Charmonium *A*-Dependence at HERA-B

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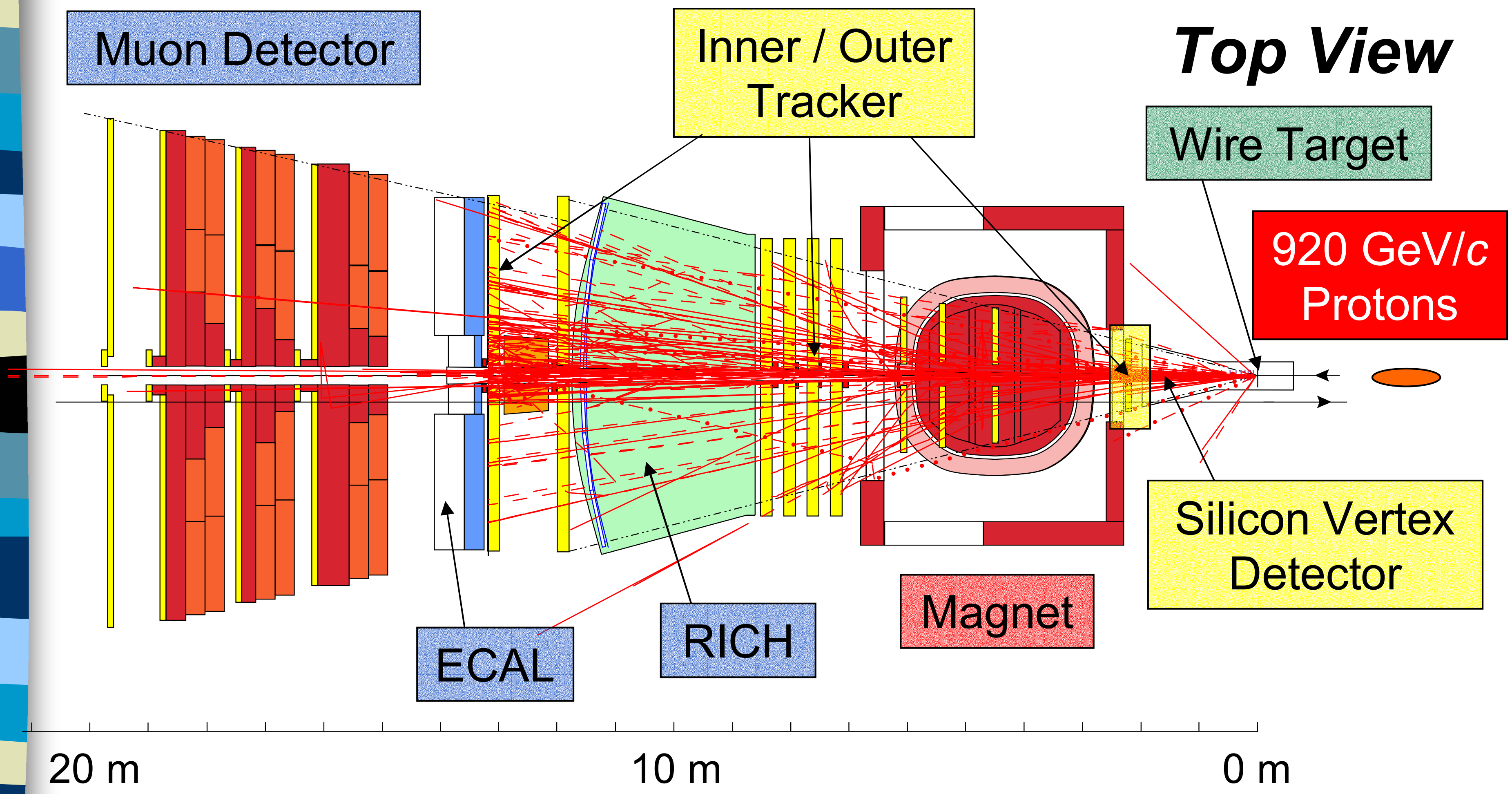
Ulrich Husemann

for the HERA-B Collaboration

husemann@hep.physik.uni-siegen.de

Experimentelle Teilchenphysik, Universität Siegen

The HERA-B Detector



The Di-Lepton Trigger

HERA-B detector: data is read out and buffered for 10 μs
(proton bunches cross every 96 ns, 0.5 interactions/BX)

5 MHz

Pretriggers: ECAL clusters or hit coincidences in
Muon Detector as trigger seeds (custom hardware)

3 MHz

First Level Trigger (FLT): Track trigger in custom hardware
using tracking detectors behind magnet

20 kHz

Second Level Trigger (SLT): FLT tracking confirmed,
extrapolation to Vertex Detector, vertex fit (PC farm)

100 Hz

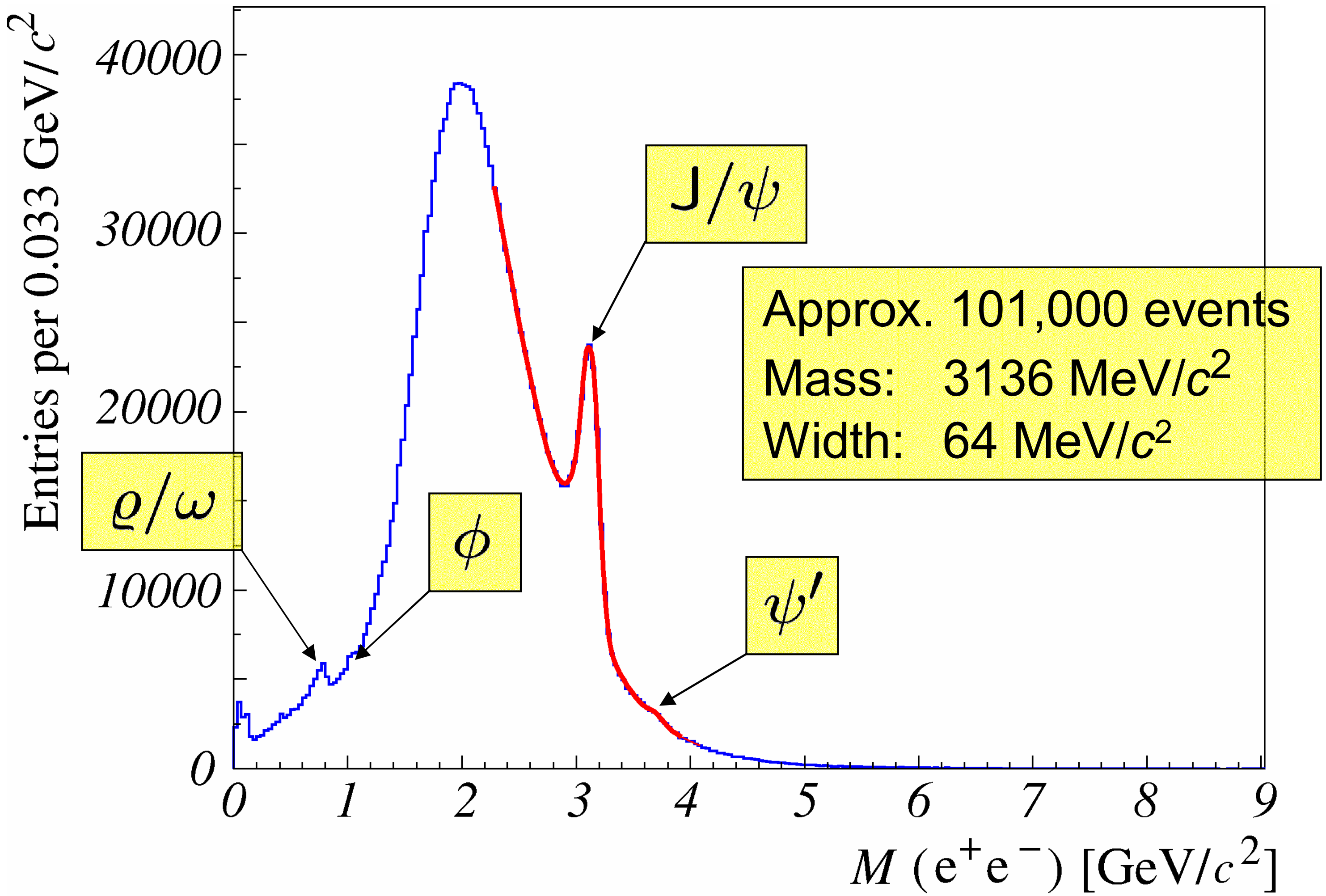
Data Set & Physics Program 2002/2003

- 3 months of data-taking in 2002/2003 (11/02 – 02/03)
- 150 million events with di-lepton trigger, ^{12}C and ^{184}W targets

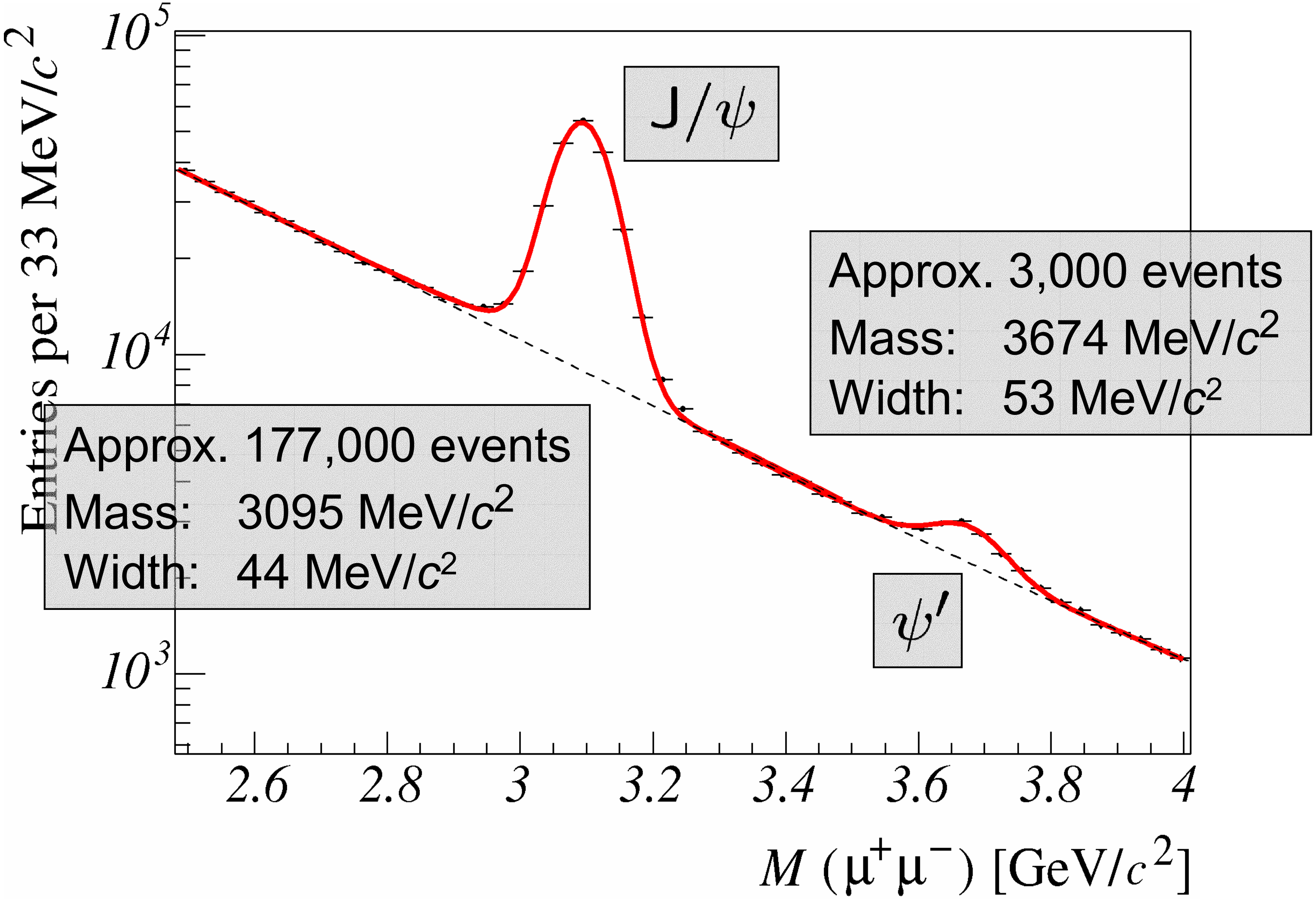
J/ψ (muon channel)	170,000
J/ψ (electron channel)	150,000

- Trigger performance: 1,000 – 1,500 J/ψ per hour (cf. data-taking in 2000: 25 – 30 h^{-1})
- Physics program for di-lepton trigger:
  A. How does the production of charmonium depend on the atomic number *A* of the target nucleus? → "*A*-dependence"
  B. What is the $b\bar{b}$ production cross-section?
  C. Charmonium production: J/ψ, ψ', χ_c (see talk by R. Spighi)
- Minimum-bias trigger: strangeness, hyperons, open charm

Di-lepton Spectrum: Electron Channel

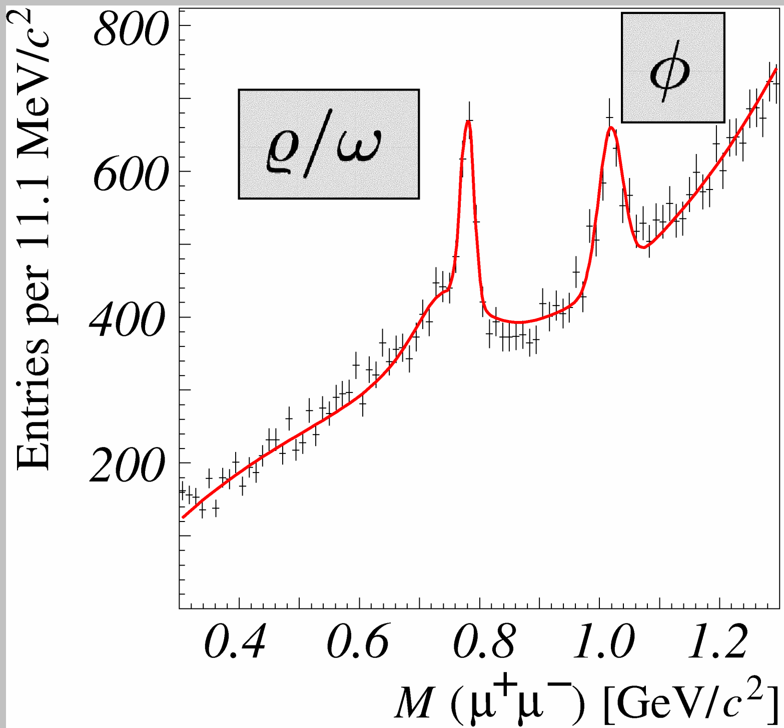


Di-lepton Spectrum: Muon Channel

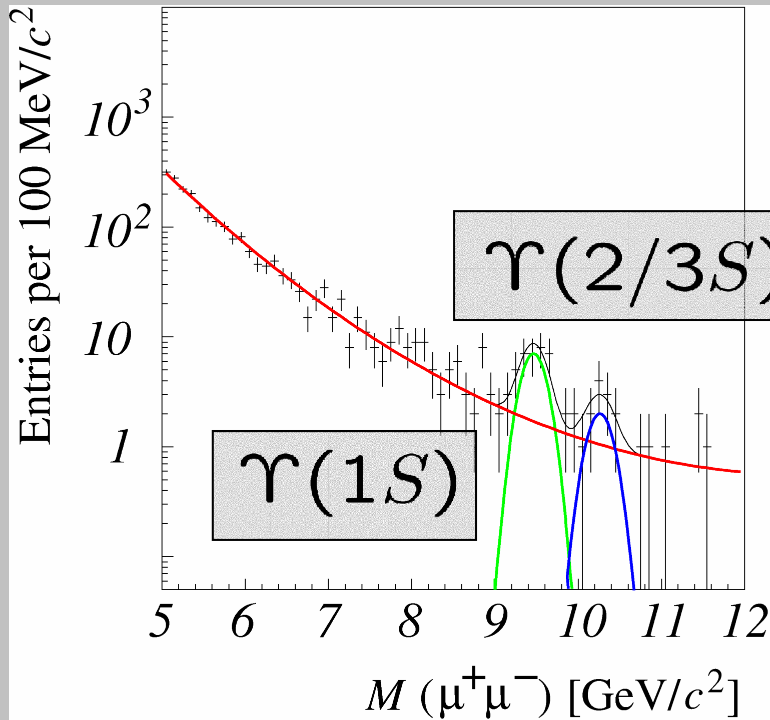


Di-lepton Spectrum: Muon Channel

Low-mass region:



High-mass region:



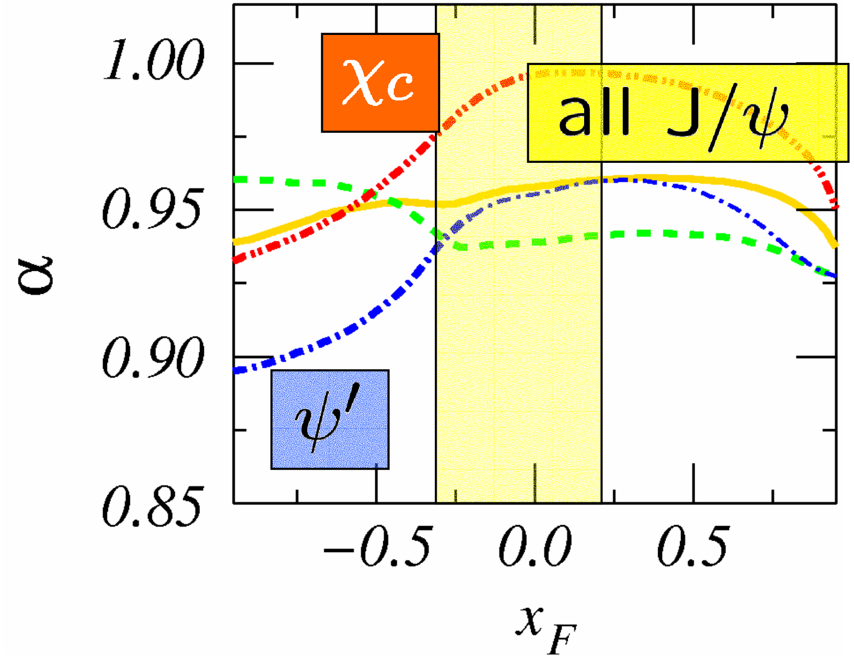
A-Dependence: Theory

- Charmonium production: theoretical models
  - Color Evaporation Model (CEM)
  - Color Singlet Model (CSM)
  - Non-relativistic QCD (NRQCD):
    color singlet & color octet contributions
  - Other models (e.g. Regge-inspired)
- Modification of models via nuclear effects
  - Initial state effects: shadowing, energy loss, p_T broadening by multiple scattering
  - Final state effects: absorption in nuclear matter, co-mover interaction
  - Parametrization: power law with exponent $\alpha = \alpha(x_F, p_T)$

$$\boxed{\sigma_{\mathrm{pA}} = \sigma_{\mathrm{pN}} \cdot A^{\alpha}}$$

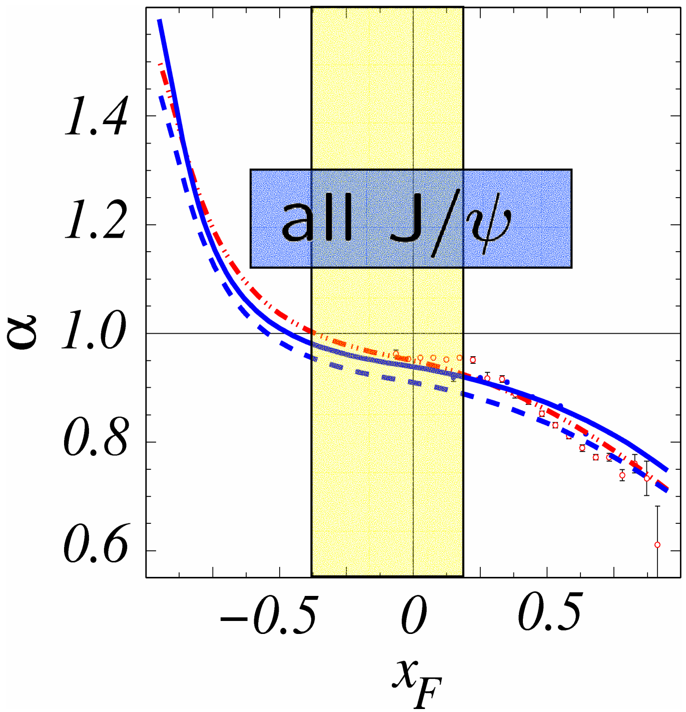
Theory: Predictions

- Prediction 1: NRQCD + nuclear absorption



R. Vogt,
Nucl. Phys. **A700** (2002) 539

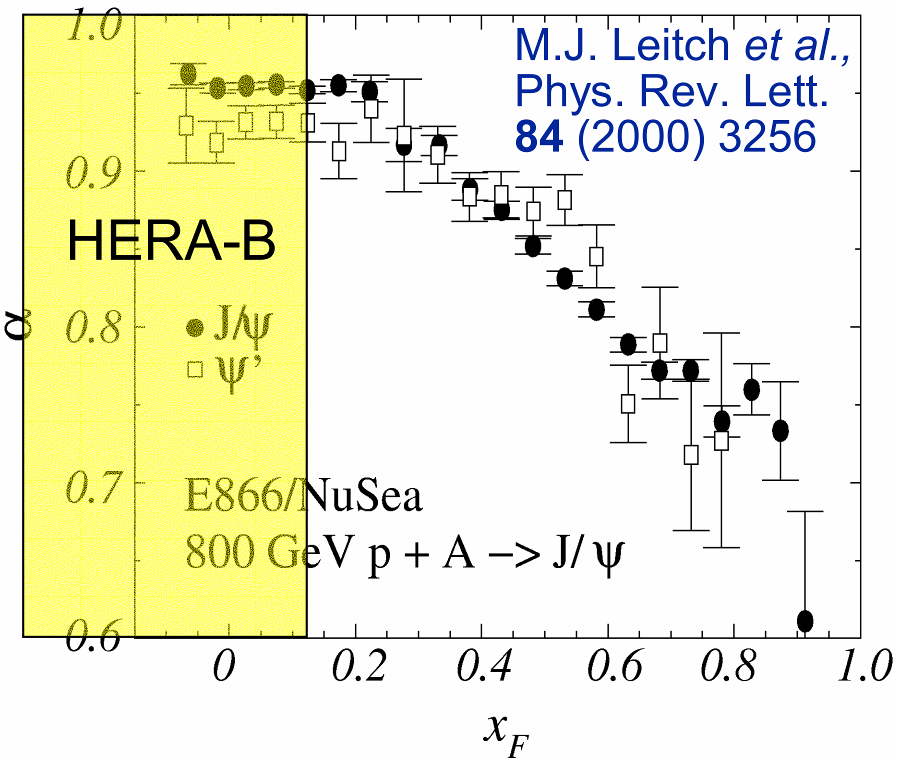
- Prediction 2: BCKT (Reggeon-based)



K.G. Boreskov, A.B. Kaidalov,
JETP Lett. **77** (2003) 599

A-Dependence: HERA-B's Contribution

Measurements in proton-nucleus scattering (Fermilab E866/NuSea) as a function of x_F



HERA-B:

- Extend to $x_F \approx -0.3$
- Triggering 2 channels simultaneously: e, μ
- 2 materials simultaneously (C, W) → control systematics
- New: χ_c *A*-dependence

Analysis Chain

- Parametrization: $\sigma_{\mathrm{pA}} = \sigma_{\mathrm{pN}} A^{\alpha}, \quad \sigma = N/\varepsilon\mathcal{L}$

  → α can be determined from measurements with two materials, in HERA-B: two-wire running

$$\alpha = \frac{1}{\log(A_1/A_2)} \log\left(\frac{N_1}{N_2}\frac{\mathcal{L}_2}{\mathcal{L}_1}\frac{\varepsilon_2}{\varepsilon_1}\right)$$

- 3 ingredients of *A*-dependence measurement:

  1: Ratio of J/ψ yields

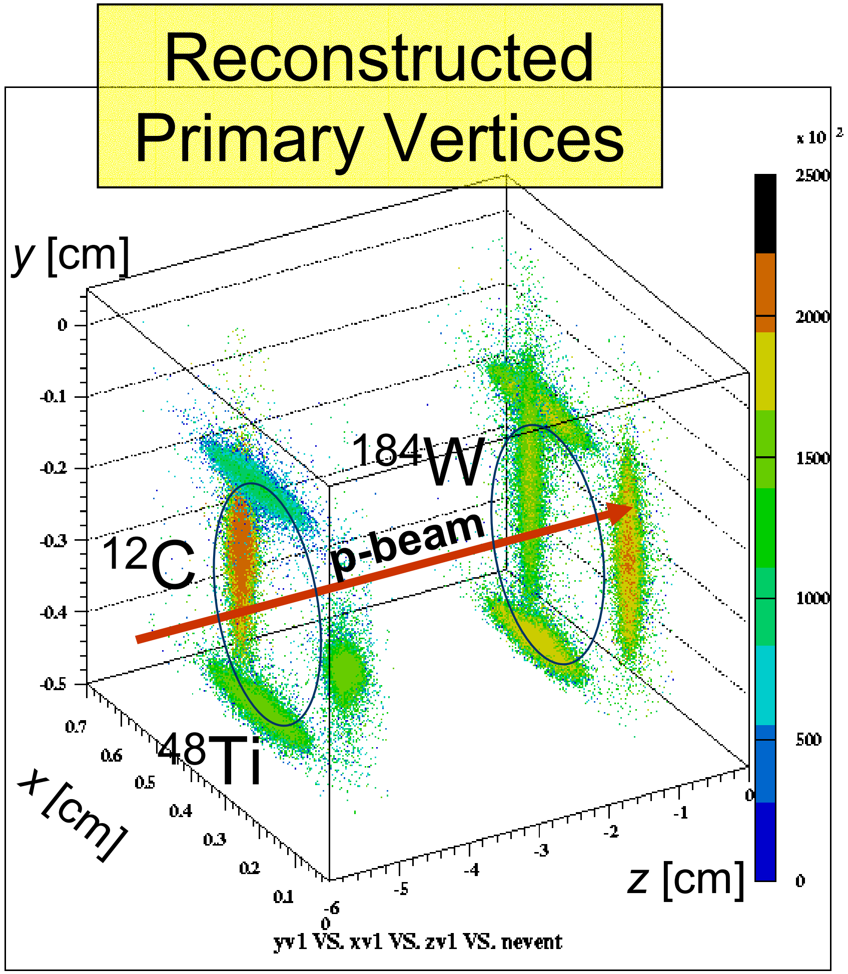
  2: Ratio of luminosities

  3: Ratio of efficiencies

Data Samples for *A*-Dependence Analysis

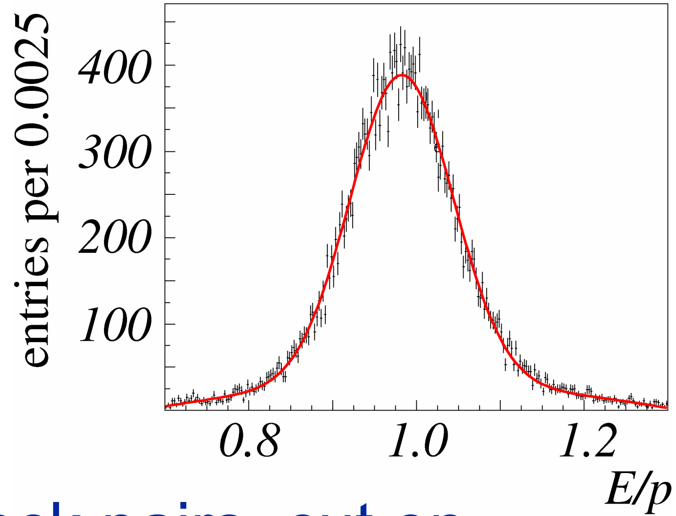
- Target: 2 stations with 4 wires each
- 3 different combinations of Carbon/Tungsten wires
  - Approx. 150,000 J/ψ
  - Different systematic effects (mainly acceptance)
- Sample w/o *A*-dependence for cross-checks: 2× Carbon, approx. 35,000 J/ψ

→ This talk: preliminary results on Carbon/Tungsten combination from same station



J/ψ Yield

- Selection of muons:
  - "Long" tracks crossing Vertex Detector and Main Tracker, confirmed by Muon Detector
  - Kinematics: 6 GeV/c < p < 460 GeV/c, p_T > 0.6 GeV/c
- Selection of electrons:
  - Tracks crossing Vertex Detector & Main Tracker, combined with ECAL cluster
  - Cuts on track-cluster matching, E_T, cluster shape, and E/p

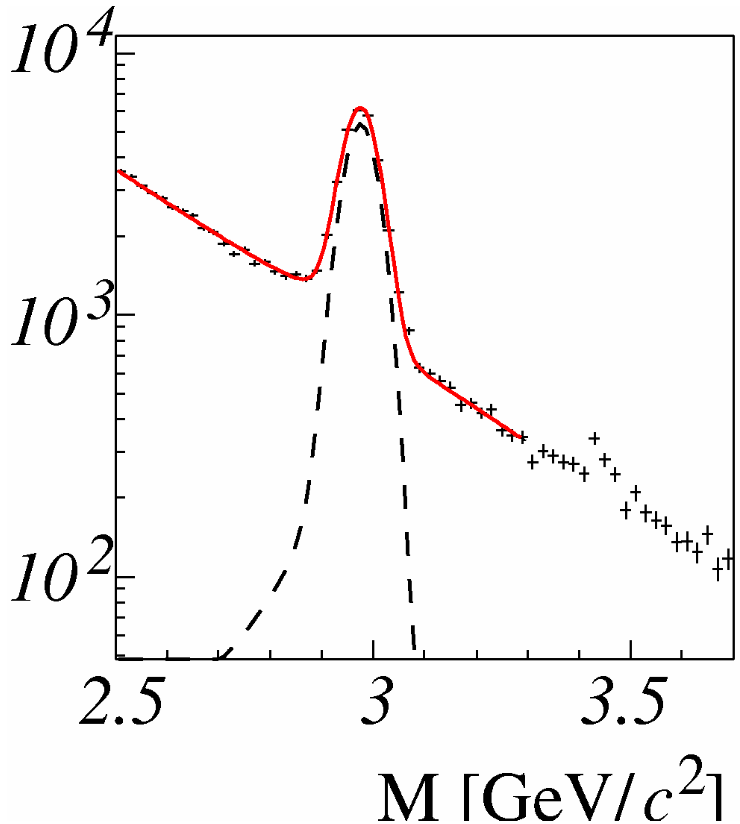


- Vertex fit of opposite-charge track pairs, cut on minimum χ^2-probability of vertex

Fit to Di-Muon Spectrum

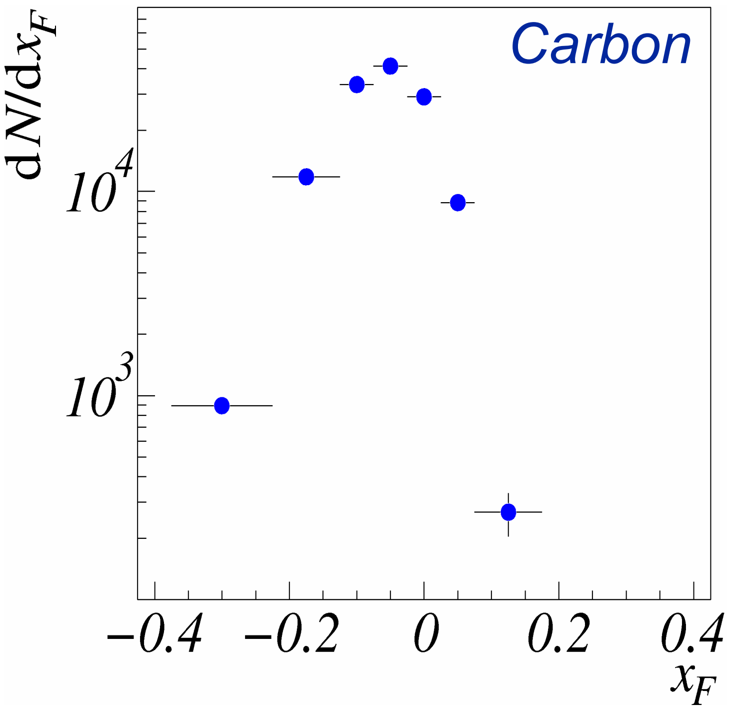
Number of J/ψ from maximum likelihood fit to invariant mass spectrum:

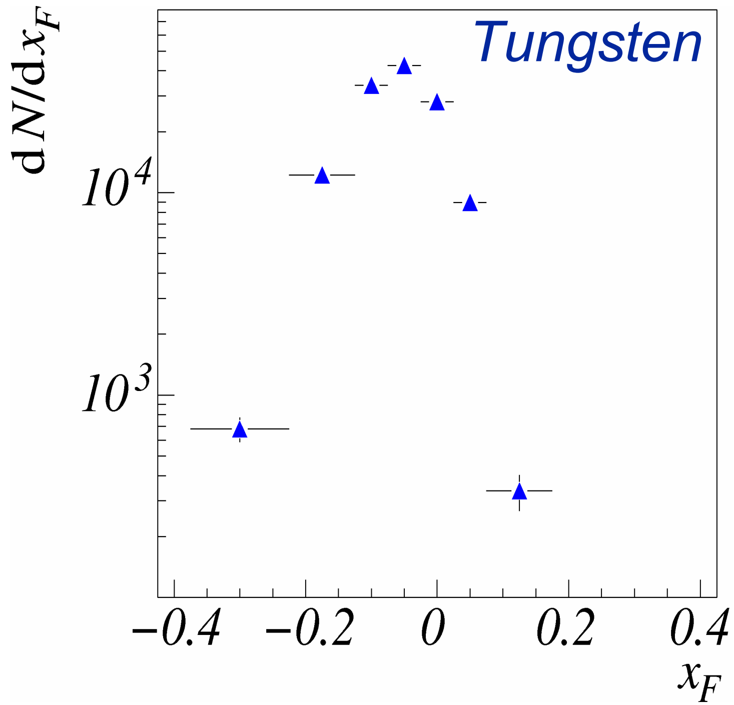
- Signal width dominated by detector resolution:
  - → Gaussian signal model with 5% tail from final state radiation
- Combinatorial background, mainly decays in flight of pions and kaons $\pi/K \to \mu\nu$
  - → Exponential background model



From Raw Spectra to α

- Fit invariant mass spectrum in bins of x_F (split data into per-wire samples)





- Correct for acceptance and efficiency
- Calculate (logarithm of) ratio

Efficiency

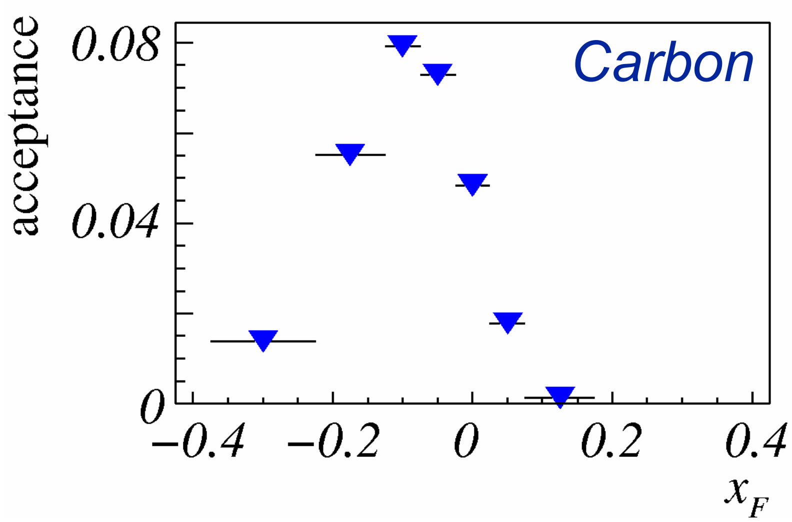
- Efficiency to detect J/ψ is composed of
  - Geometrical acceptance of detector and trigger
  - Detector and trigger efficiency (varying in space & time)
  - Reconstruction efficiency
  - → All efficiencies are functions of the kinematic variables
- Relative measurement: need only efficiency ratios
  - Efficiencies expected to cancel to first order in ratios
  - Remaining: ratio of detector and trigger acceptances
- Acceptance correction based on MC-simulation
  - Correct every x_F/p_T-bin by $N(\mathrm{J}/\psi)_{\mathrm{reconstructed}} / N(\mathrm{J}/\psi)_{\mathrm{generated}}$
  - First tests with unfolding techniques

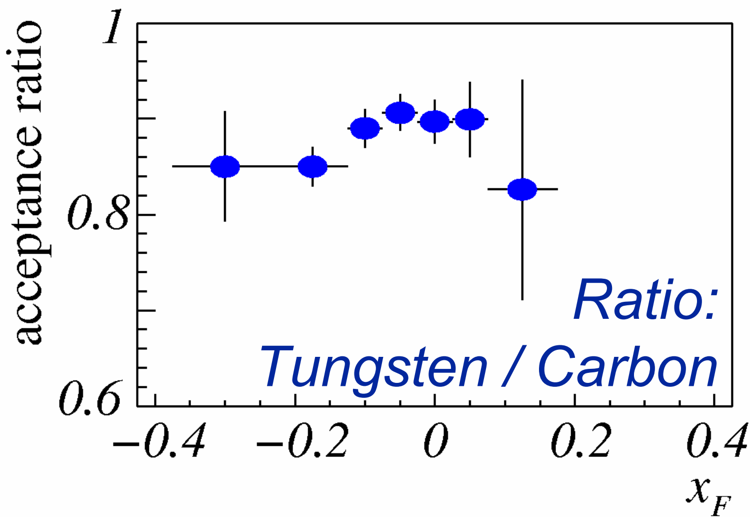
Efficiency (cont'd)

- HERA-B MC-simulation chain:

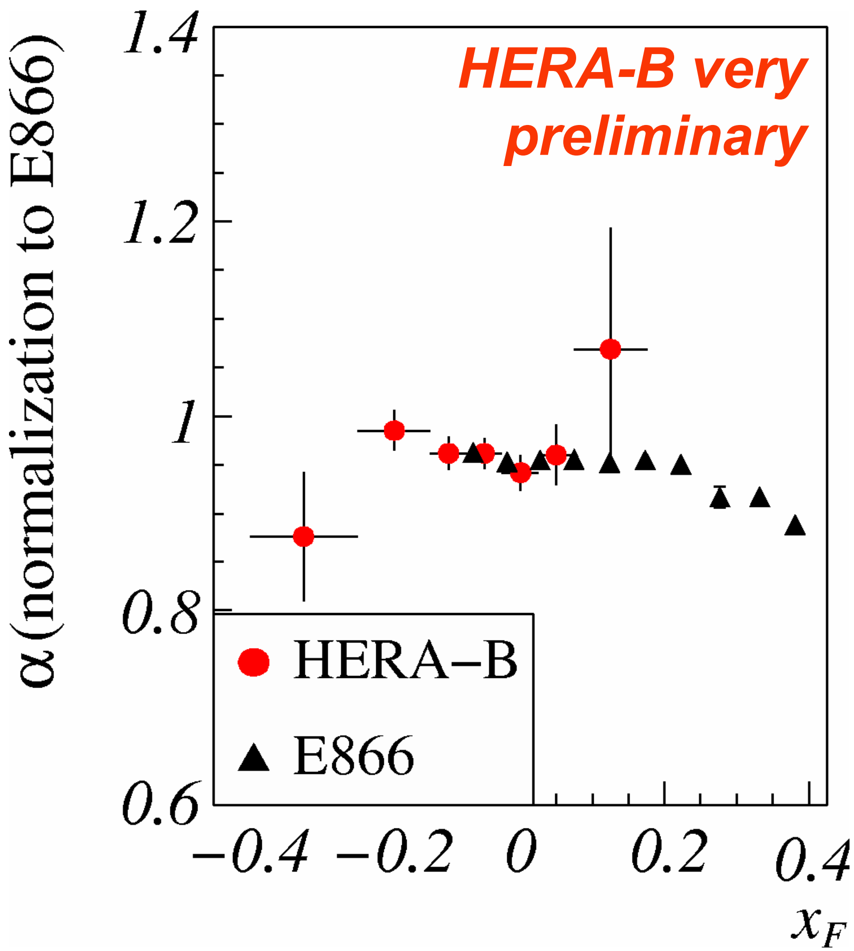
Generators: PYTHIA, FRITIOF → Detector Simulation: GEANT3 → Reconstruction & Trigger Simulation

- Di-muon efficiency: example
  (limited MC statistics)





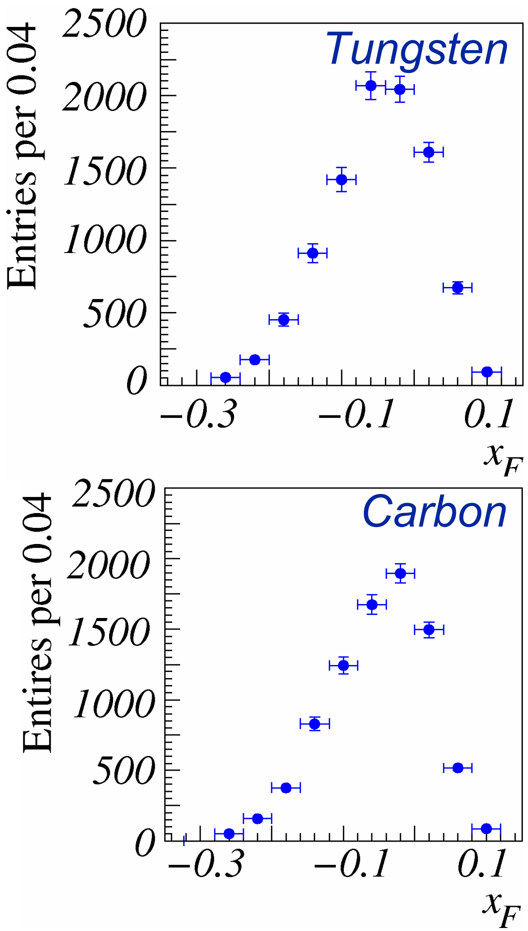
Preliminary Results: Muon Channel



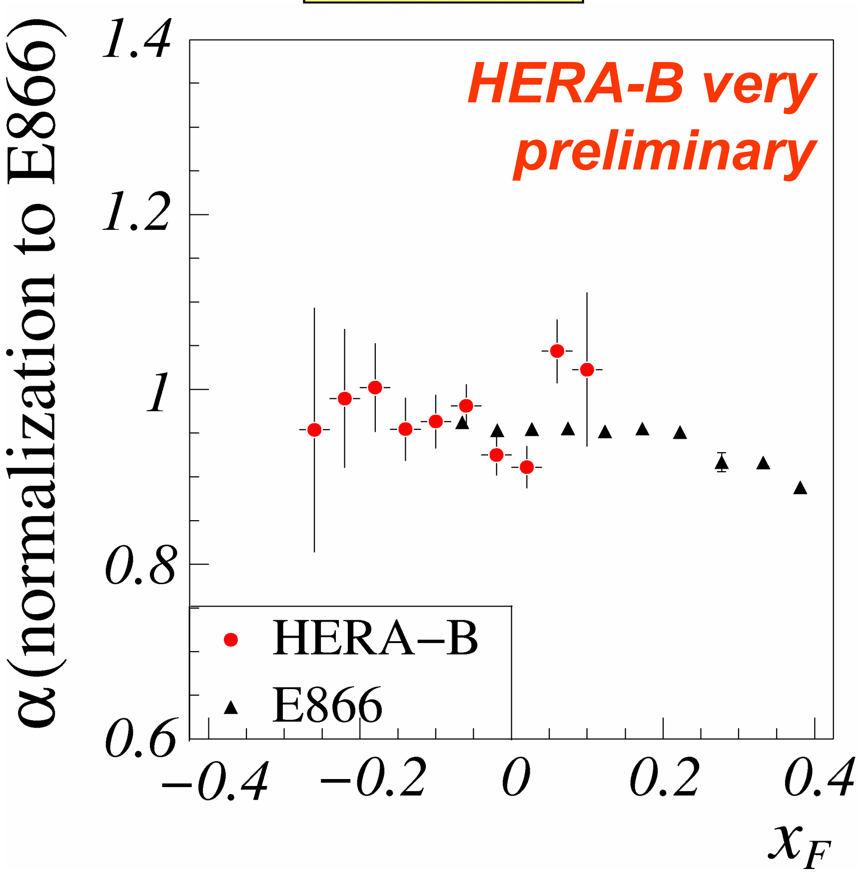
- Wire configuration: both wires from same station
  → Only ¼ of full statistics
- Luminosity ratio not yet available
  → Normalization to E866
- Central x_F region under good control

Preliminary Results: Electron Channel

Raw Spectra



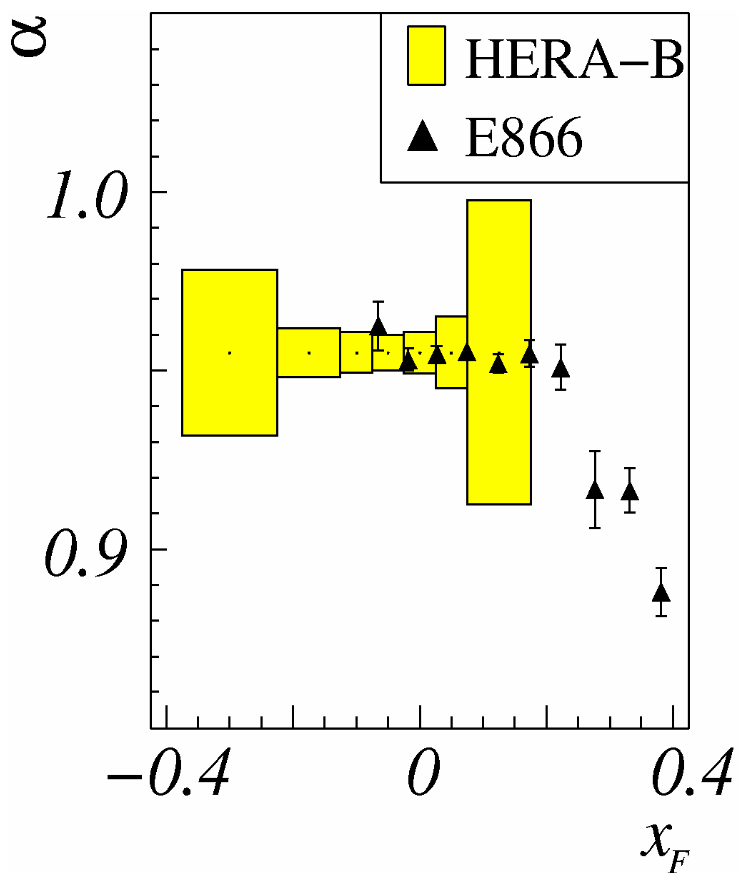
$\alpha(x_F)$



Plans & Expectations

- Analysis of all data sets and combination
  → 4× more data available both in electron and muon channel
- Work on systematic effects ongoing:
  – Improved MC description of detector and trigger efficiency
  – Improved MC statistics
  – Absolute normalization via luminosity ratio

Full Data-Sample:
Expected Statistical Error



Summary & Conclusions

- HERA-B has finished the data-taking period 2002/2003 → approx. 300,000 J/ψ on tape
- One of the main physics goals: *A*-dependence of charmonium production
- HERA-B: unique experiment – materials from ^{12}C to ^{184}W, negative x_F
- *A*-dependence analysis ongoing:
  - First results expected end of this year
  - Experimental and theoretical input is welcome
- Thanks to: HERA-B Charmonium Working Group

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bmb+f - Förderschwerpunkt

HERA - B

Großgeräte der physikalischen Grundlagenforschung