J/ψ as a probe of proton and nuclei

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Ideal probe:

large cross sections,

easy detection by ee or μμ decay channels

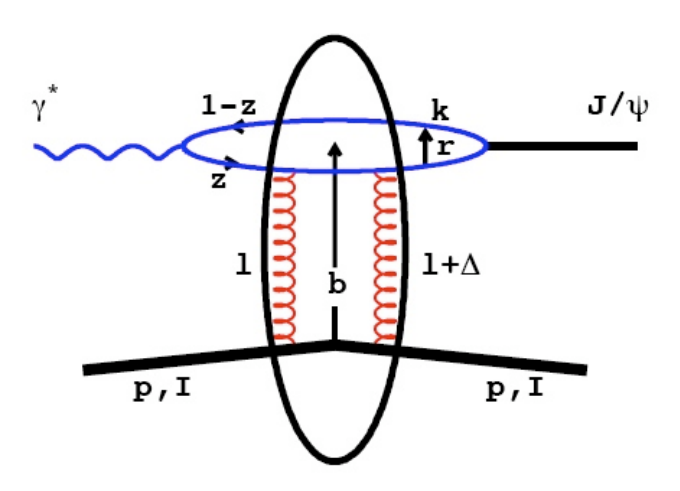
small width ➔ well separated from background

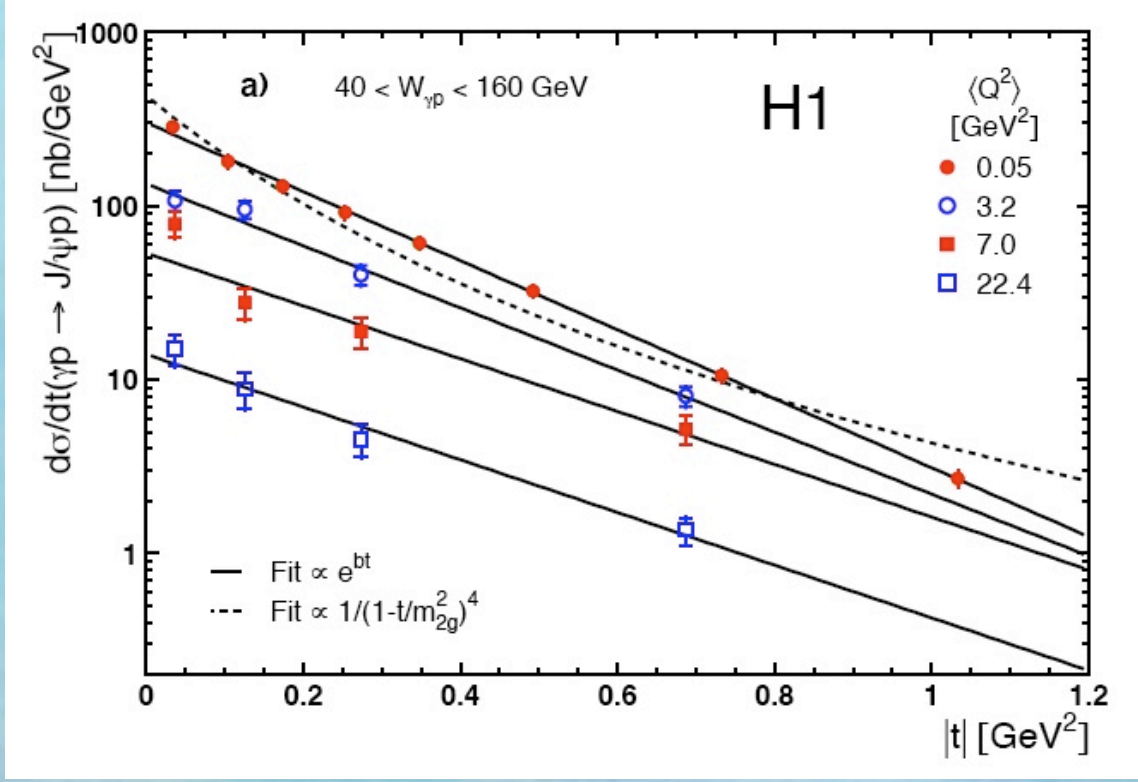
decay leptons are not re-interacting with nucleus

J/ψ dipole interacts only by 2g exchange at low x

process is well understood in QCD

Proton shapes from exclusive J/ψ





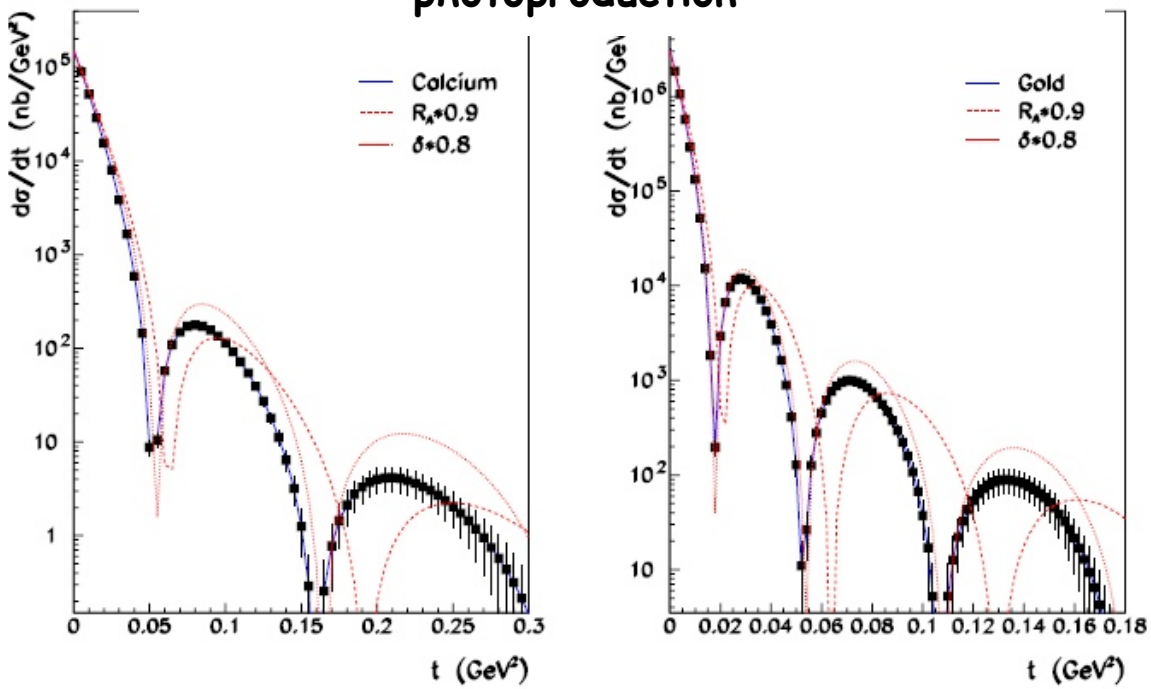
Exponential behavior ➔ B_D size of the interaction region

$$\frac{d\sigma^{diff}}{dt} \sim \exp(B_D \cdot t) \qquad \Rightarrow T(b) \sim \exp(-\vec{b}^{\,2}/2B_G)$$

Nuclear gluonic shapes at EIC

Coherent $eA \rightarrow J/\psi A$ production

photoproduction



$\Delta p_T \sim 10$ MeV

Look into inner arrangements of nucleons in nucleus?

X-section for elastic J/ψ photoproduction

$$\frac{d\sigma}{dW^2} = \frac{\alpha}{2\pi}\frac{1}{s}\left[\frac{1+(1-y)^2}{y}\ln\frac{Q^2_{max}}{Q^2_{min}} - \frac{2(1-y)}{y}\left(1-\frac{Q^2_{min}}{Q^2_{max}}\right)\right]\cdot\sigma^{\gamma p}(W^2)\,.$$

$$\sigma^{\gamma p\to J/\psi p}(W^2) \approx 75\text{nb}\cdot\left(\frac{W^2}{8100}\right)^{0.35}$$

ZEUS parametrization

$$Q^2_{min} = \frac{m_e^2 y^2}{1-y}$$

$$Q^2_{max} = 10^{-2}\ \text{GeV}^2.$$

$$E_e + E_p = (1-x)E_p + E'_e + E_V$$

Energy conservation

$$E' = (1-y)E_e$$

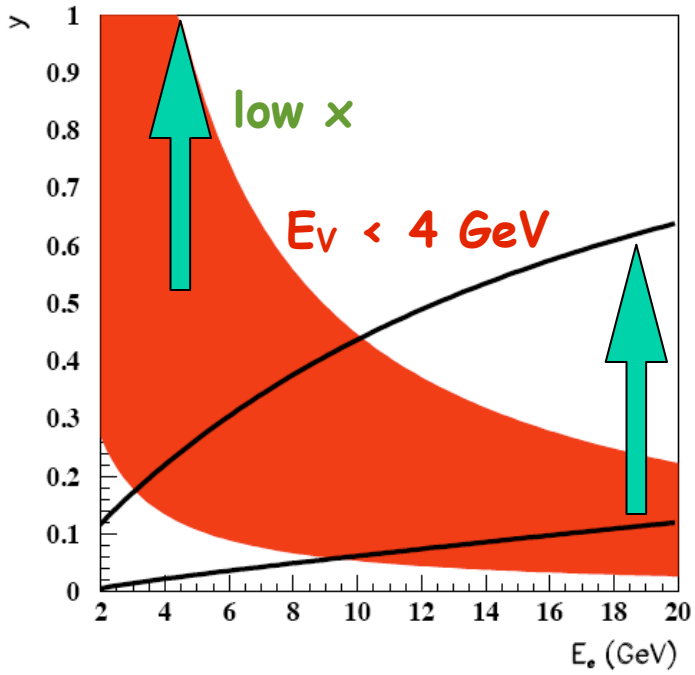
Energy of the scattered electron

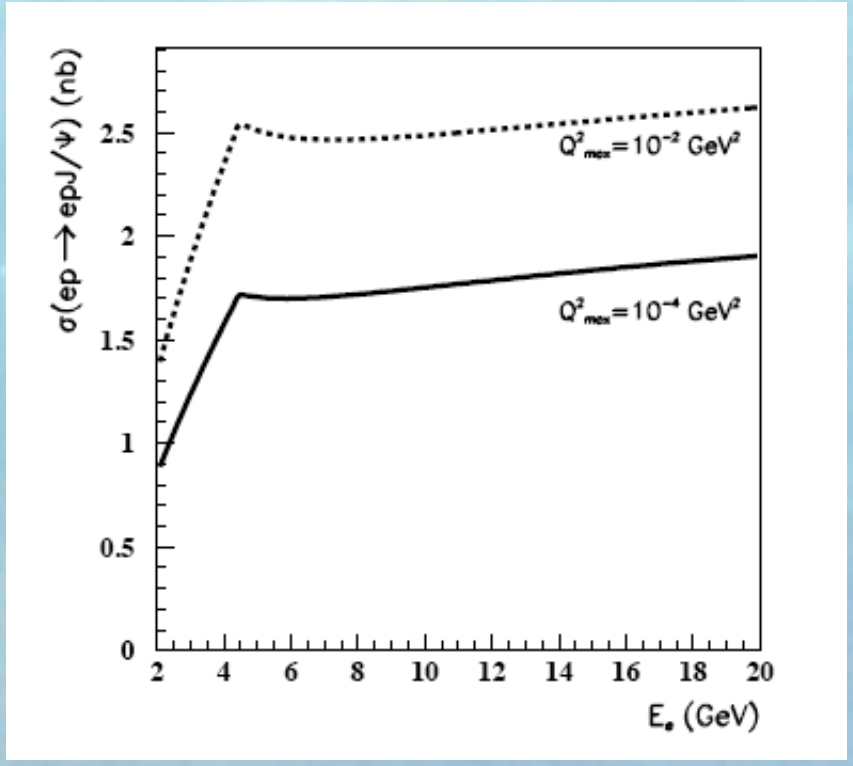
Acceptance and X-sec for elastic J/ψ photoproduction at eRHIC, E_p = 100 GeV

E_V - Energy of J/ψ

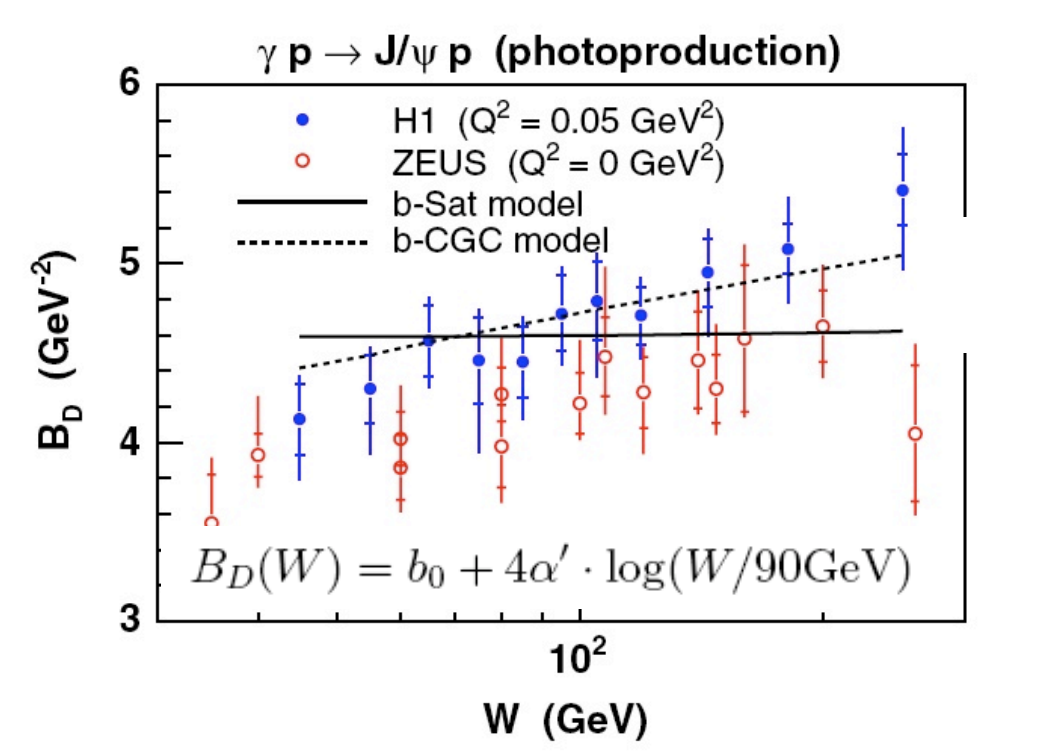
$$y_{max} = min\left[1, \frac{E_V + P_V}{2E_e}\right]$$
$$y_{min} = max\left[0, \frac{E_V - P_V}{2E_e}\right]$$

E_V < 4 GeV





Proton radius



at W 30 GeV

$$\sqrt{< r_{2g}^2 >} = \sqrt{3 \cdot B_G} = 0.61 \pm 0.04 \text{ fm}$$

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to compare with

$r_p = 0.875 \pm 0.008$ fm **electric**

$r_A = 0.675 \pm 0.02$ fm **axial**

the gluonic proton radius is smaller than the quark radius

Measurement of momenta of J/ψ decay muons

Expected resolution of drift chambers:

$$(\sigma_{p_t}/p_t)_{meas} = \frac{p_t\,\sigma_{r\phi}}{0.3L^2B}\sqrt{\frac{720}{N+4}}$$

$$(\sigma_{p_t}/p_t)_{MS} = \frac{0.05}{LB\beta}\sqrt{1.43\frac{L}{X_0}}[1+0.038\log(L/X_0)]$$

$$\sigma_{p_t}/p_t = (\sigma_{p_t}/p_t)_{meas} \oplus (\sigma_{p_t}/p_t)_{MS}.$$

1. outer radius $R = 2$ m
2. solenoidal field $B = 3.5$ T
3. gas density $X_0 = 450$ m
4. point resolution $\sigma = 100$ μm
5. measurement $N = 200$ points.

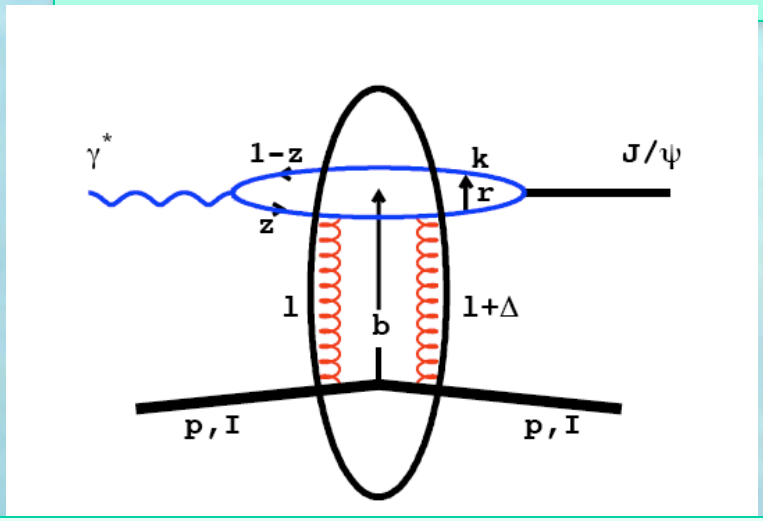
⇐ TPC parameters ⇓

$$\sigma_{p_t}/p_t = 0.005 \cdot p_t \oplus 0.045/\beta\ \%$$

⇓

Δp_T < 1 MeV

J/psi p_T resolution



J/psi p_T can be determined from the momentum of ee or μμ decay pair

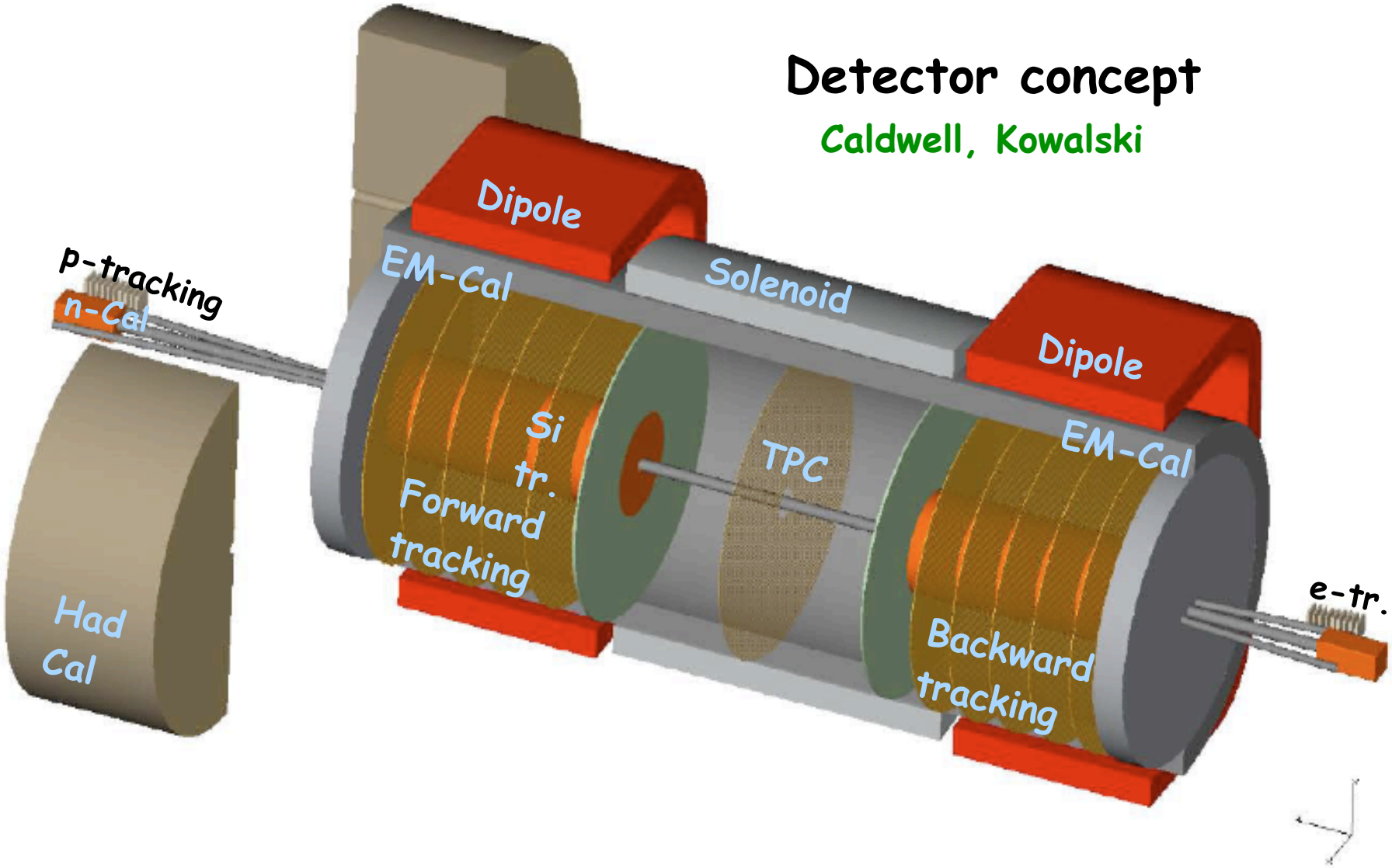
p_T resolution for J/psi - O(2) MeV for a TPC with 1m of the radius

no measurement proton or ion momentum necessary

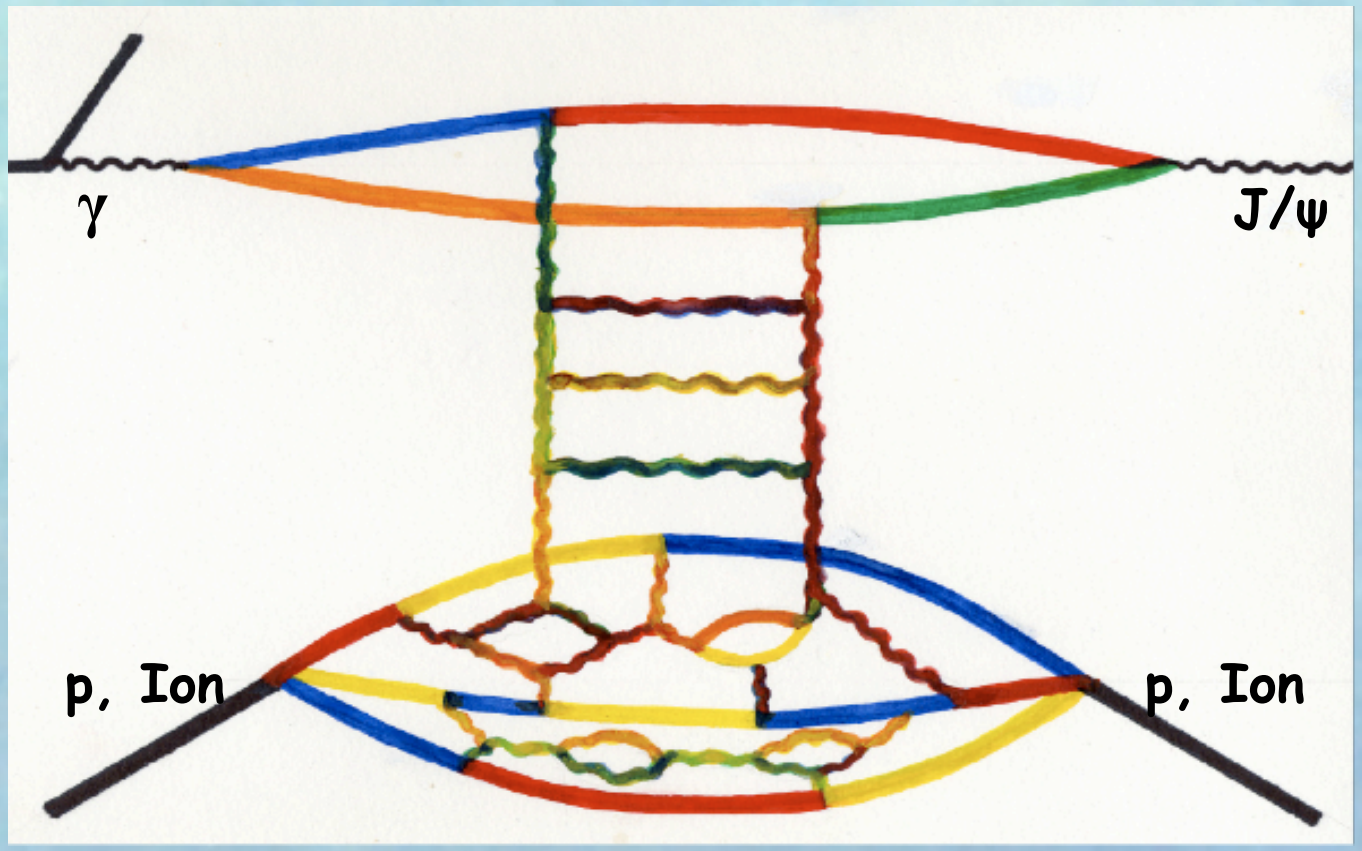
beam electron p_T < 1 MeV
scattered electron can be easily detected in the forw. det.

Detector concept

Caldwell, Kowalski



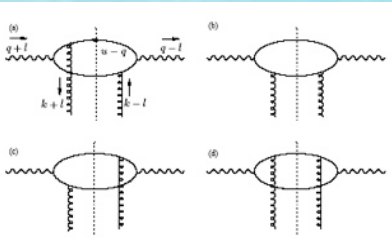
eA Physics with the ENC/EIC/LHEC



BACKUP SLIDES

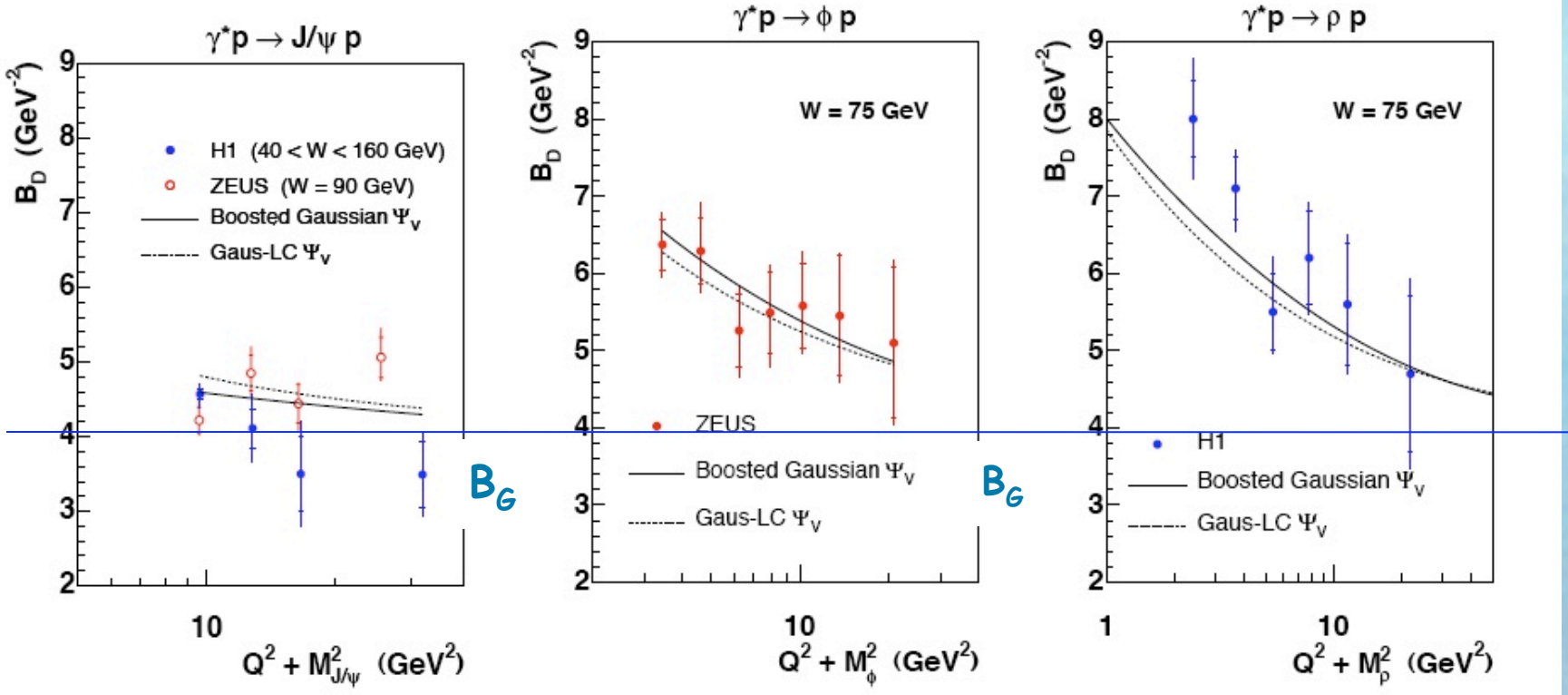
The size of interaction region B_D for various VM

Modification by Bartels, Golec-Biernat, Peters



$$e^{i\vec{b}\cdot\vec{\Delta}} \Rightarrow e^{i(\vec{b}+(1-z)\vec{r})\cdot\vec{\Delta}}$$

KMW



For J/ψ $B_D - B_G = 0.6 +/- 0.2\ GeV^{-2}$