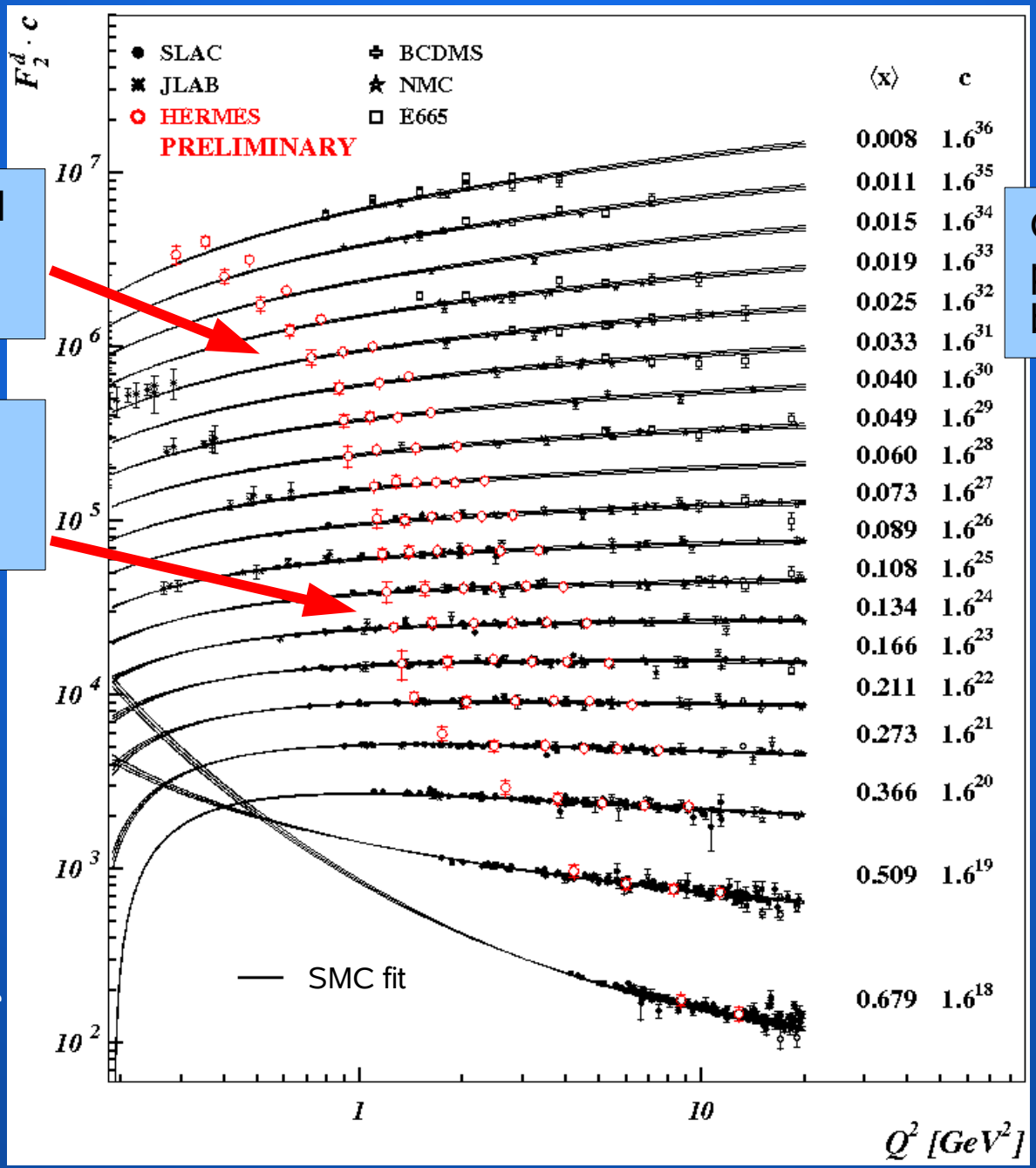
Comparison with parameterization by SMC and GD07

Results on F_2^d

Deuteron

New region covered by HERMES

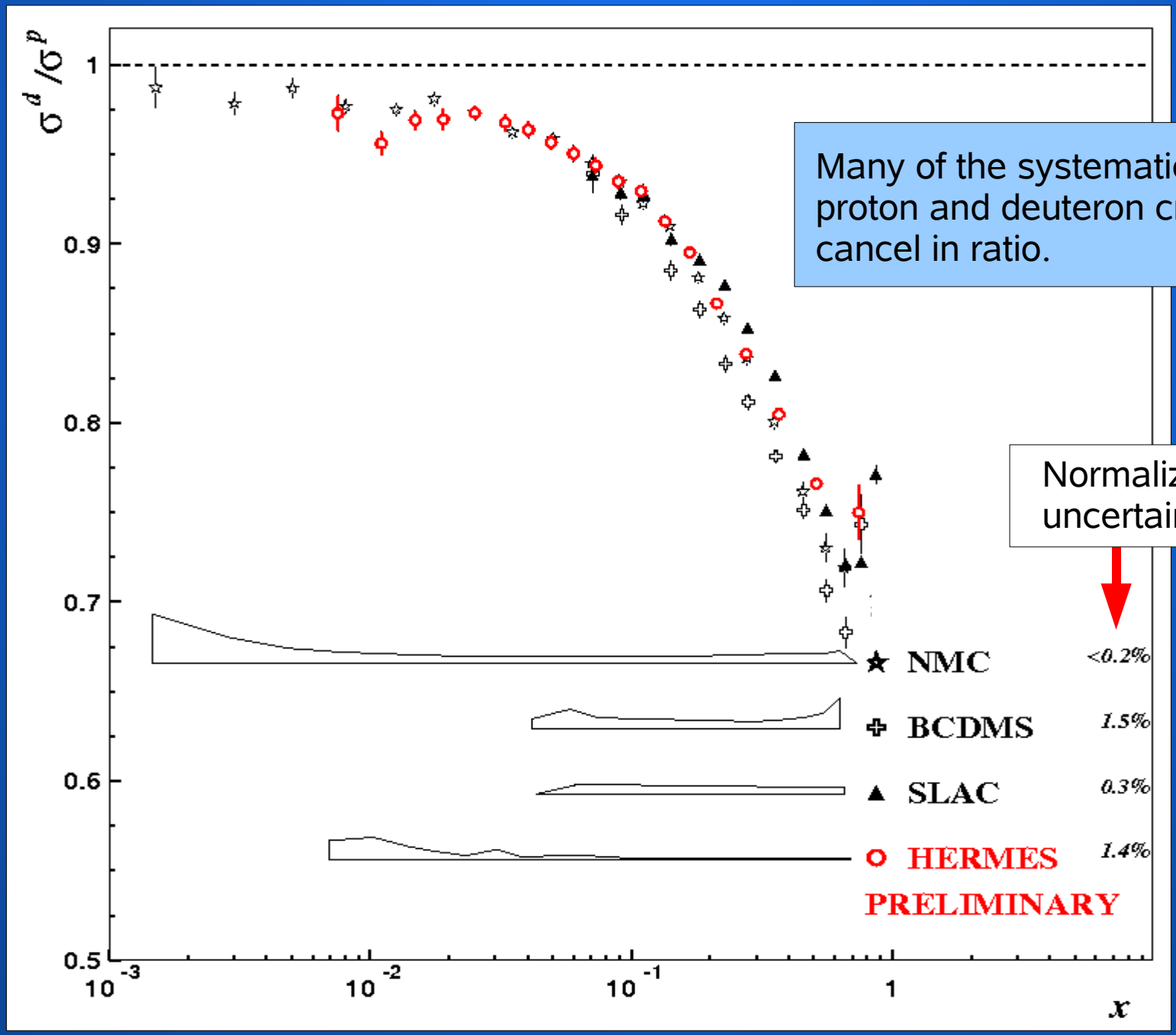
Agreement with world data in the overlap region



SMC fit Phys. Rev. D, Vol. 58, 112001

Comparison with parameterization by SMC

World data on σ^d/σ^p



Many of the systematics common to proton and deuteron cross sections cancel in ratio.

Normalization uncertainties

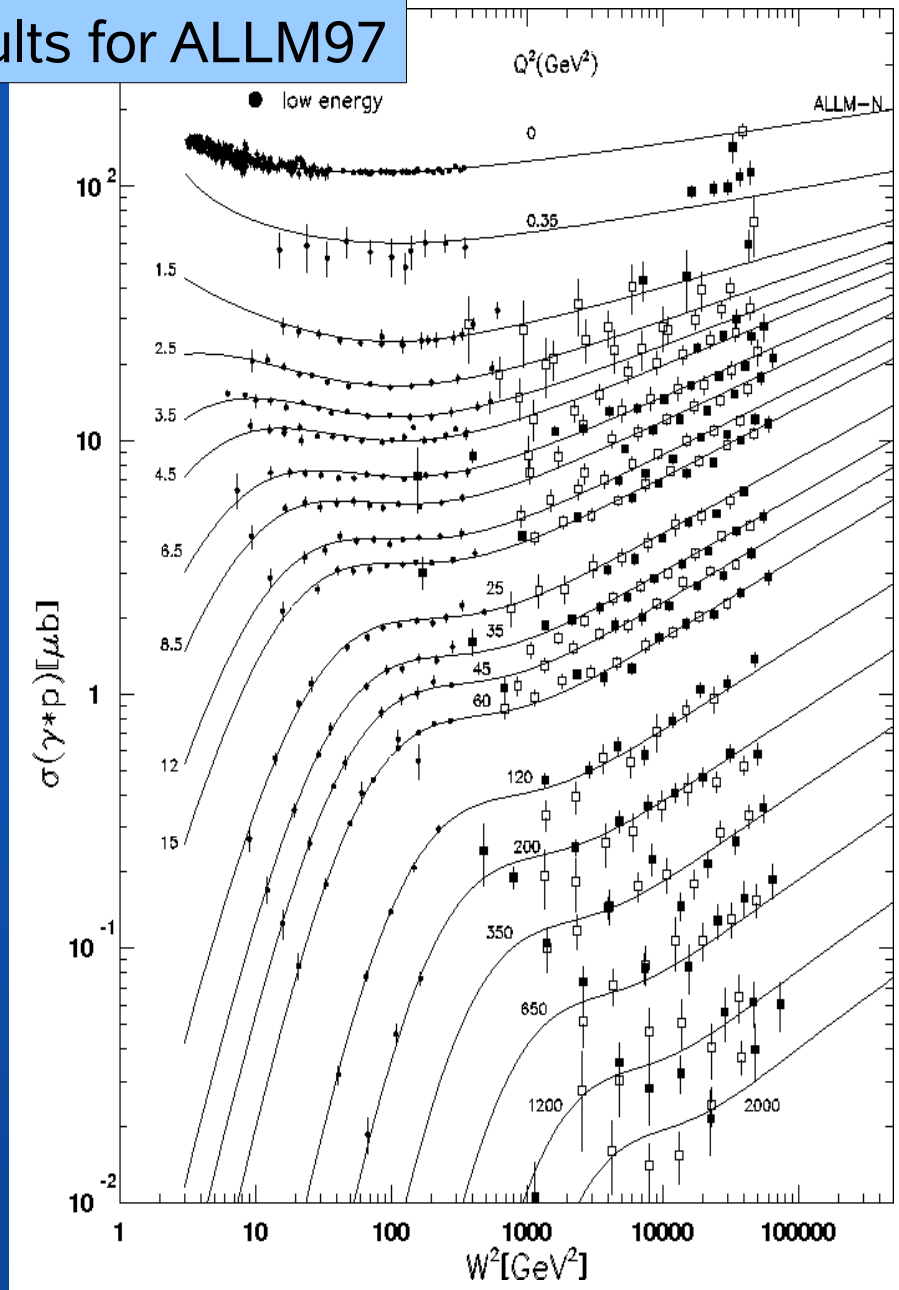
Summary

- **First measurement at HERMES of the**
  - Inclusive DIS cross sections σ^p, σ^d,
  - the structure functions F_2^p and F_2^d and
  - the cross section ratio σ^d/σ^p
- Outlook:
  - New fit to world data including HERMES
  - Extraction of the Gottfried integral
  - Extraction of the valence quark ratio

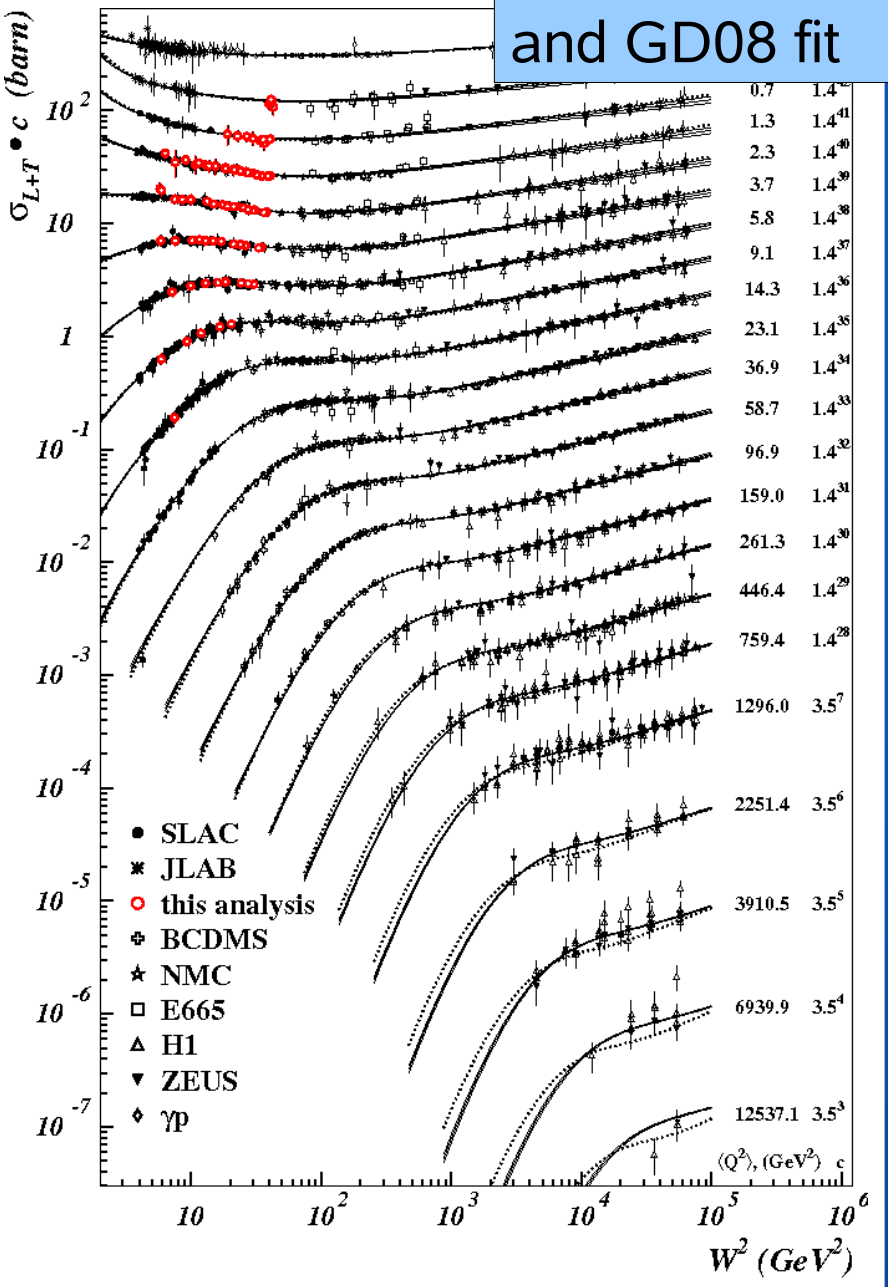
Backup slides

World data and fits

World data and fit results for ALLM97

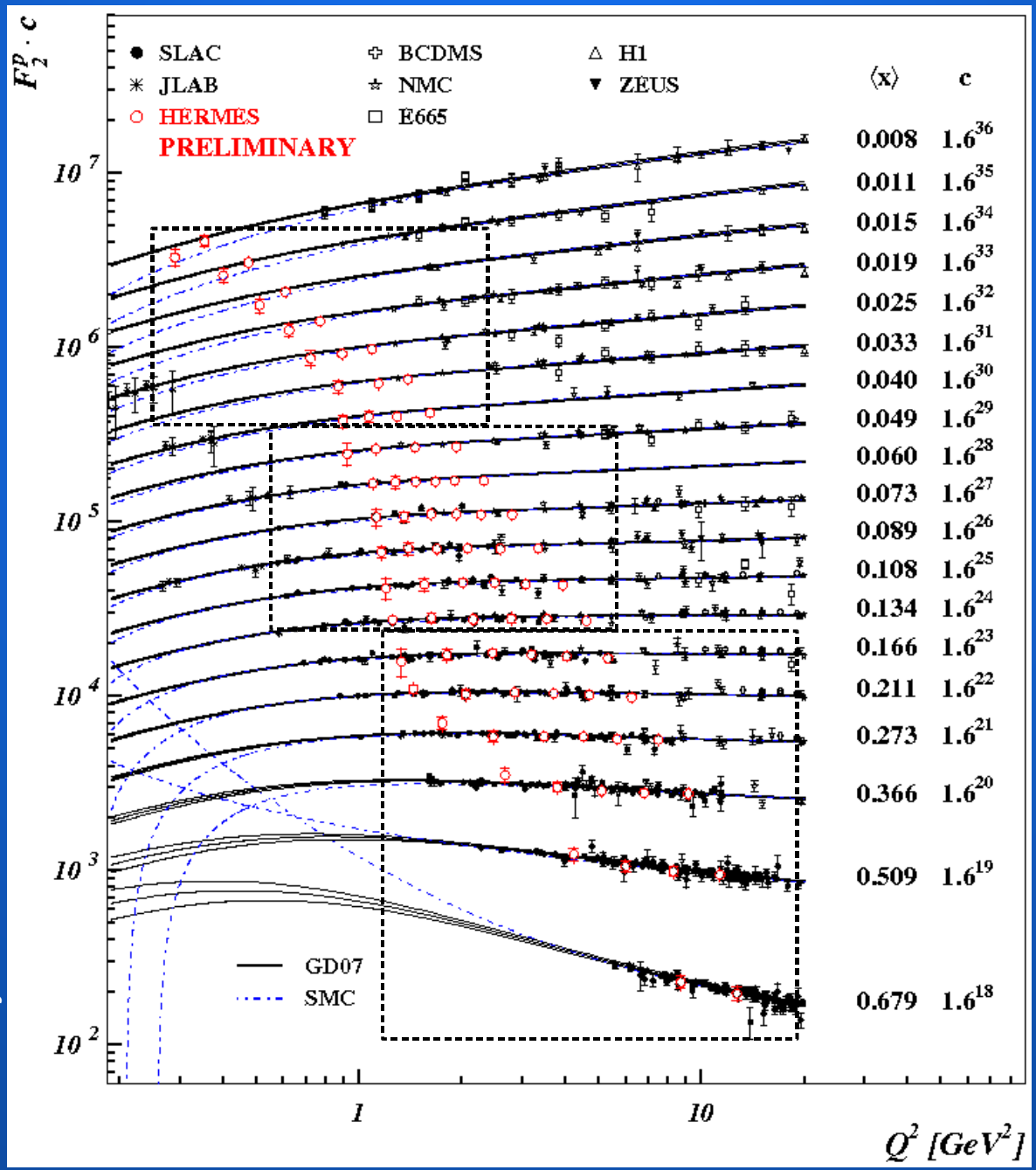


Current World data and GD08 fit



Results on F_2^p

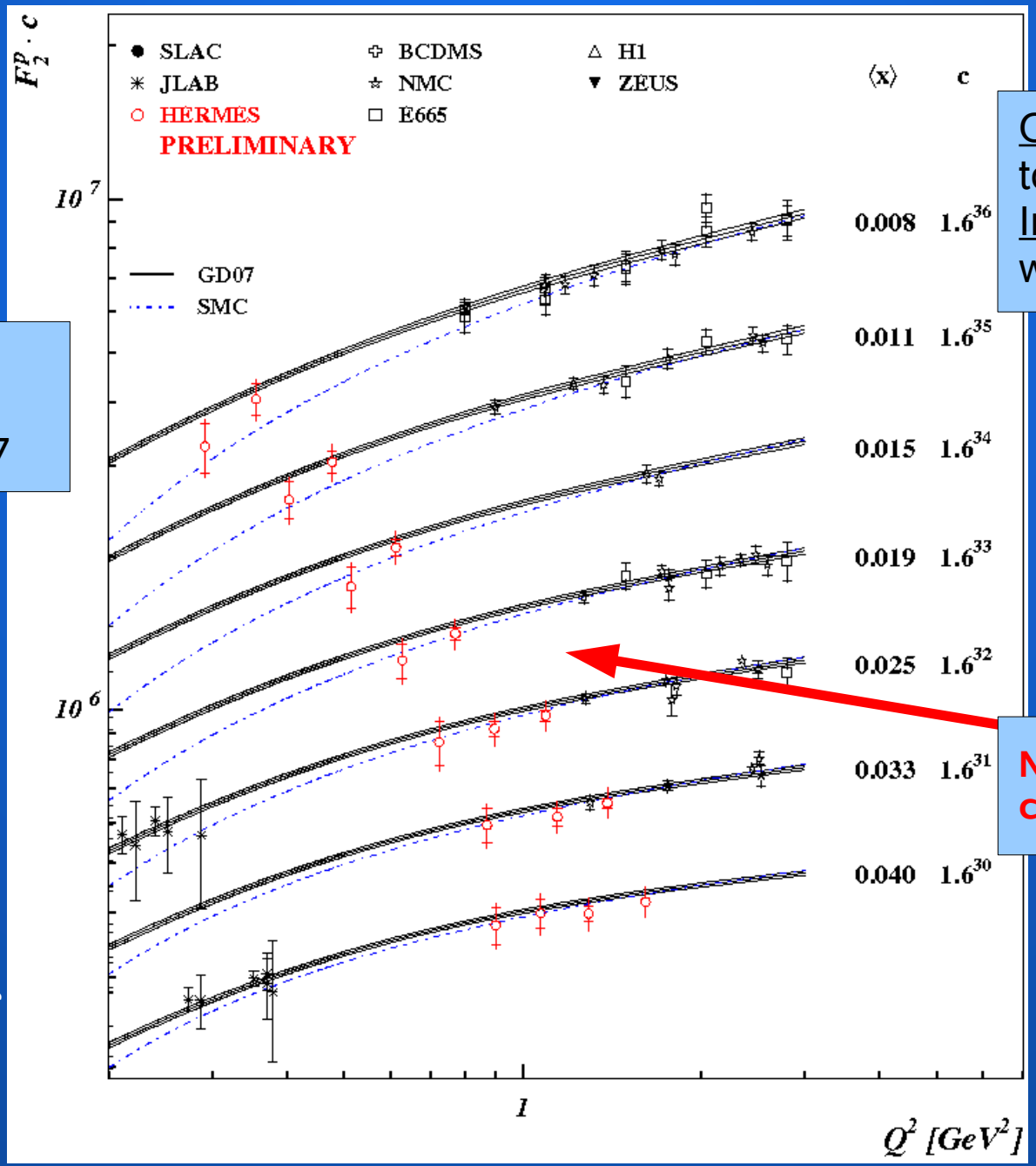
Proton



GD07 fit hep-ph 0708.3196
SMC fit Phys. Rev. D, Vol. 58, 112001

Results on F_2^p

Proton



Comparison with parameterizations by SMC and GD07

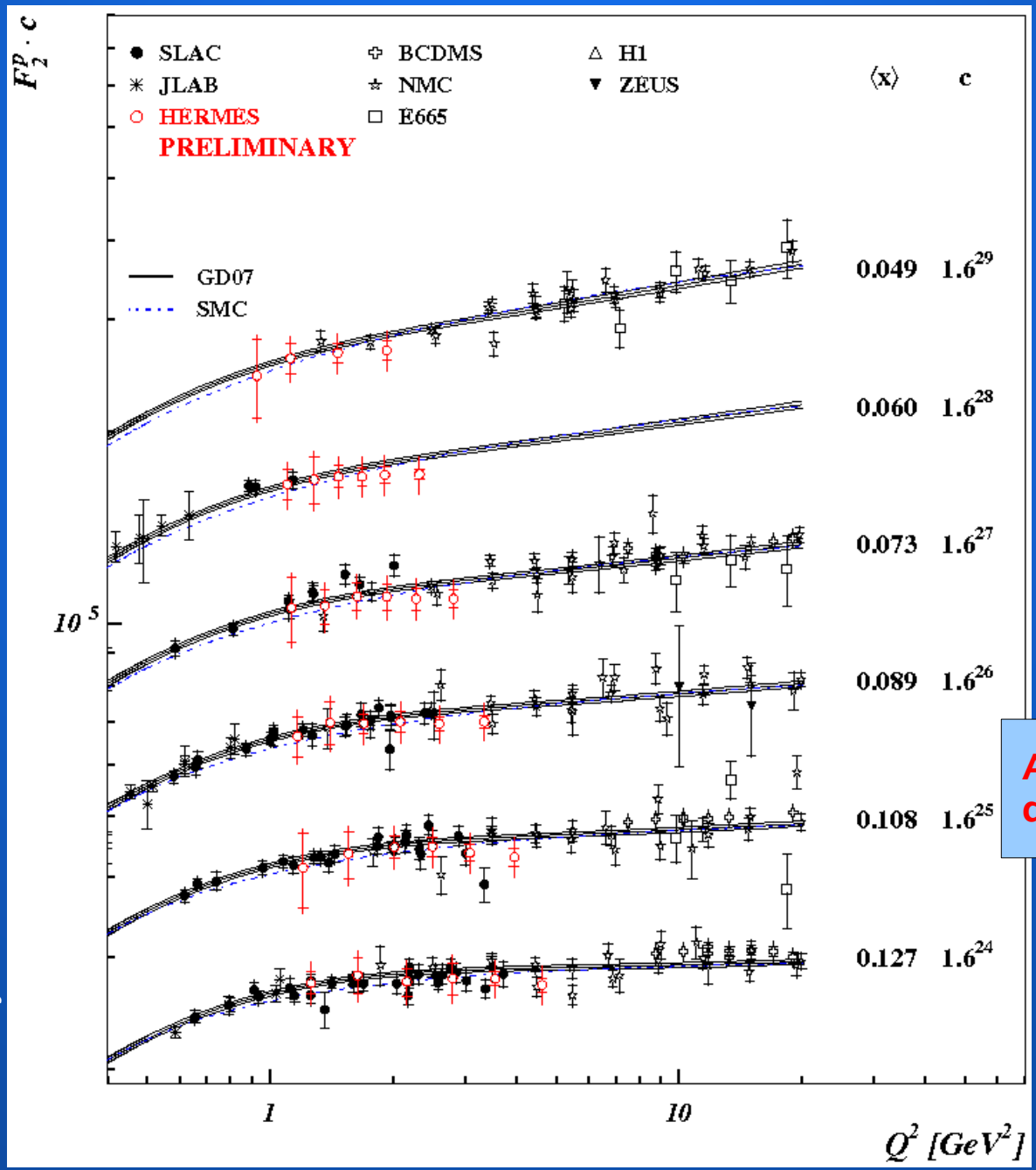
GD07 fit hep-ph 0708.3196
SMC fit Phys. Rev. D, Vol. 58, 112001

Outer error bars;
total uncertainties
Inner error bars;
without normaliz. unc.

New kinematic region covered by HERMES

Results on F_2^p

Proton

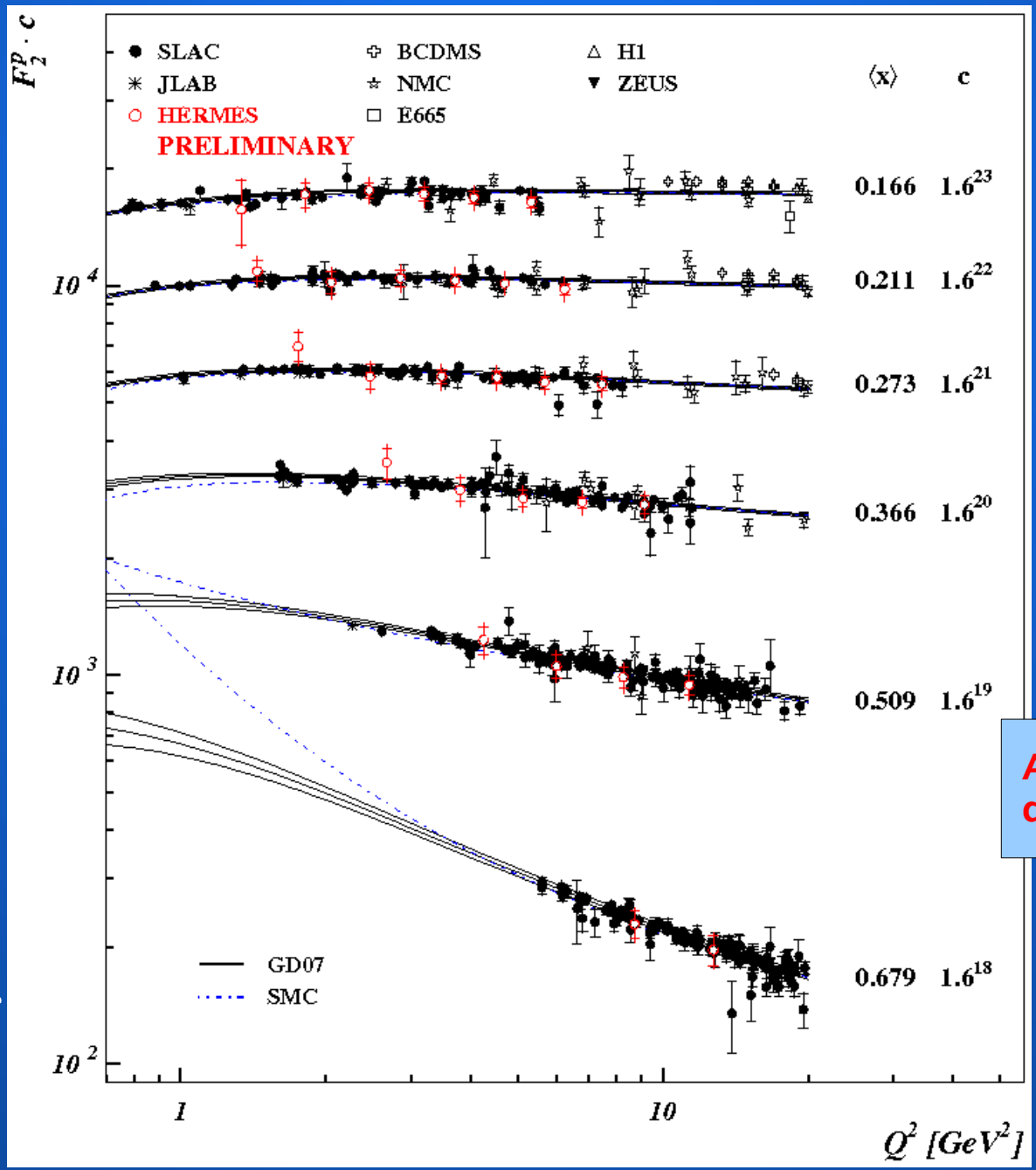


GD07 fit hep-ph 0708.3196
SMC fit Phys. Rev. D, Vol. 58, 112001

Agreement with world data in overlap region

Results on F_2^p

Proton



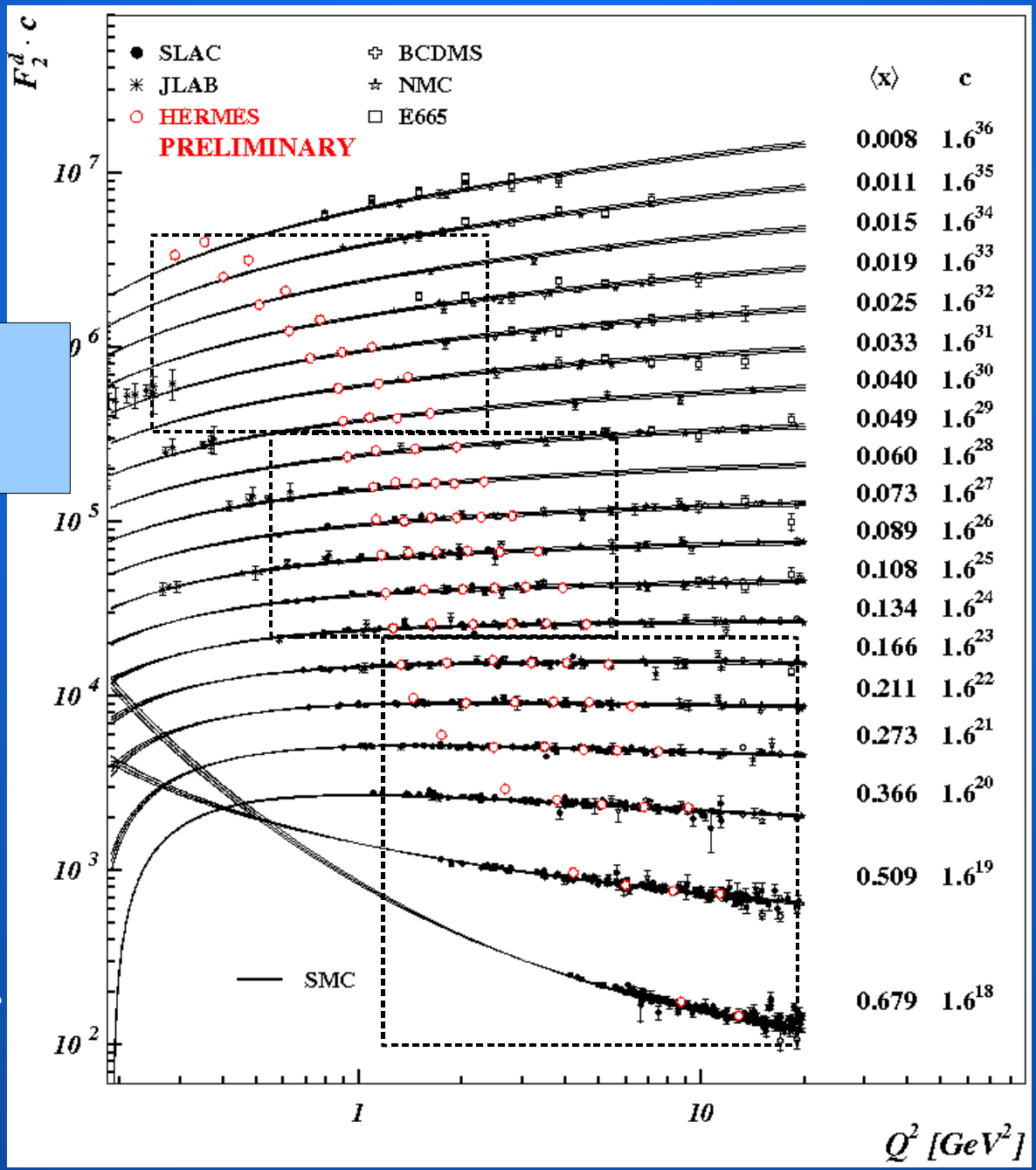
GD07 fit hep-ph 0708.3196
SMC fit Phys. Rev. D, Vol. 58, 112001

Agreement with world data in overlap region

Results on F_2^d

Deuteron

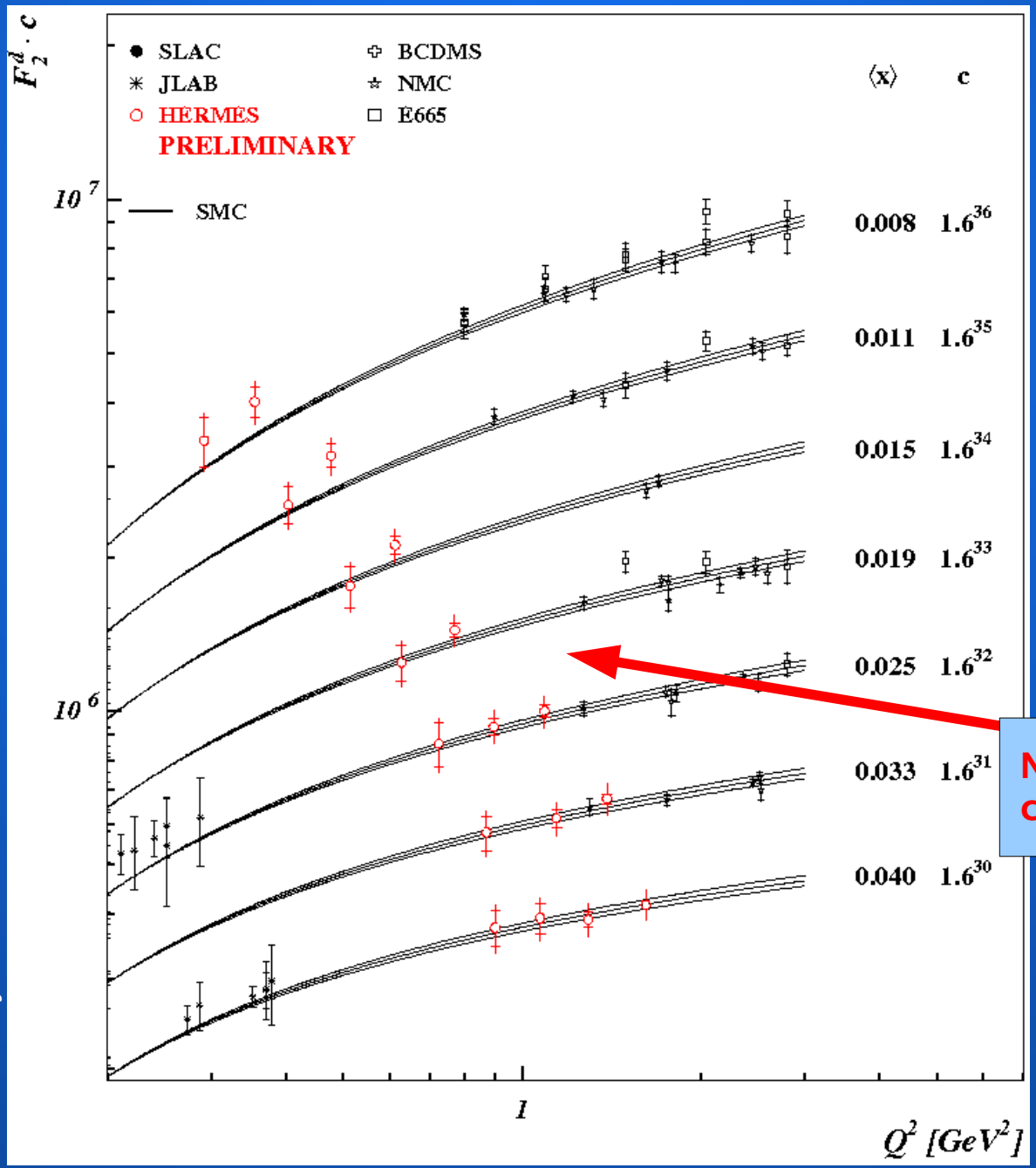
Comparison with parameterization by SMC



SMC fit Phys. Rev. D, Vol. 58, 112001

Results on F_2^d

Deuteron

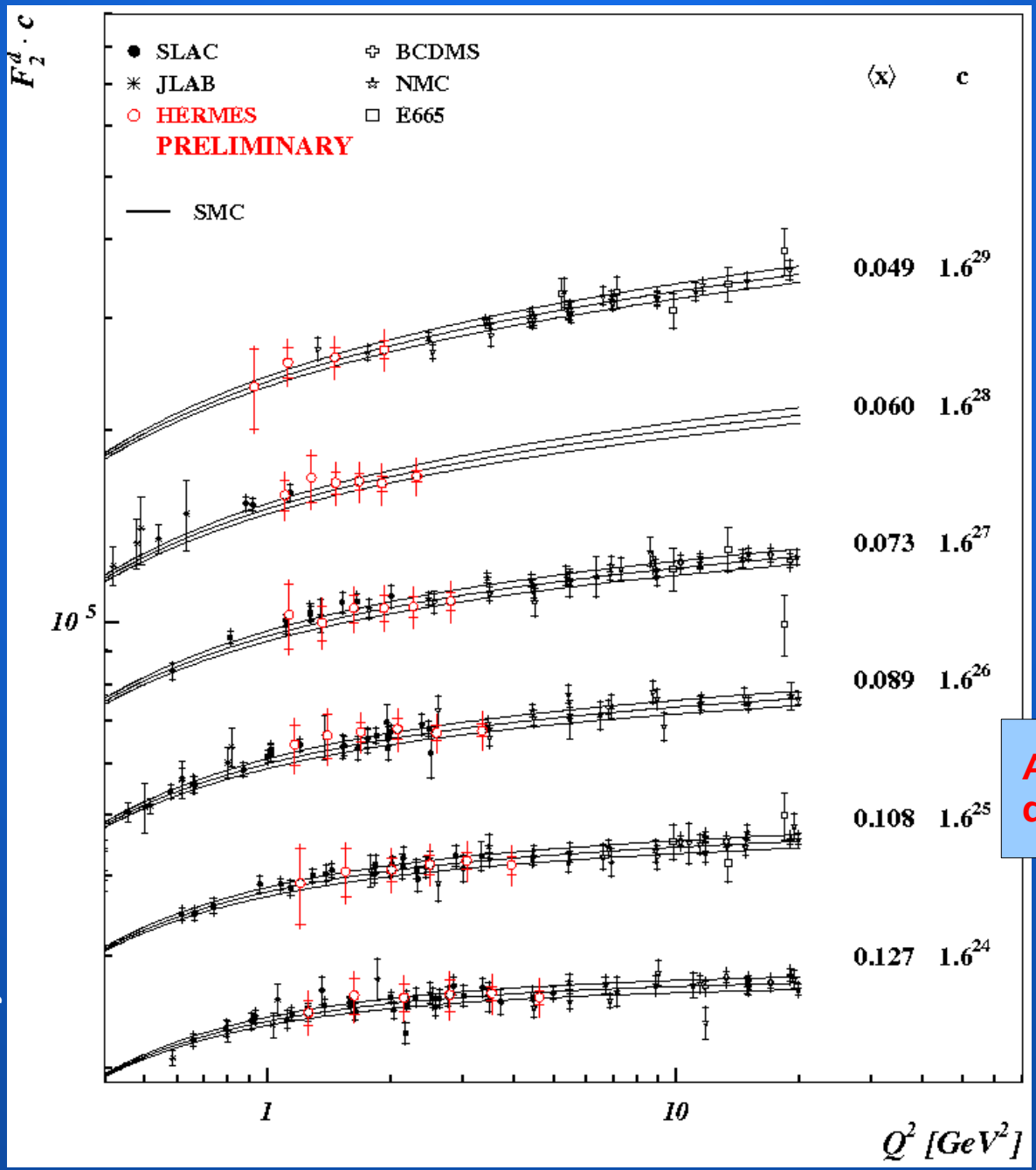


New kinematic region covered by HERMES

SMC fit Phys. Rev. D, Vol. 58, 112001

Results on F_2^d

Deuteron

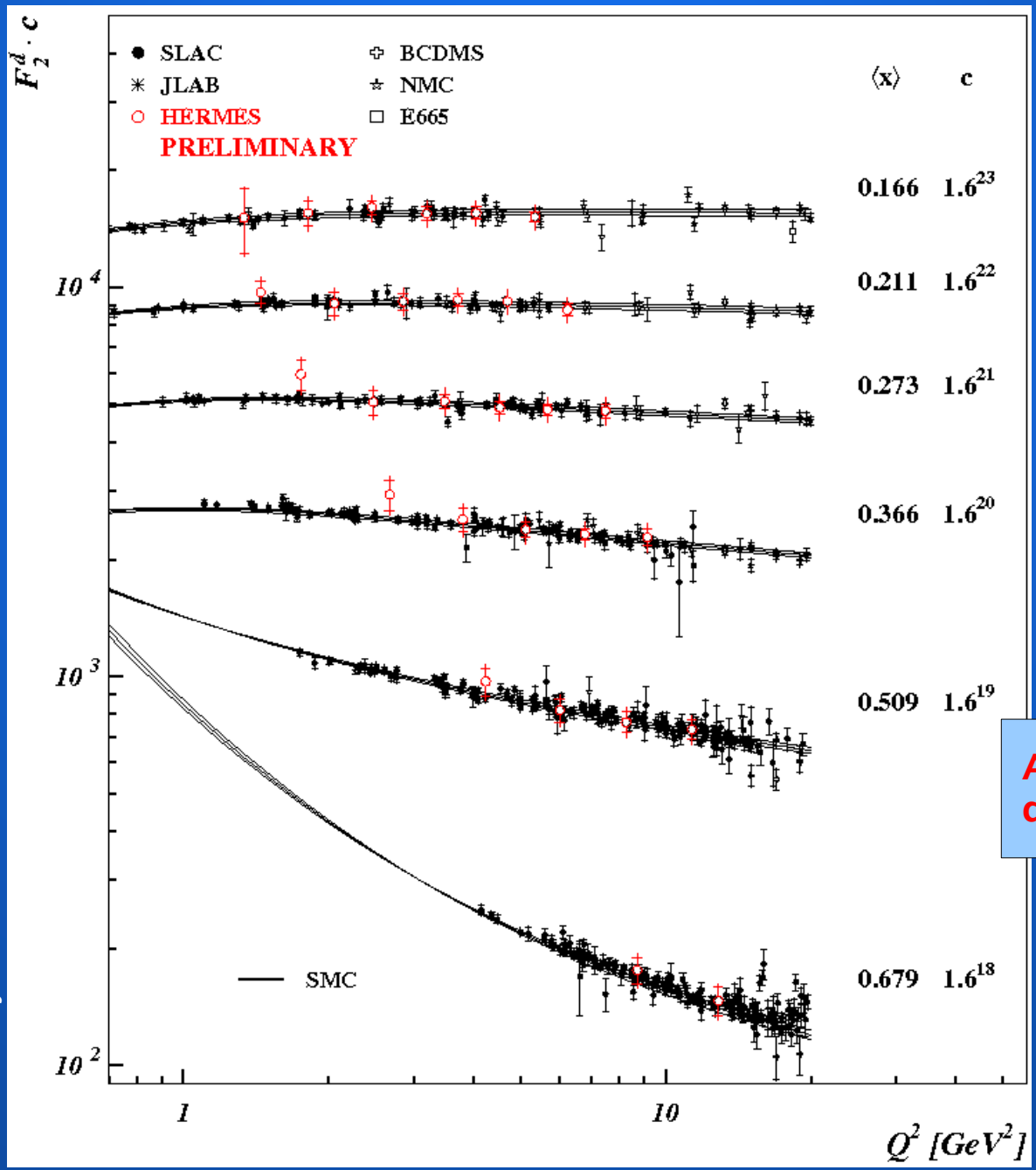


SMC fit Phys. Rev. D, Vol. 58, 112001

Agreement with world data in overlap region

Results on F_2^d

Deuteron



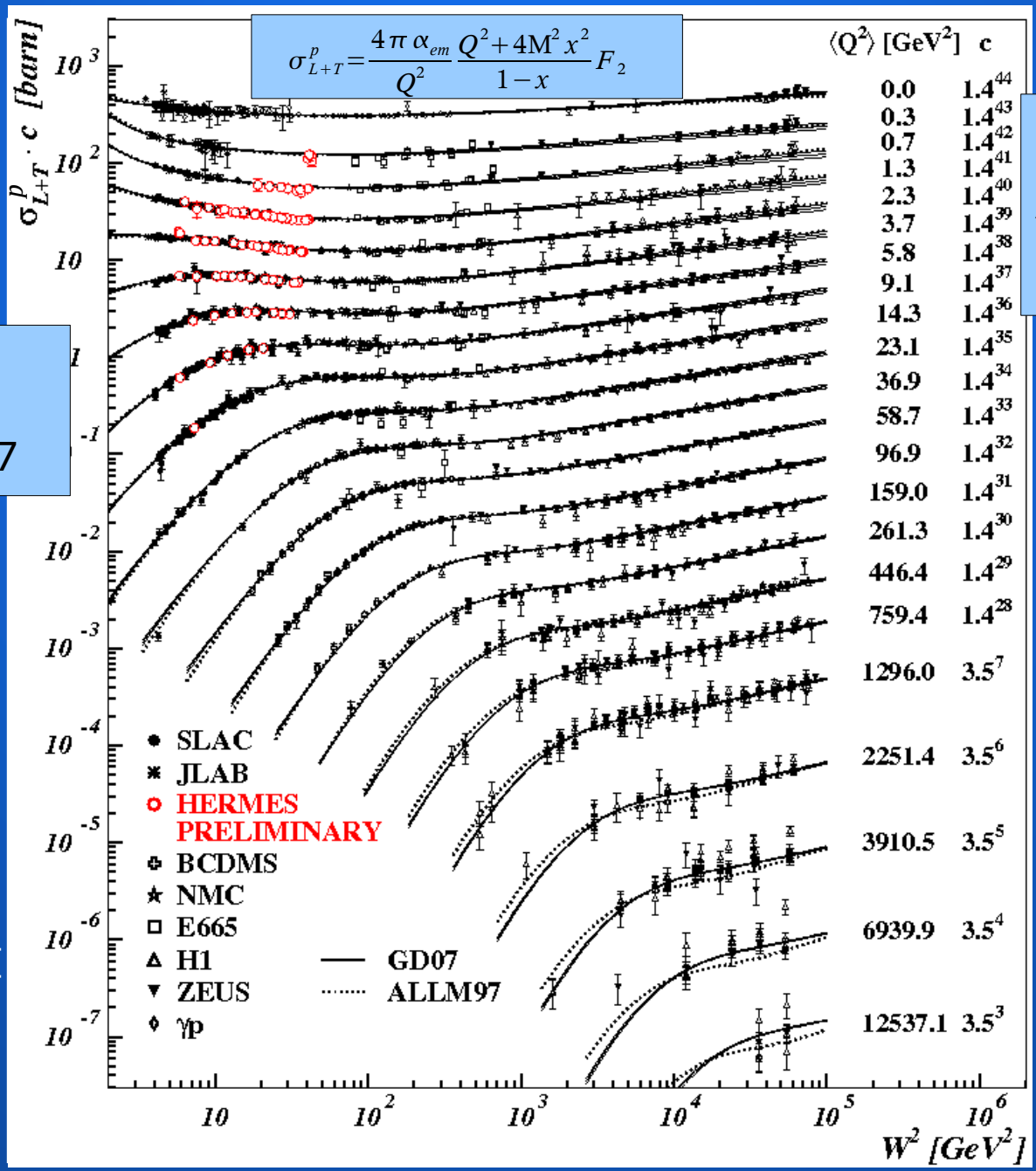
SMC fit Phys. Rev. D, Vol. 58, 112001

Agreement with world data in overlap region

Results on $\sigma^p_{L+T} = \sigma^p_L + \sigma^p_T \sim F_2$

Proton

Comparison with parameterizations ALLM97 and GD07



GD07 fit hep-ph 0708.3196
ALLM97 fit hep-ph/9712415

Quantity for which ALLM97 and GD07 are parameterizations