Gluons exploration using J/ψ photo-production and development of hybrid gaseous detectors

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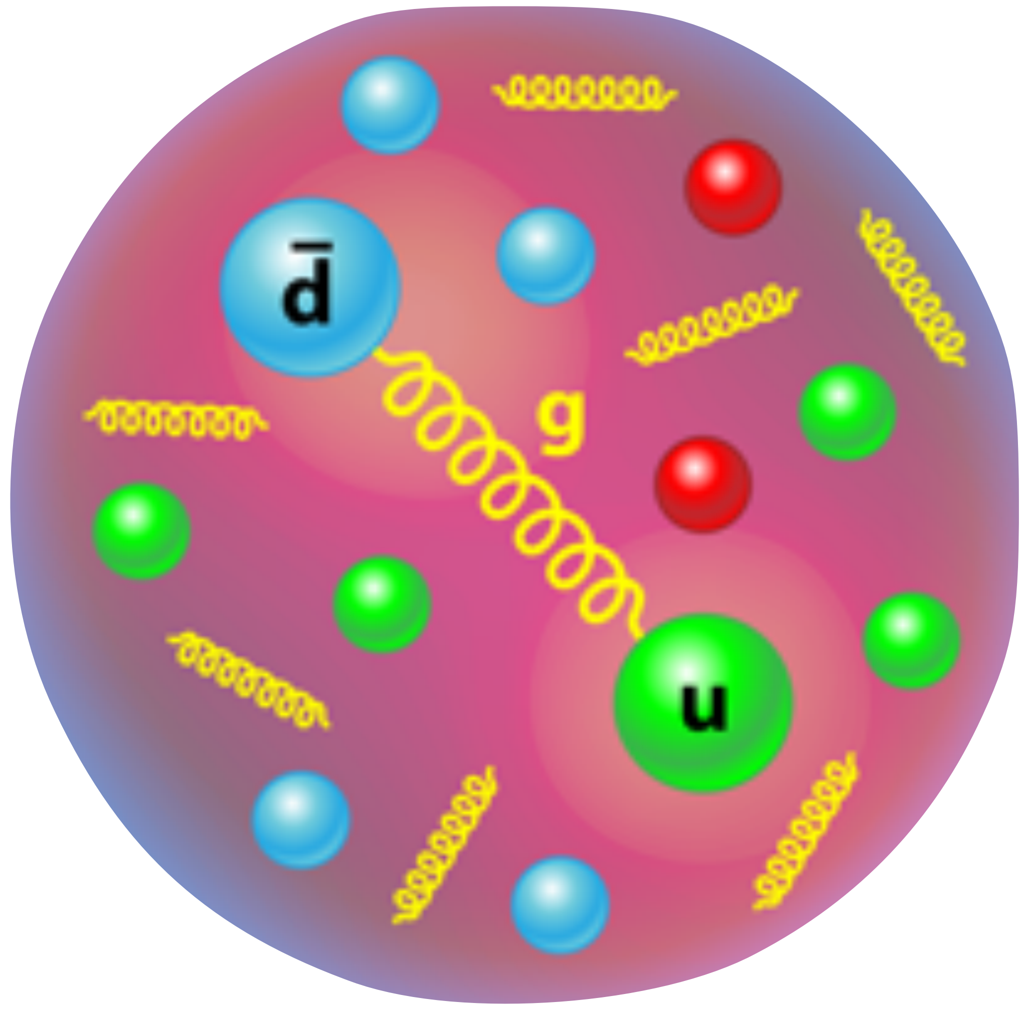
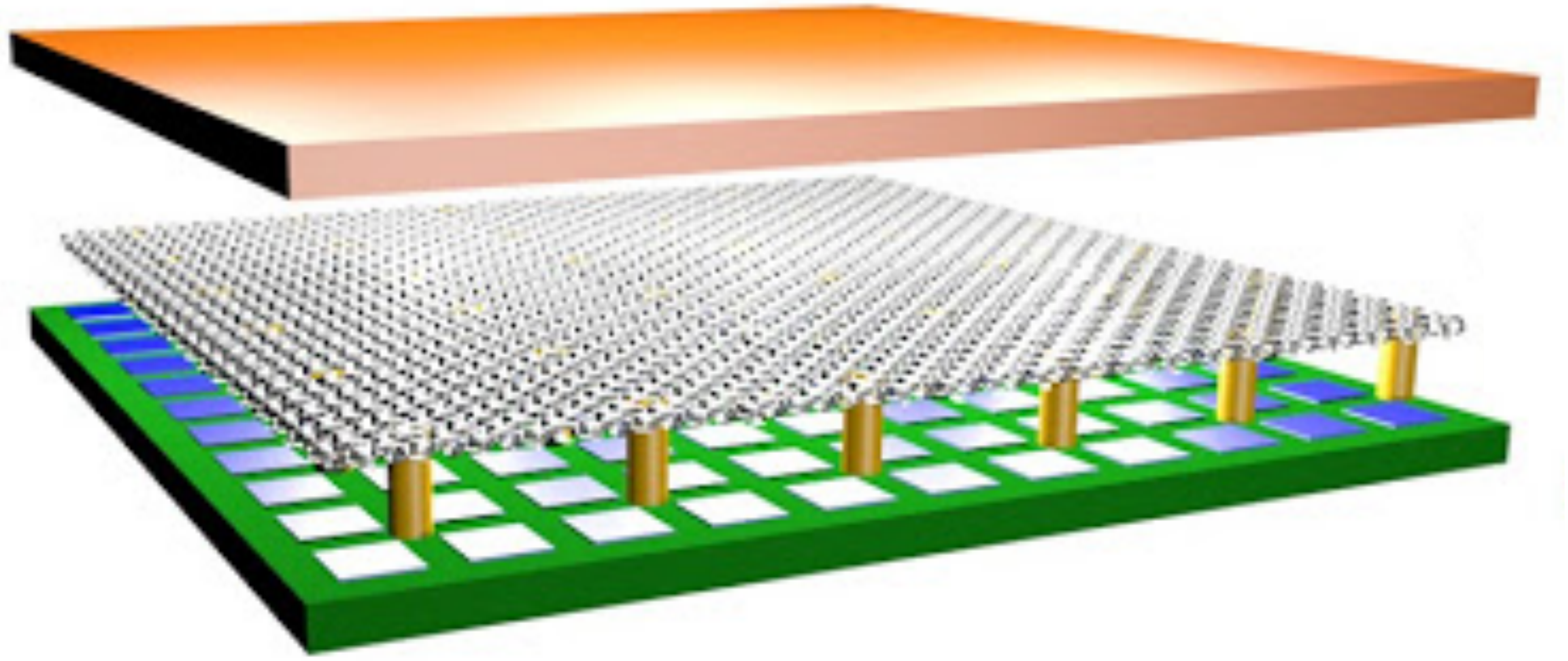
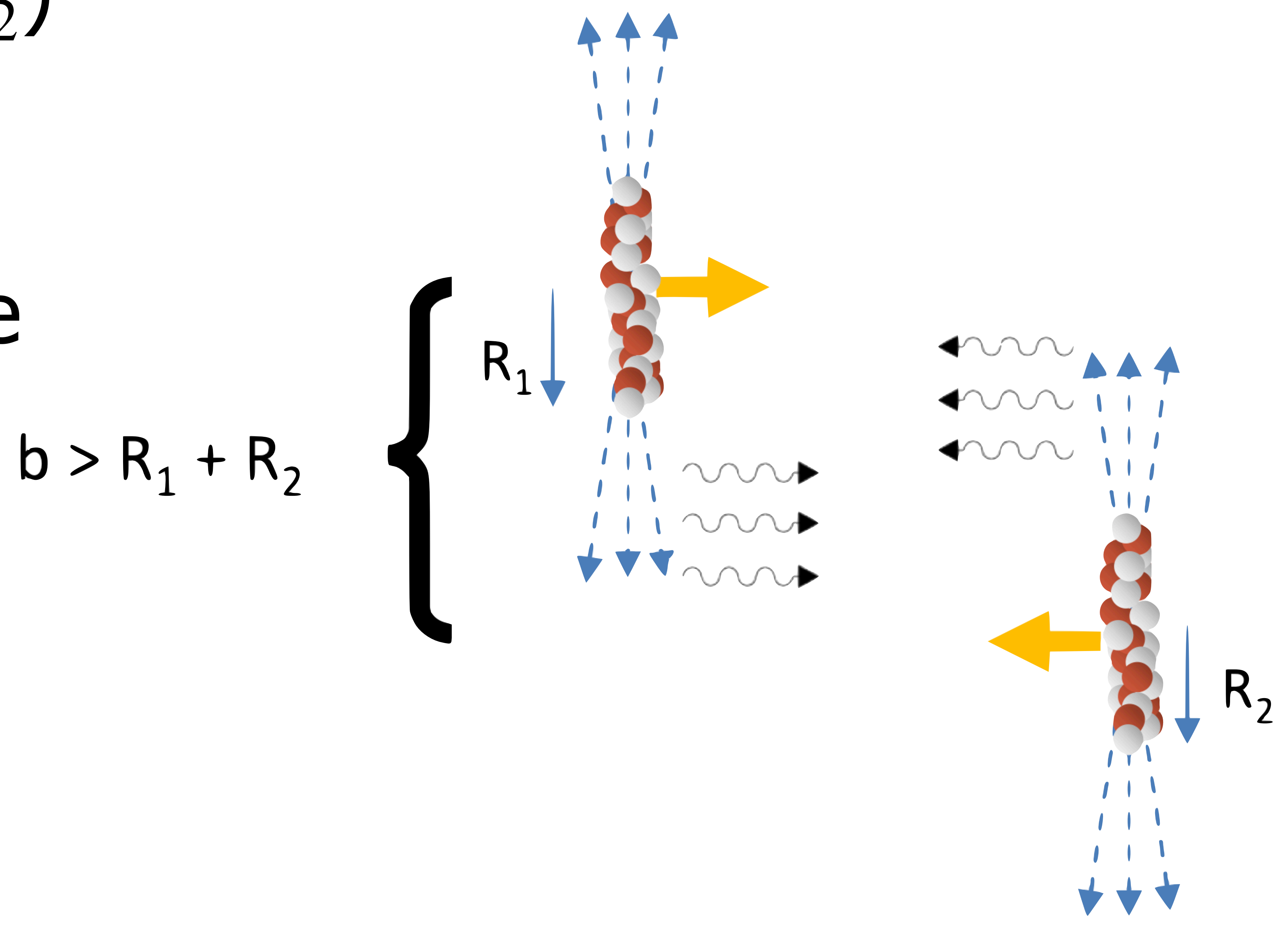




What is a UPC = Ultra Peripheral Collision?

- Ultrarelativistic system
- Large impact parameter ($b > R_1 + R_2$)
- No nuclear overlap
- Photon induced reactions dominate

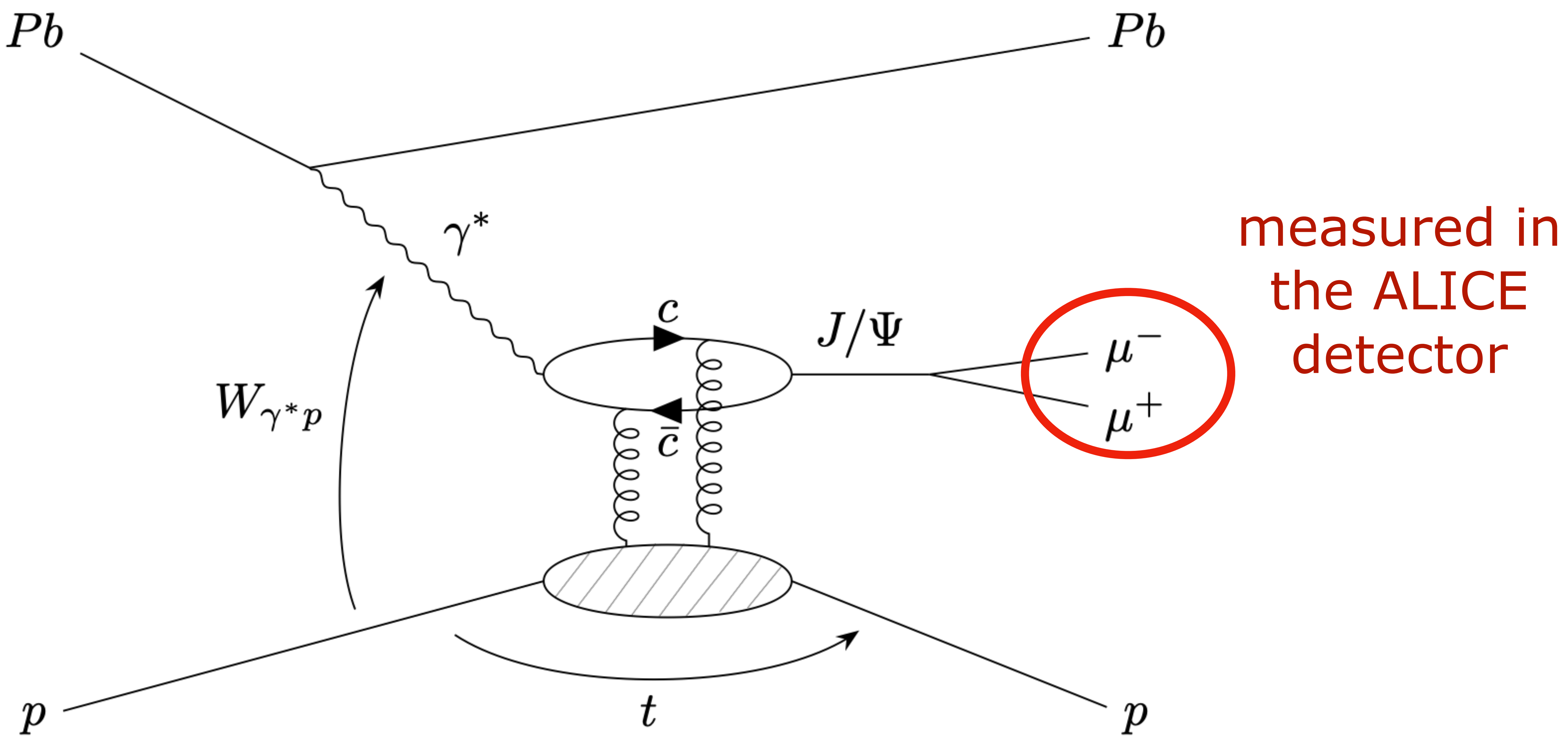


- In p-Pb UPC, lead-ion is most likely (~95%) the photon source

J/ψ photoproduction at high energy

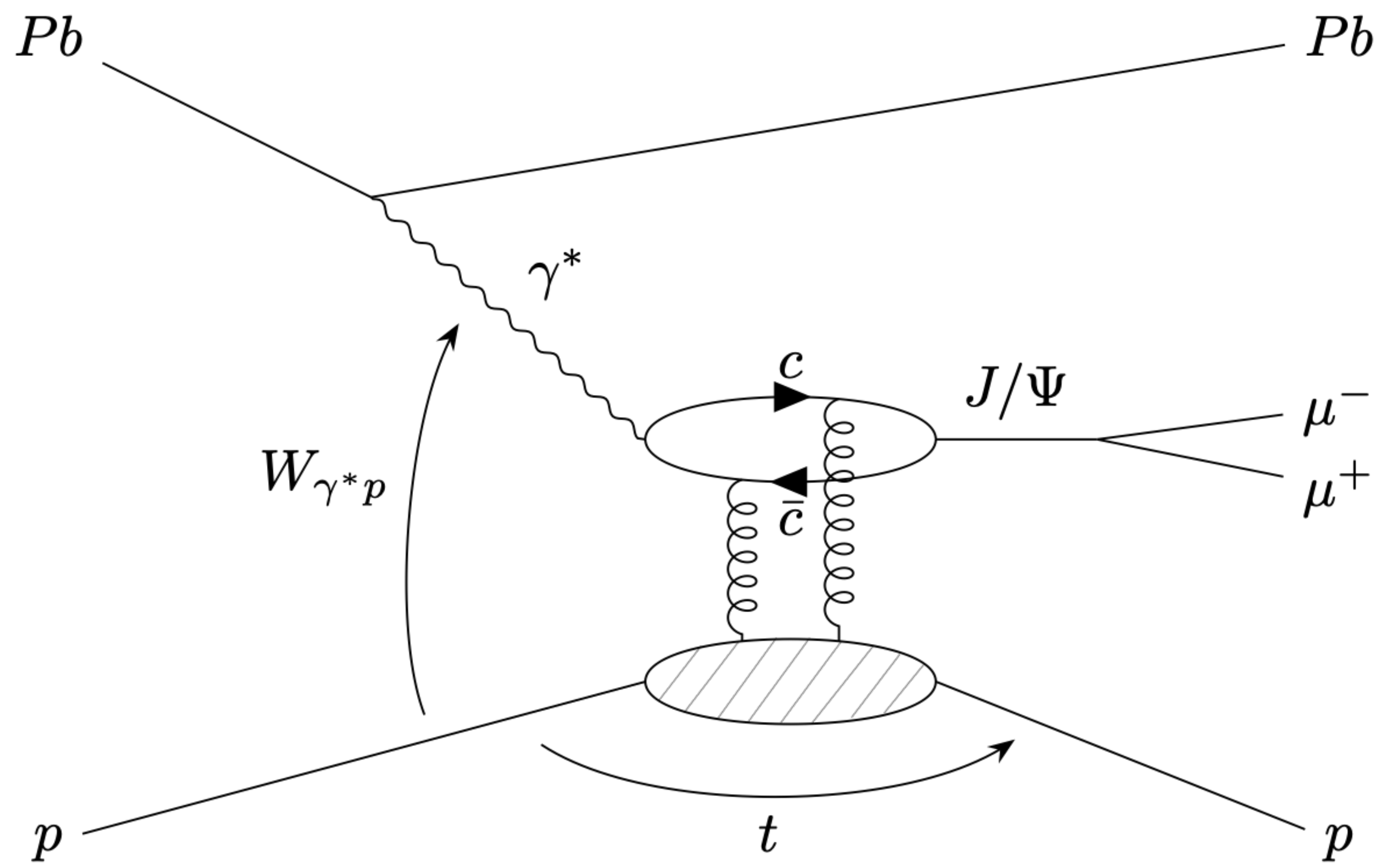
- The virtual photon fluctuates in a $q\bar{q}$ dipole
- The virtual photon interacts with the proton and probes its internal structure via the exchange of 2 gluons
- From this interaction a vector meson (here J/ψ) is produced

- The J/ψ then decays to di-leptons



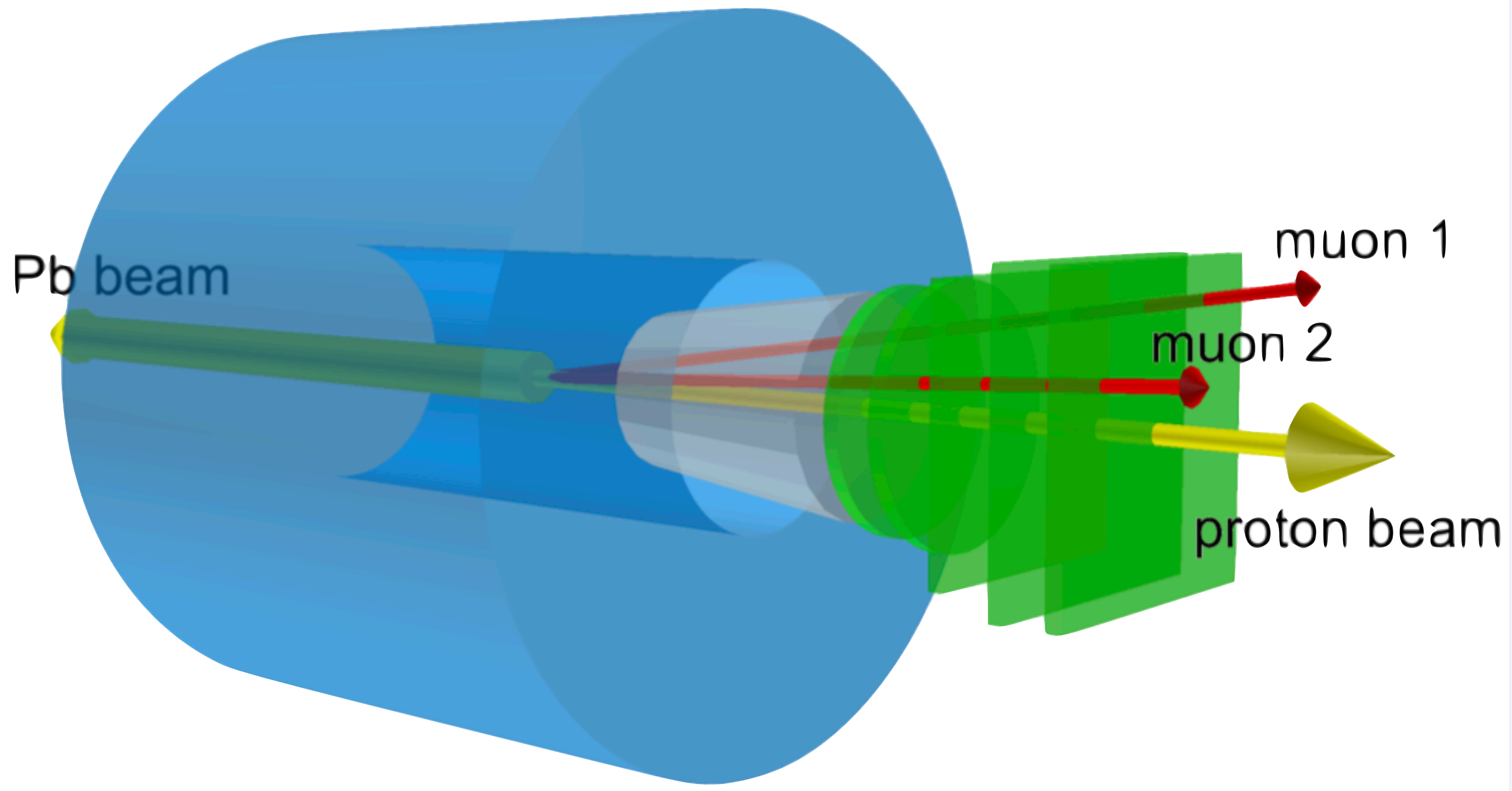
J/ψ photoproduction in ALICE

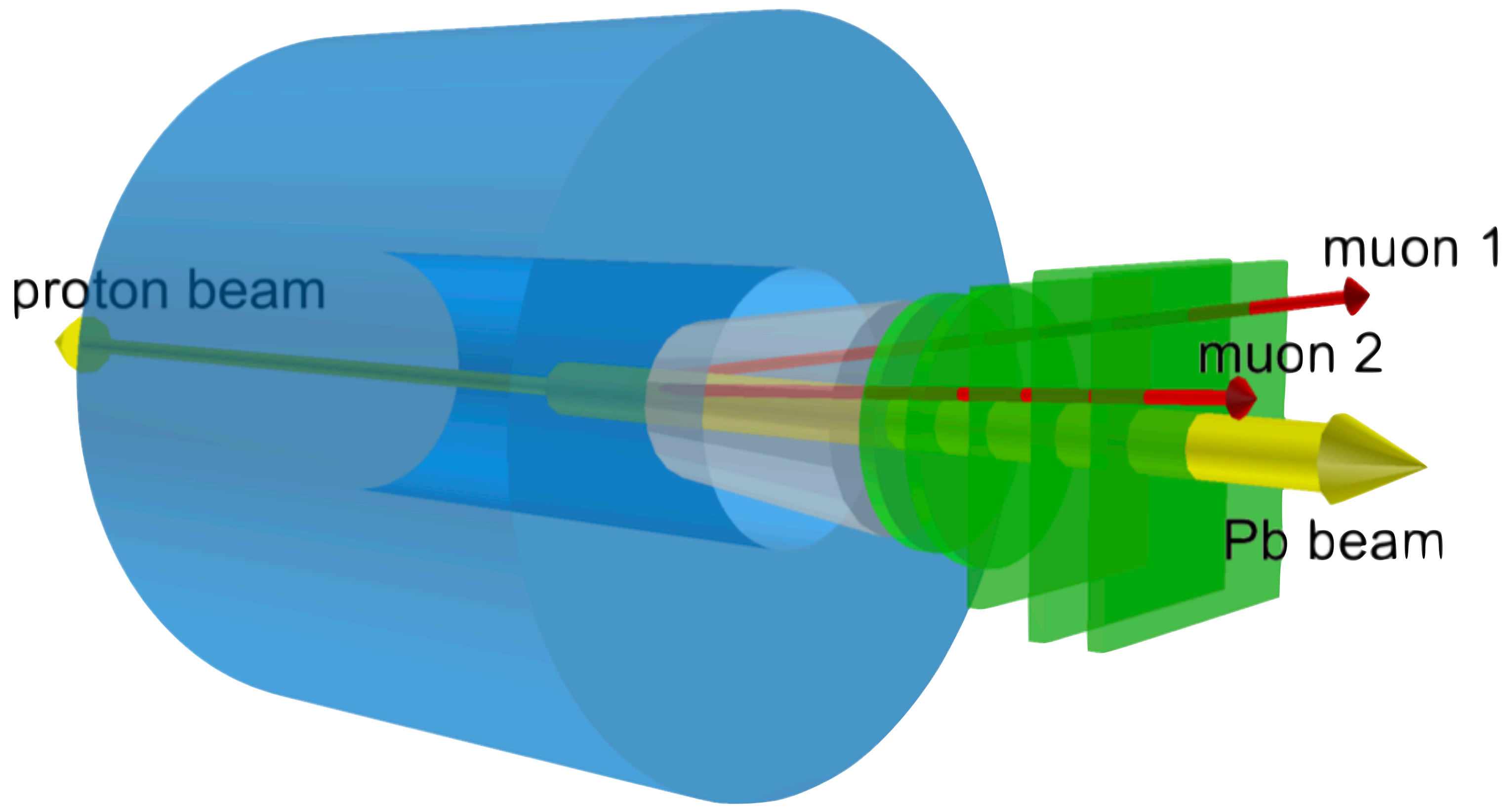
- p-γ^* center-of-mass energy given by $W_{\gamma^* p} = 2E_p \, M_{J/\Psi} \, e^{-y}$ where y is the rapidity of the J/Ψ defined according to the proton beam
- 2 energy configurations:



the J/ψ goes in the direction of the proton: 27 GeV < $W_{\gamma^* p}$ < 58 GeV

the J/ψ goes in the direction of the Pb ion: 702 GeV < $W_{\gamma^* p}$ < 1486 GeV





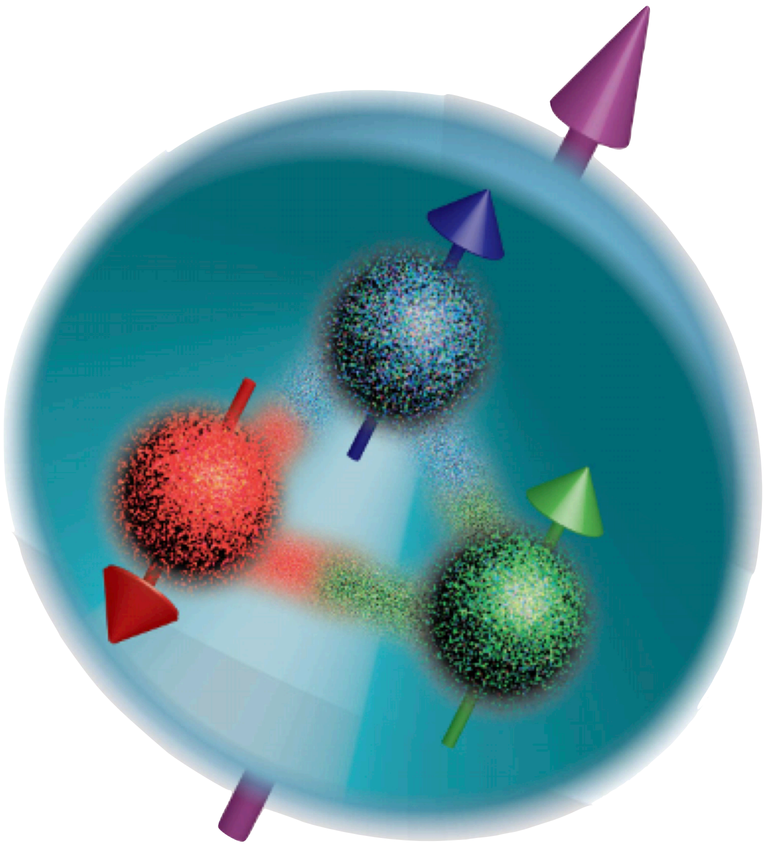
What are we probing?

The target is probed at the longitudinal momentum fraction (analogous to the Bjorken-x of DIS)

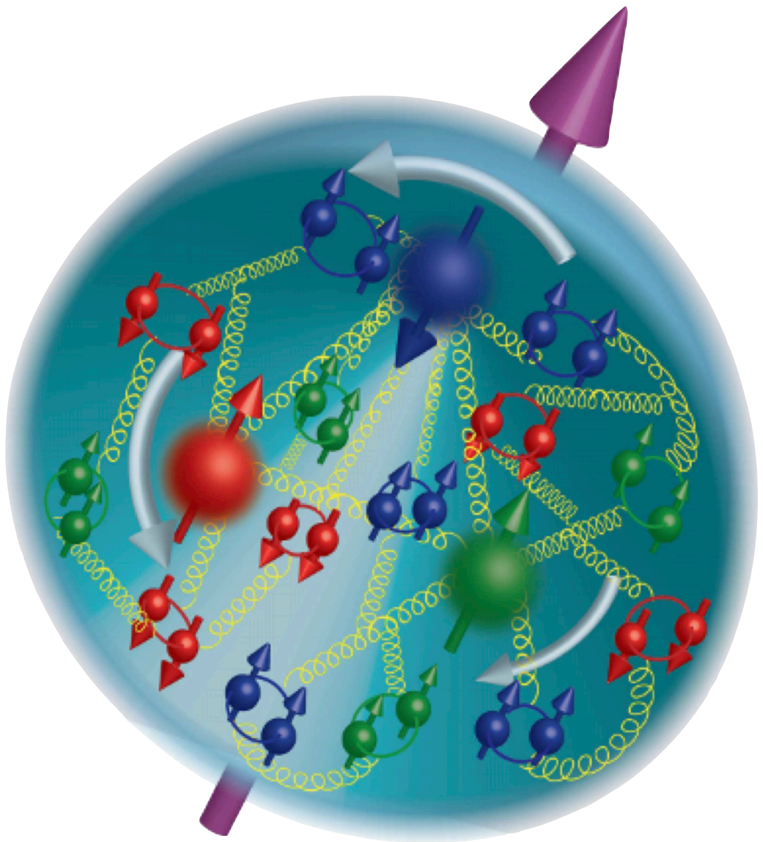
$$x_{\mathbb{P}} \propto W_{\gamma^* p}^{-2}$$

- 2 energy configurations:

the J/ψ goes in the direction of the proton: 27 GeV < $W_{\gamma^* p}$ < 58 GeV



the J/ψ goes in the direction of the Pb ion: 702 GeV < $W_{\gamma^* p}$ < 1486 GeV

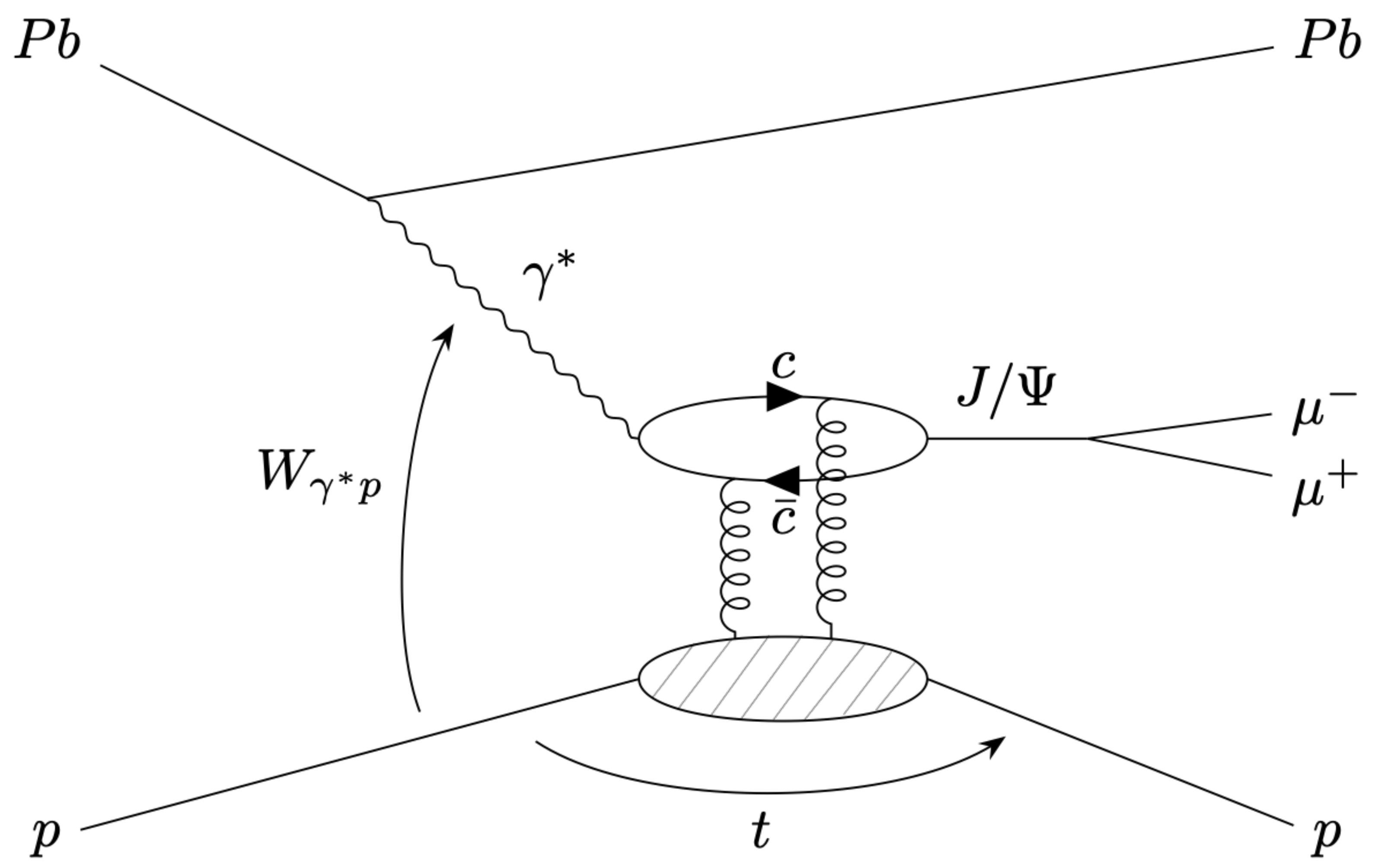


J/ψ photoproduction

- **exclusive**: the proton remains in the same quantum state

Physically: we measure the average structure (configurations) of the proton

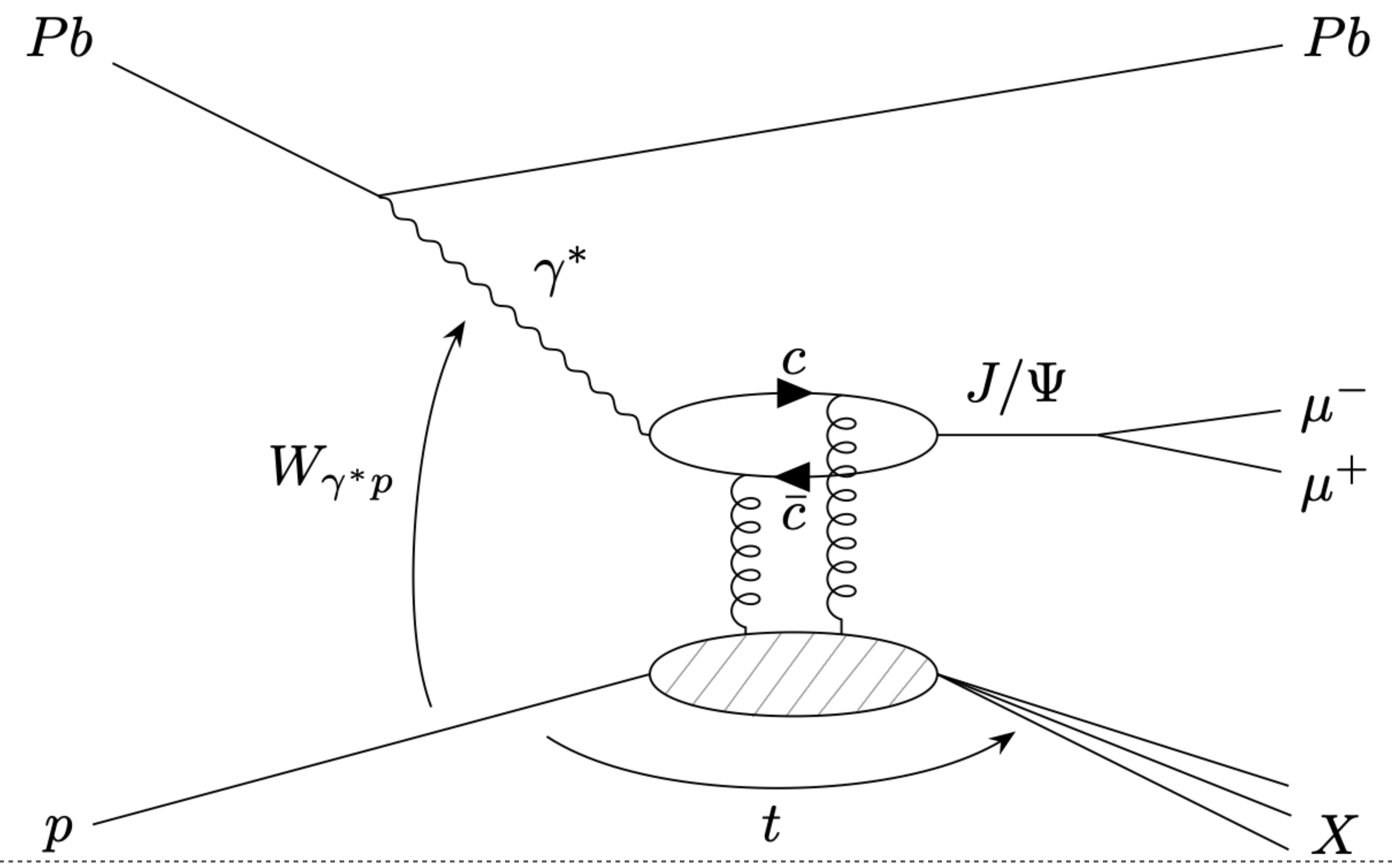
$$\frac{d\sigma^{\gamma^* p \to J/\Psi\ p}}{dt} \propto |\langle A^{\gamma^* p \to J/\Psi\ p} \rangle|^2$$



- **dissociative**: initial and final states are required to be different

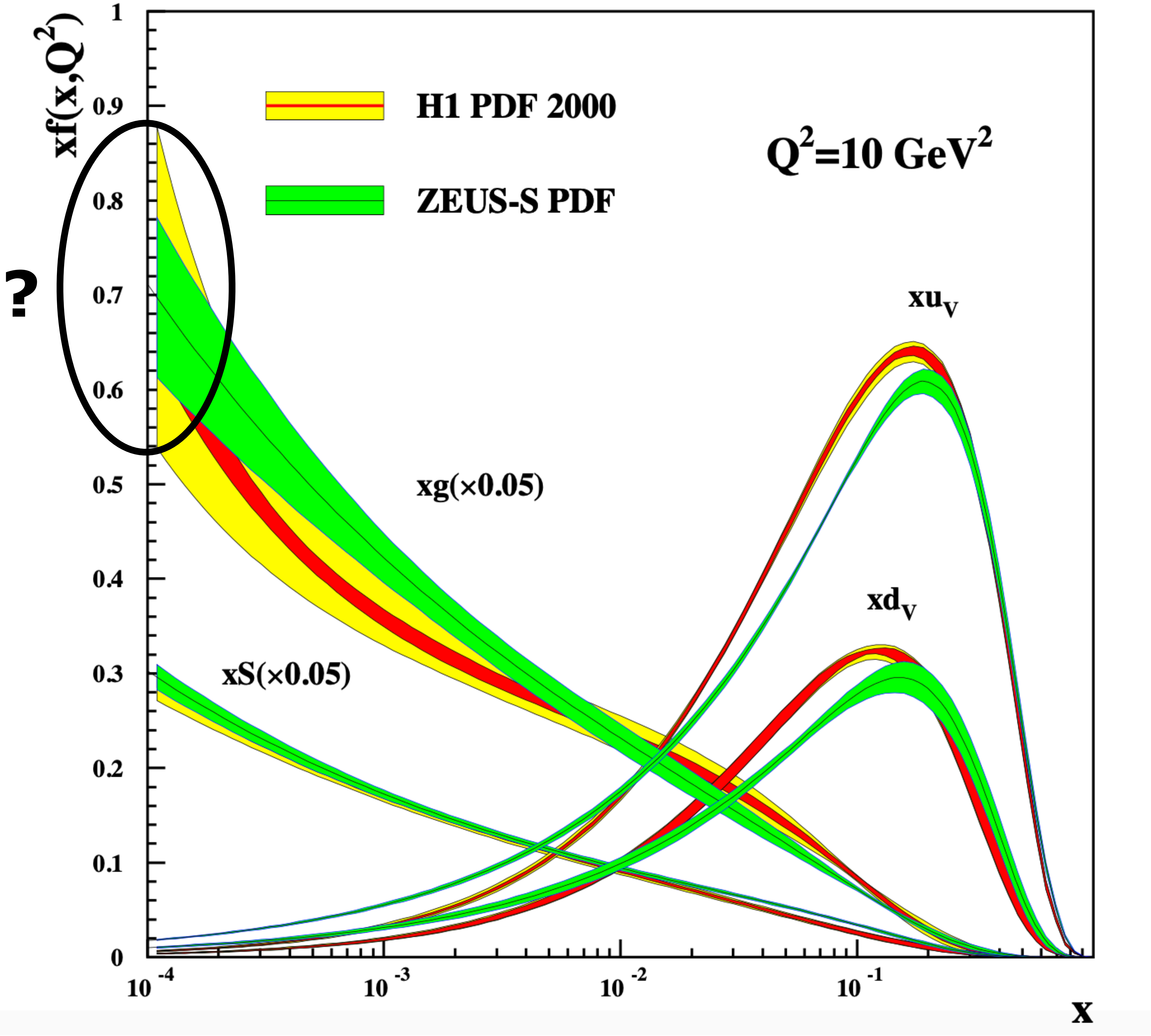
Physically: we measure the fluctuations of the configurations of the proton

$$\frac{d\sigma^{\gamma^* p \to J/\Psi\ X}}{dt} \propto \langle |A^{\gamma^* p \to J/\Psi\ p}|^2 \rangle - |\langle A^{\gamma^* p \to J/\Psi\ p} \rangle|^2$$



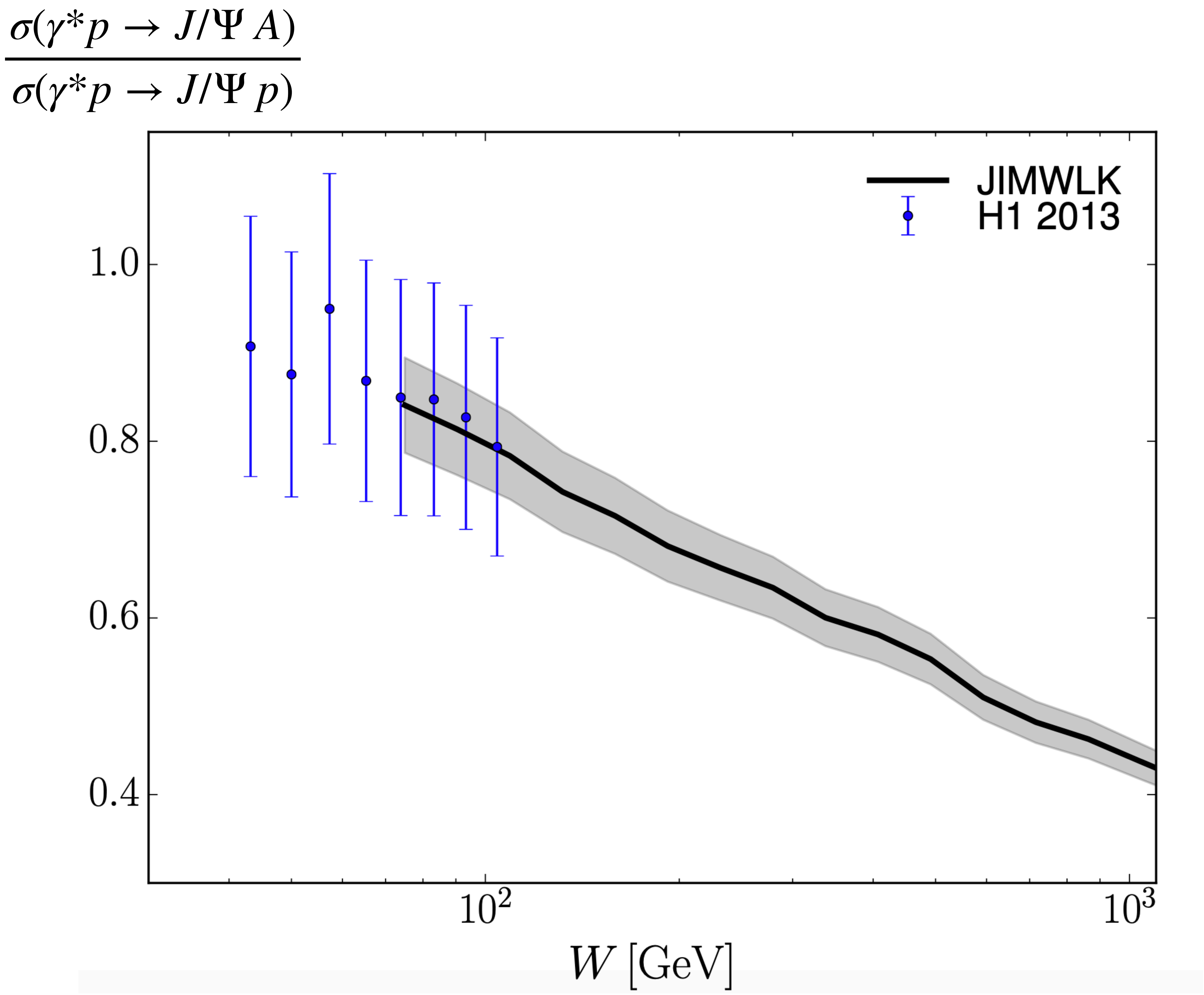
Saturation

- Black disk limit
- Non–linear effects



ref: L.V. Gribov, E.M. Levin, and M.G. Ryskin, Phys. Rept. 100 (1983) 1.

Saturation

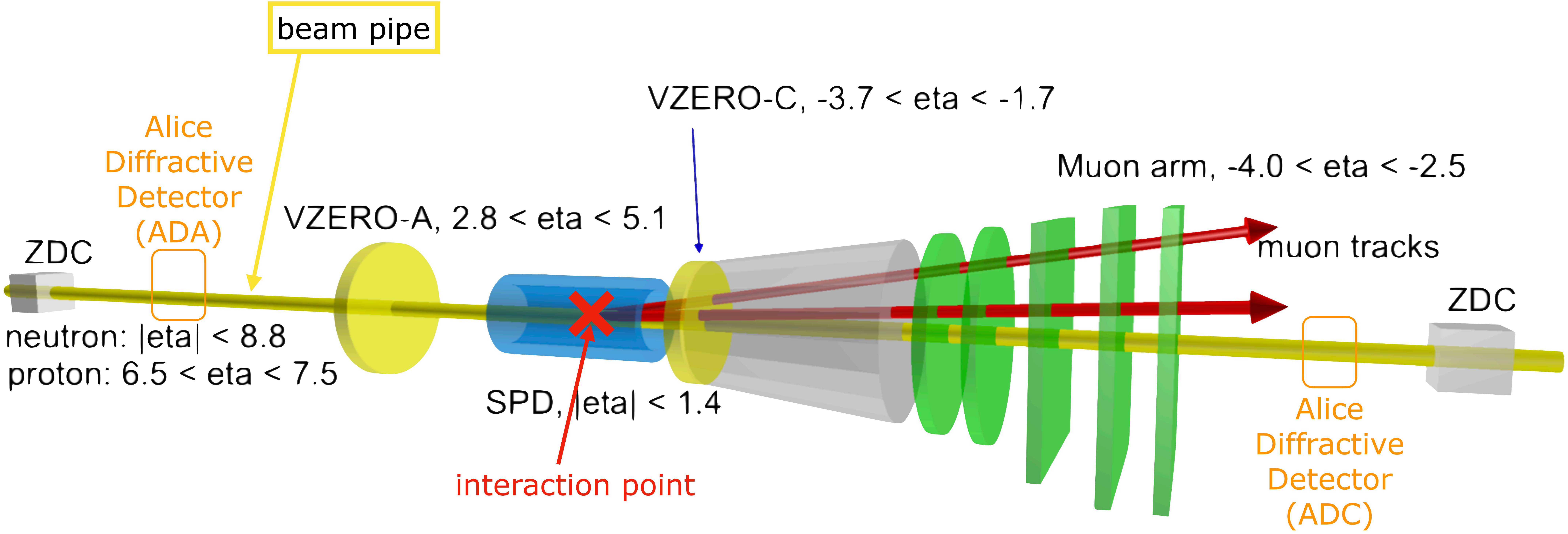


- Black disk limit
- Non–linear effects

source : Heikki Mäntysaari 2020 Rep. Prog. Phys. 83 082201

ref: L.V. Gribov, E.M. Levin, and M.G. Ryskin, Phys. Rept. 100 (1983) 1.

Selection of data

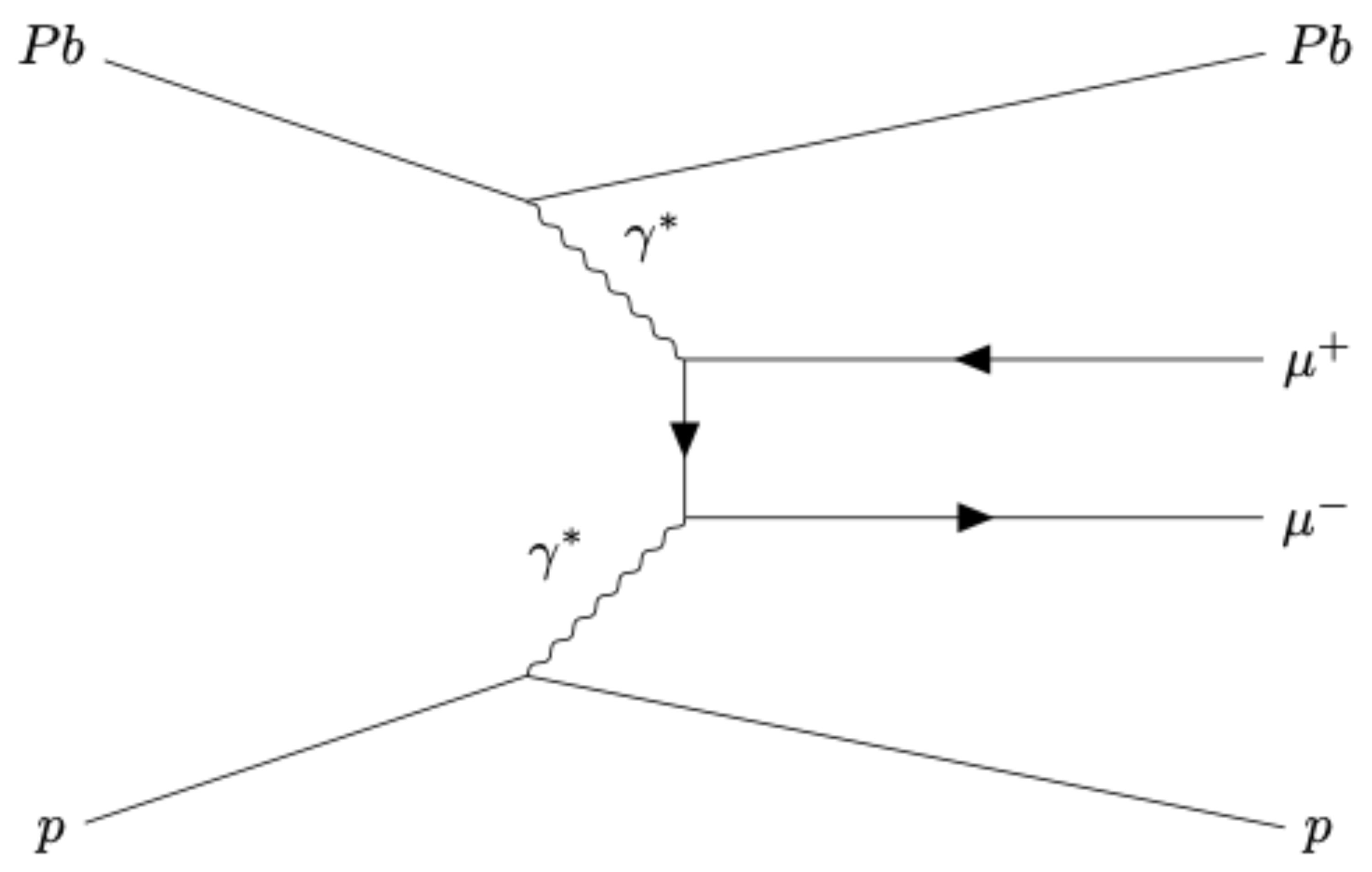


- ZDC = Zero Degree Calorimeter
- SPD = Silicon Pixel Detector
- VZERO = scintillator arrays

Signal reconstruction

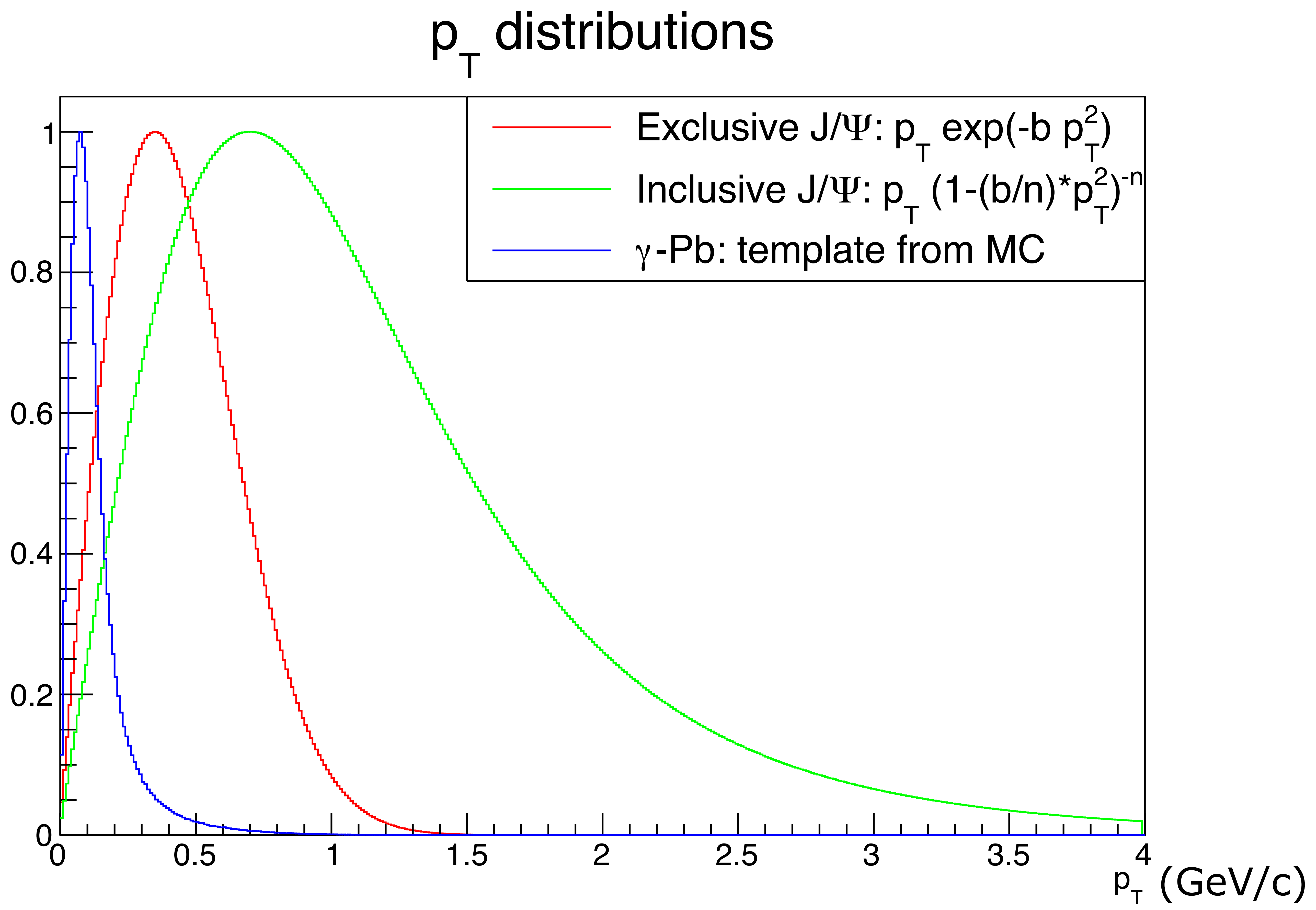
- Signal reconstructed from dimuon pairs
- Mass fit with a Crystal Ball ($J/\Psi \to \mu^-\mu^+$) and an exponential function (dimuon continuum, $\gamma\gamma \to \mu^-\mu^+$)

dimuon continuum:



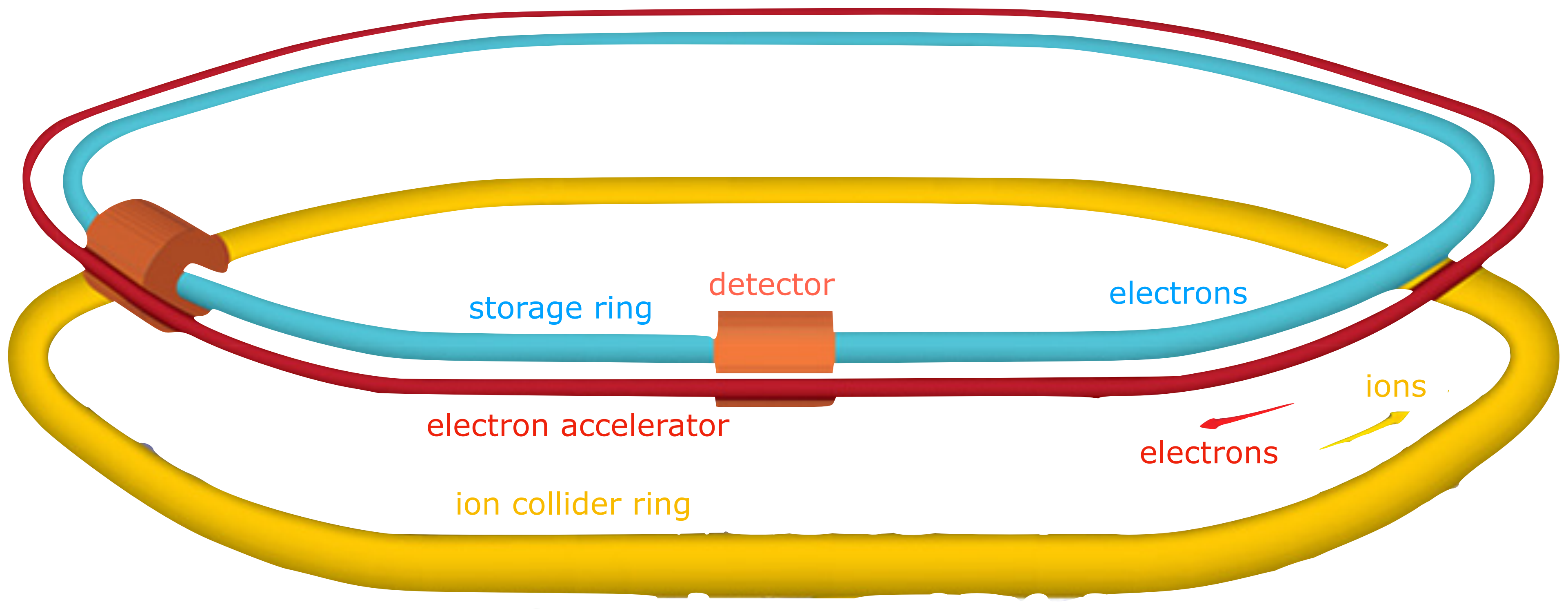
Different contributions in J/ψ peak

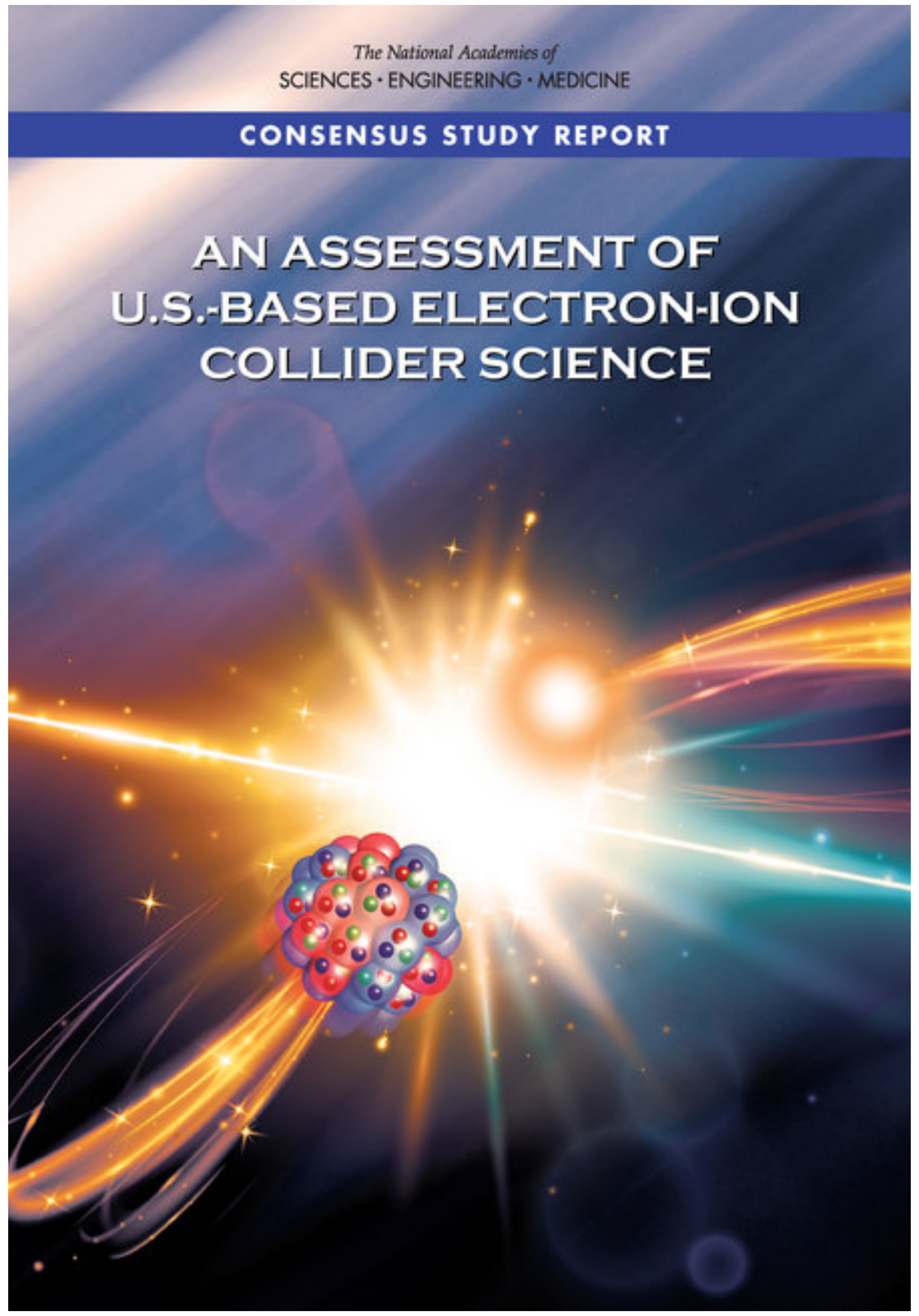
- The different contributions in the J/ψ peak can be discriminated because of their different p_T distribution



Current study and next

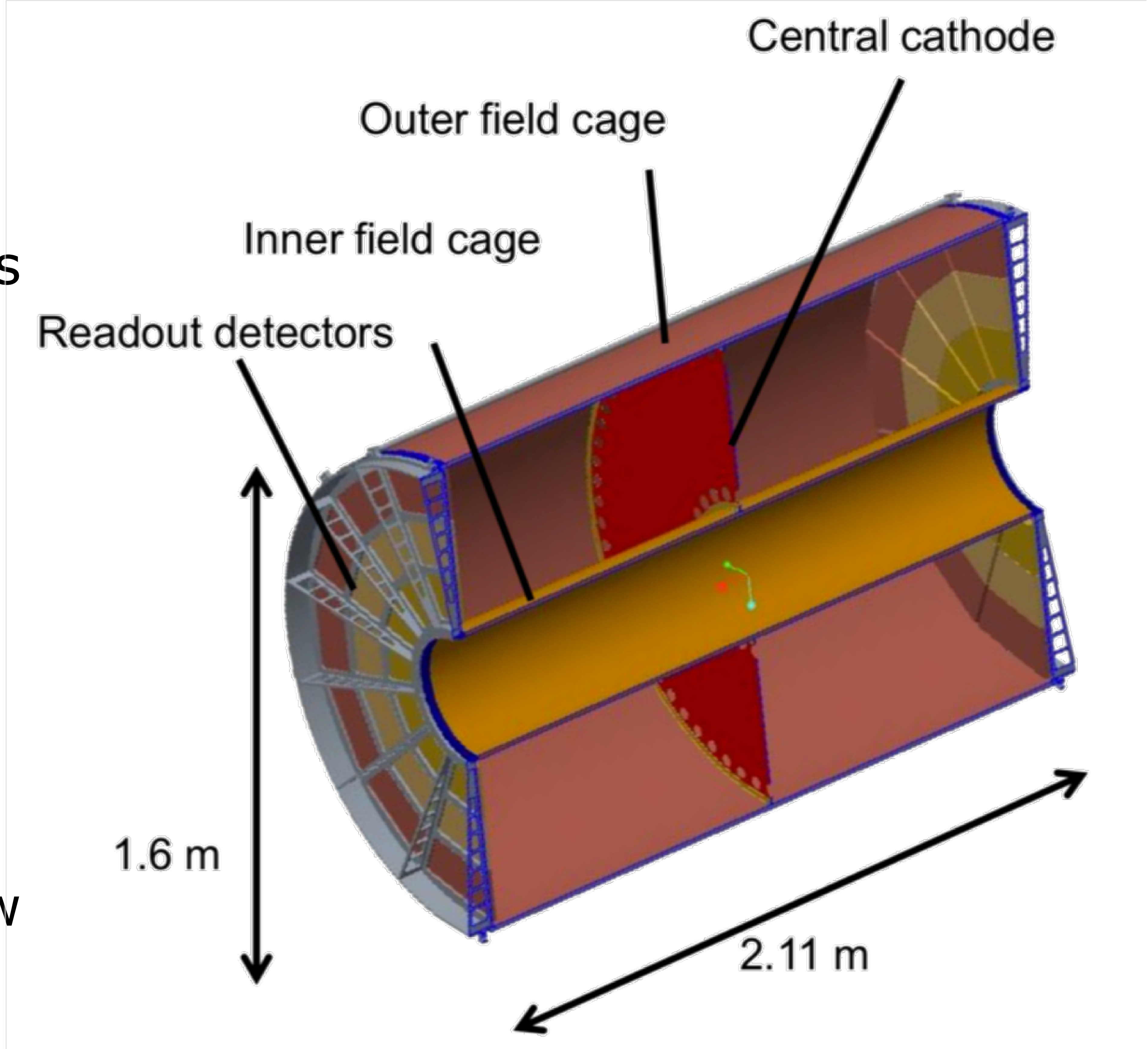
- Ongoing analysis: computation of efficiency, luminosity, and systematics done
- Currently: computation of the cross section (both exclusive and inclusive)
- One of my interests also lies in the development of future particle physics experiments, which will investigate further the proton structure, gluon saturation… Like EIC





Micromegas and GEMs for TPC readout

- A solution based on a TPC + Barrel detectors is considered for an EIC detector
- TPC readout planes equipped with Micromegas / GEMs are under consideration
- R&D of readout detectors for TPC application
  - good energy resolution, < 20%
  - gain ~ 2.e3
  - low IBF ~ 0.3%
- Simulation and tests on hybrid detectors
- Goal of energy resolution < 20%, gain ~ 2.e3 and low IBF ~ 0.3% reached and more tests are ongoing

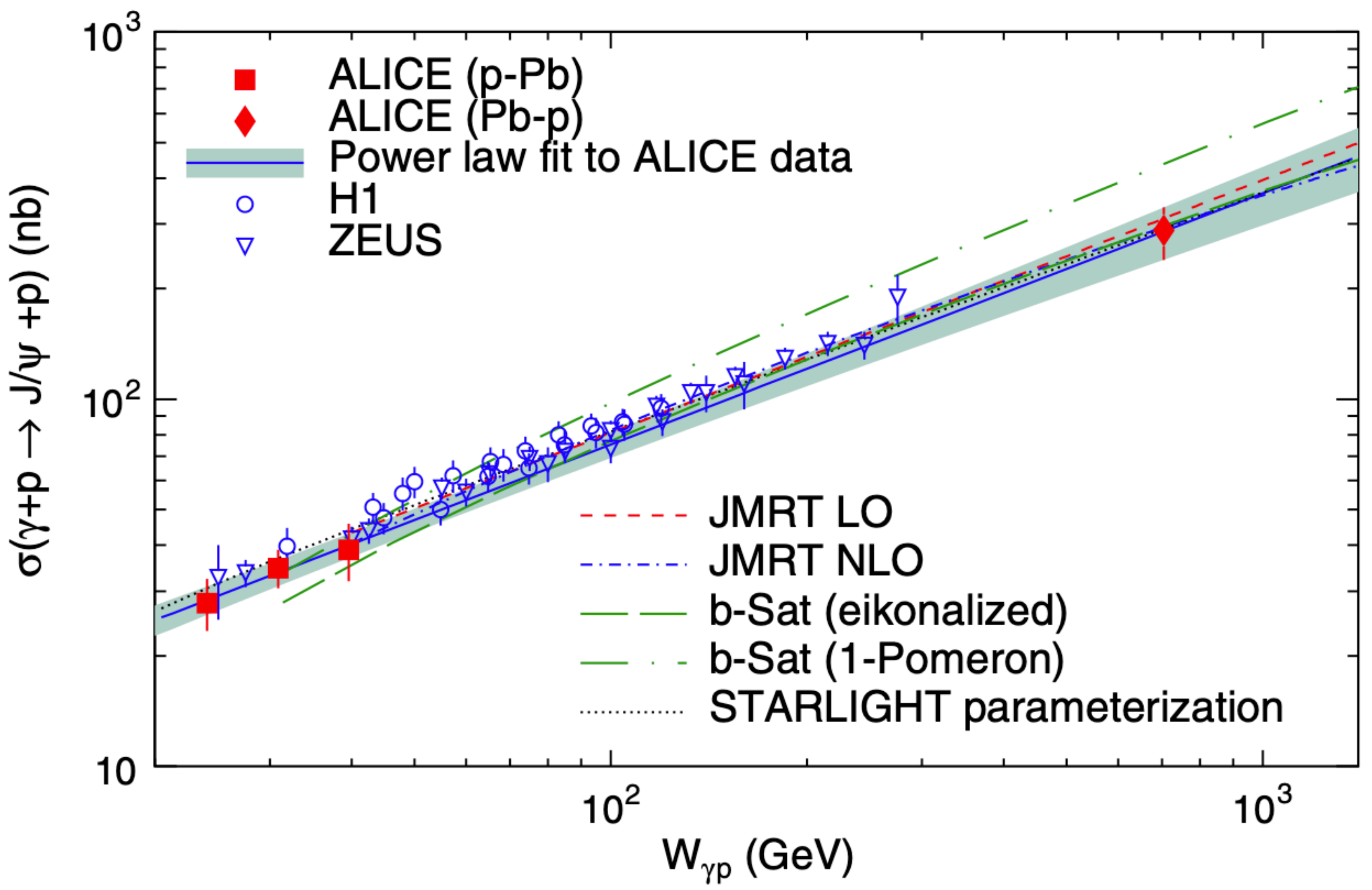


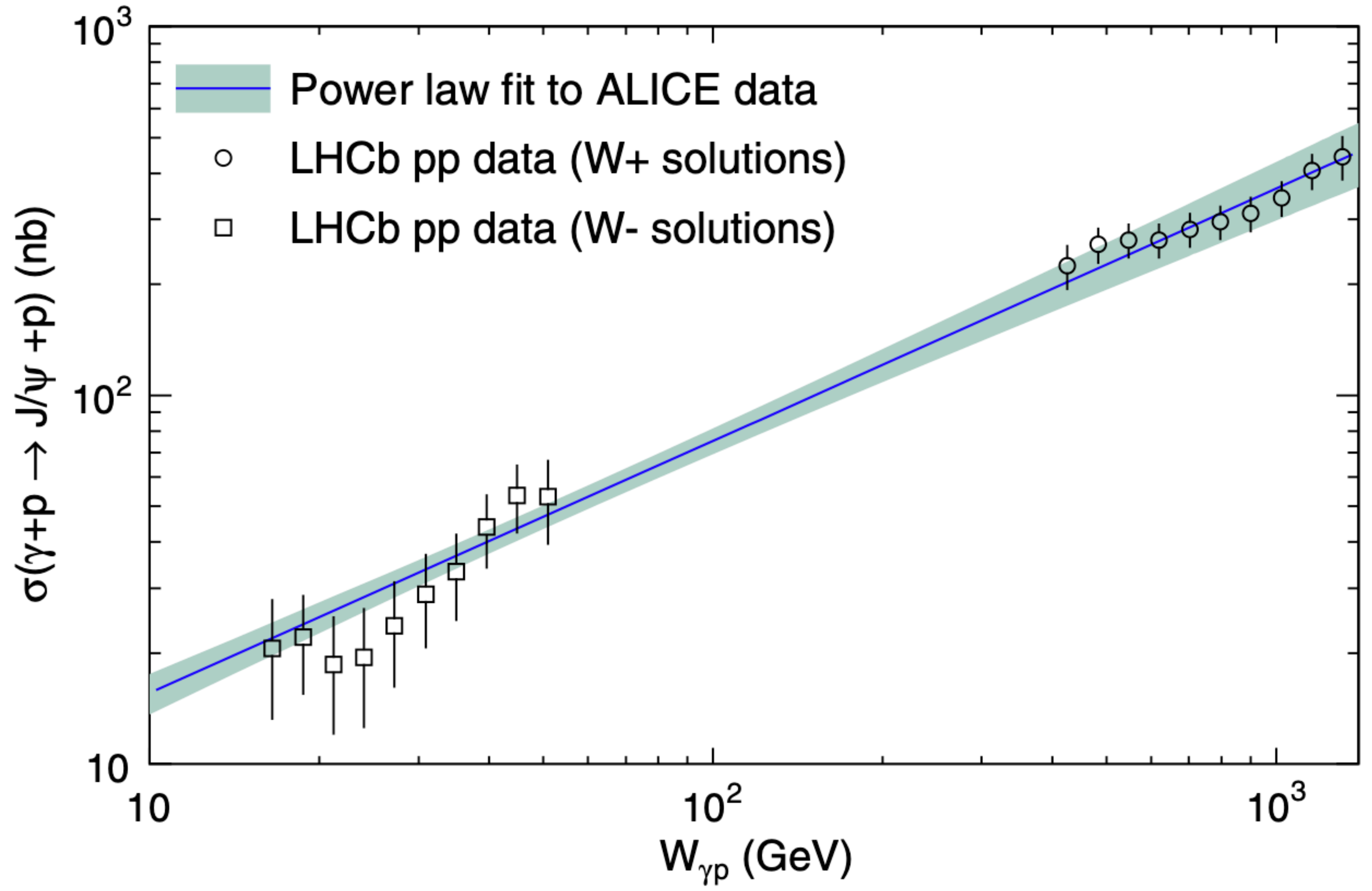
Thank you for you attention!

Back up ALICE

Has this measurement been done before?

- HERA: H1 and ZEUS have measured the cross section of J/ψ photoproduction at energies $W_{\gamma^* p}$ from 20 to 305 GeV
  - Results are inconclusive regarding the question of gluon saturation: data can be described with or without it
- @LHC, LHCb studied the same process in p-p collisions (symmetric system : impossible to identify the photon emitter)
- @LHC, ALICE studied this in 2013 in p-Pb collisions for $W_{\gamma^* p}$ up to 700 GeV

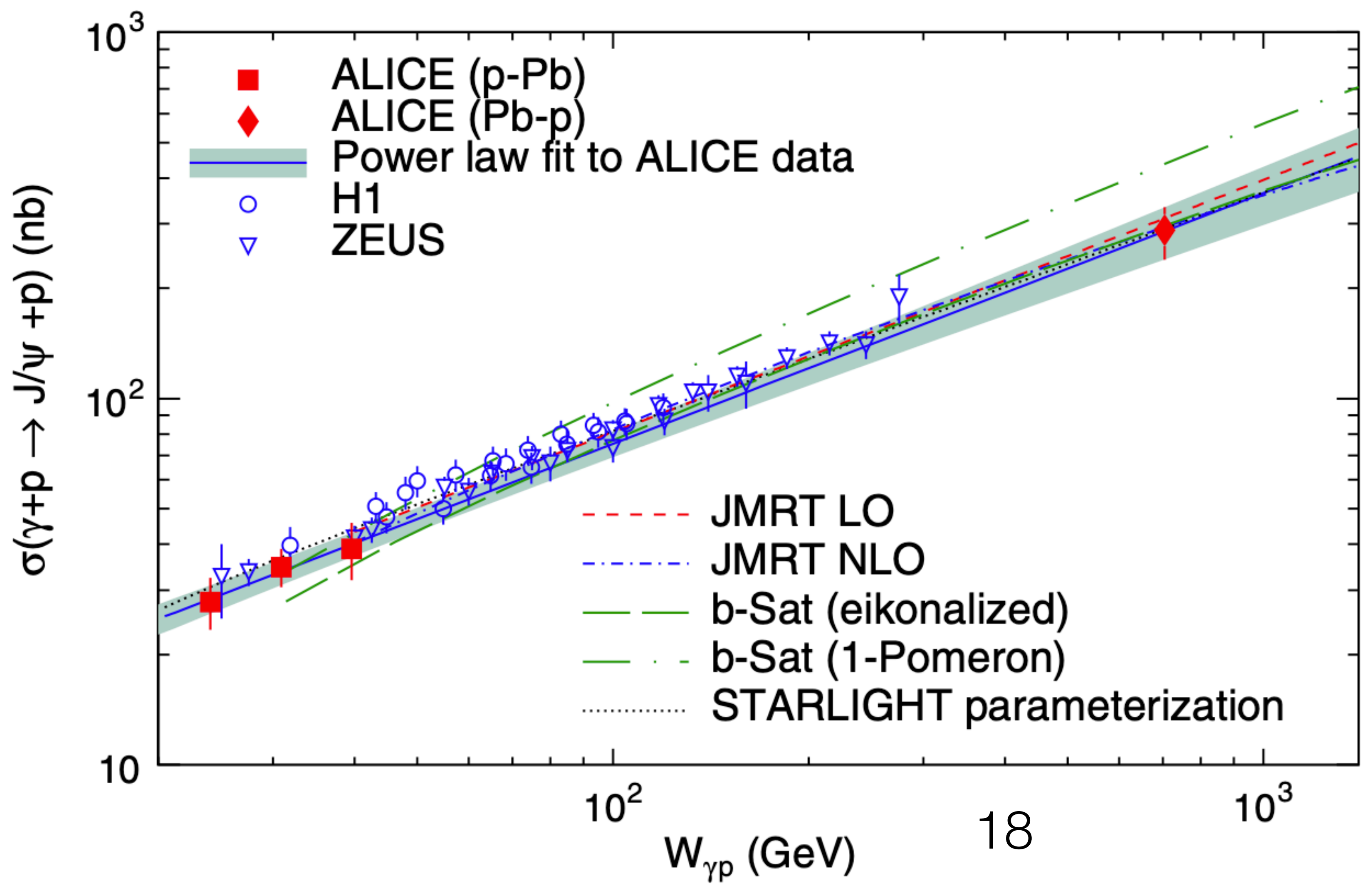




from PRL 113 (2014), 232504

So what’s new?

- In this analysis (2016 data), the CM energy in the p-Pb system is $\sqrt{s}$ = 8.16 TeV (5 TeV in 2013), allowing to reach up to $W_{\gamma^* p}$ = 1500 GeV
- Luminosity went from 3.9 nb^{-1} in p-Pb (4.5 nb^{-1} in Pb-p) in 2013 to 7.6 nb^{-1} in p-Pb (11.9 nb^{-1} in Pb-p) in 2016
- Inclusive J/ψ contribution in UPCs has not been studied in ALICE yet
- Different kinematic regime: $x \sim 8 \times 10^{-6}$ ($x \sim 4 \times 10^{-5}$ with 2013 data, gluon PDFs probed at $x \sim 10^{-4}$ at HERA)



Exclusive J/ψ photoproduction

- In Good-Waker formalism (https://arxiv.org/abs/2001.10705)
  - **exclusive**: the proton remains in the same quantum state

$$\frac{d\sigma^{\gamma^* p \to J/\Psi\ p}}{dt} \propto \sum_i |\langle i | A | i \rangle|^2 = |\langle A^{\gamma^* p \to J/\Psi\ p} \rangle|^2$$

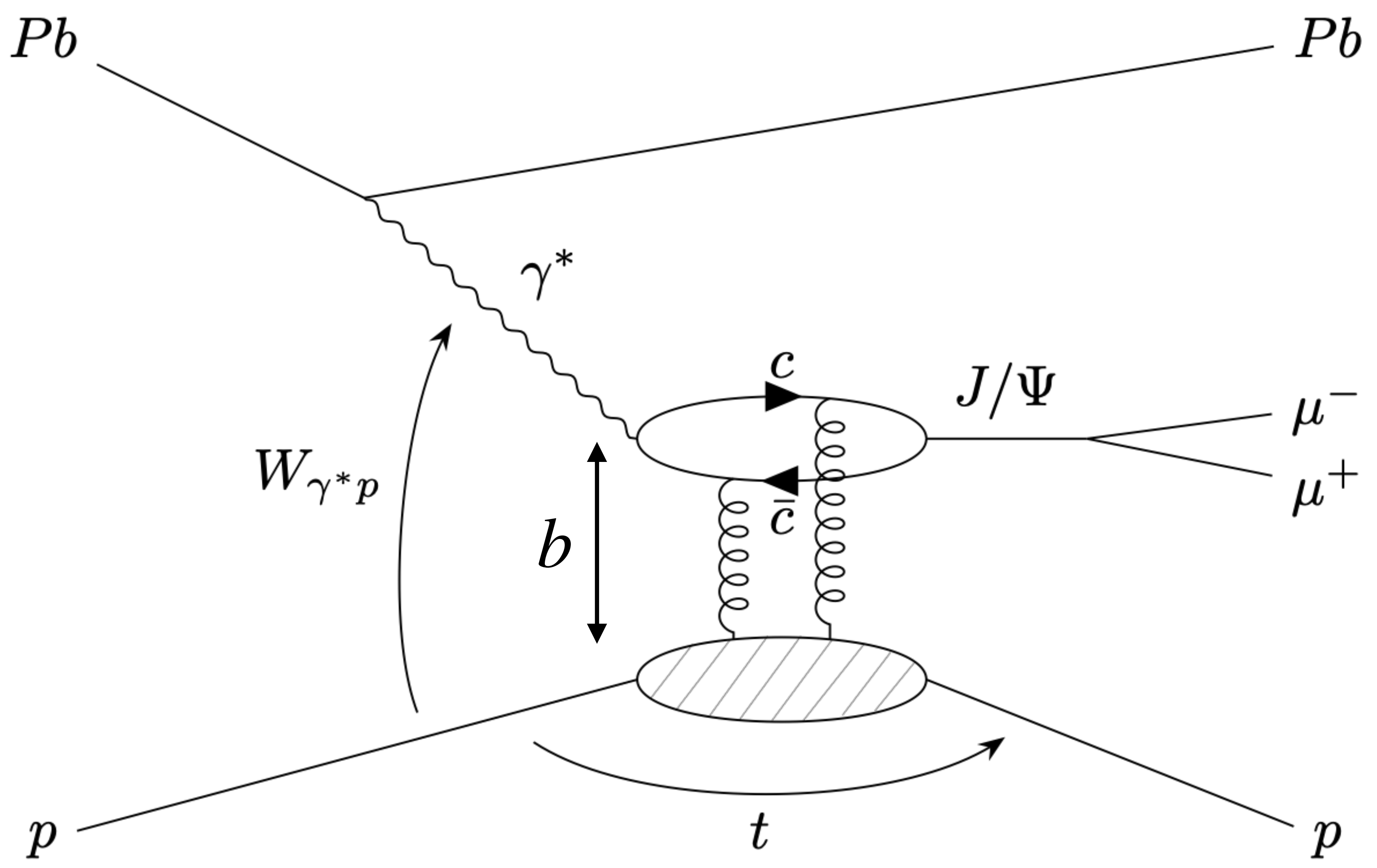
Physically: we measure the average structure (configurations) of the proton

- For small $q\bar{q}$ at leading twist, leading $\ln(1/x)$, $t \to 0 \frac{d\sigma}{dt}(\gamma^* p \to J/\Psi\ p)\Big|_{t=0} \propto [xg(x, Q^2)]^2$
  - Extraction of gluon PDF

- $\frac{d\sigma}{dt} \propto \exp(-b|t|)$
  - Measurement of impact parameter (= Fourier conjugate of $t \simeq -p_T^2$)

- Measurement of J/ψ polarisation
  - Decomposition of proton spin?

- Measurement of gluon generalized parton distribution at low x?



Inclusive J/ψ photoproduction

- In Good-Waker formalism (https://arxiv.org/abs/2001.10705)
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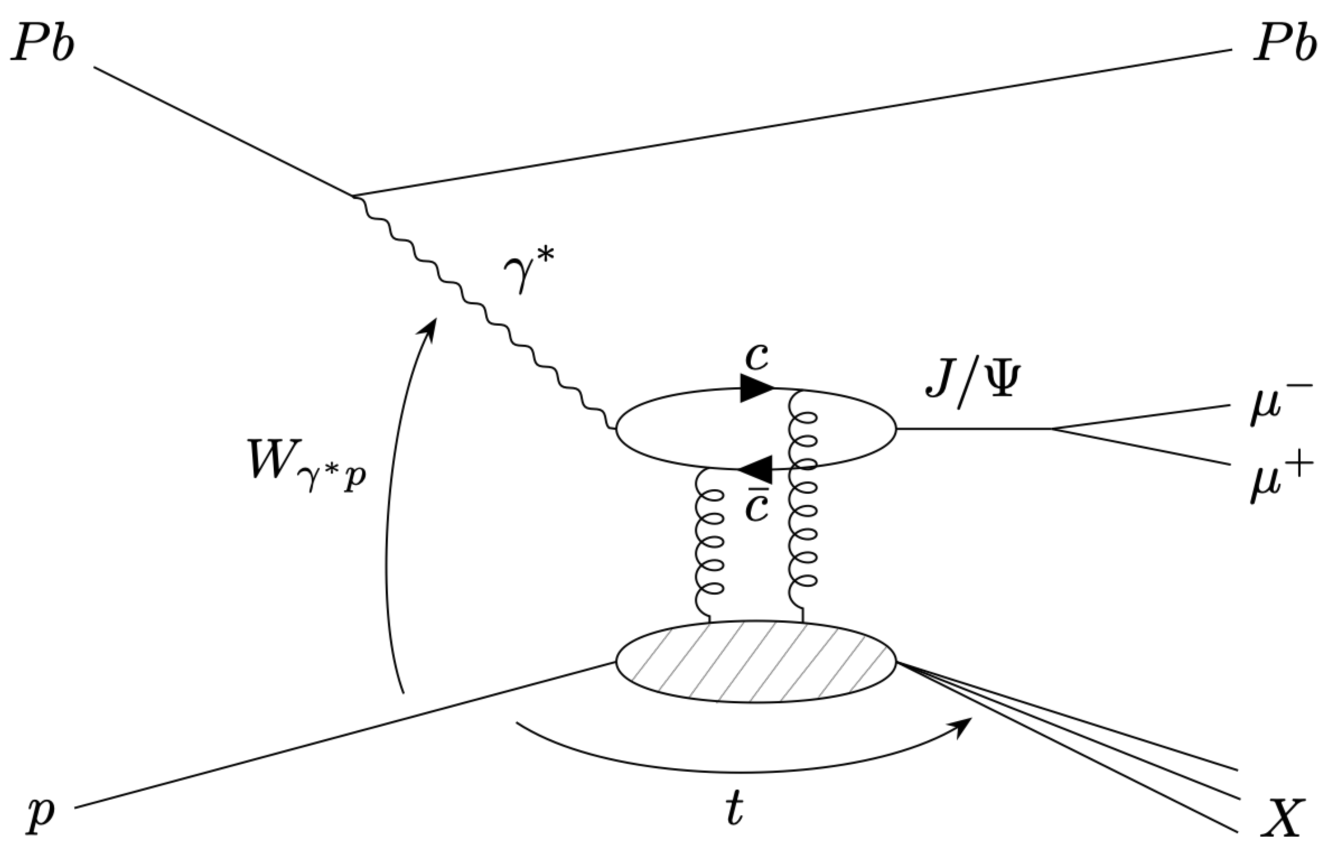


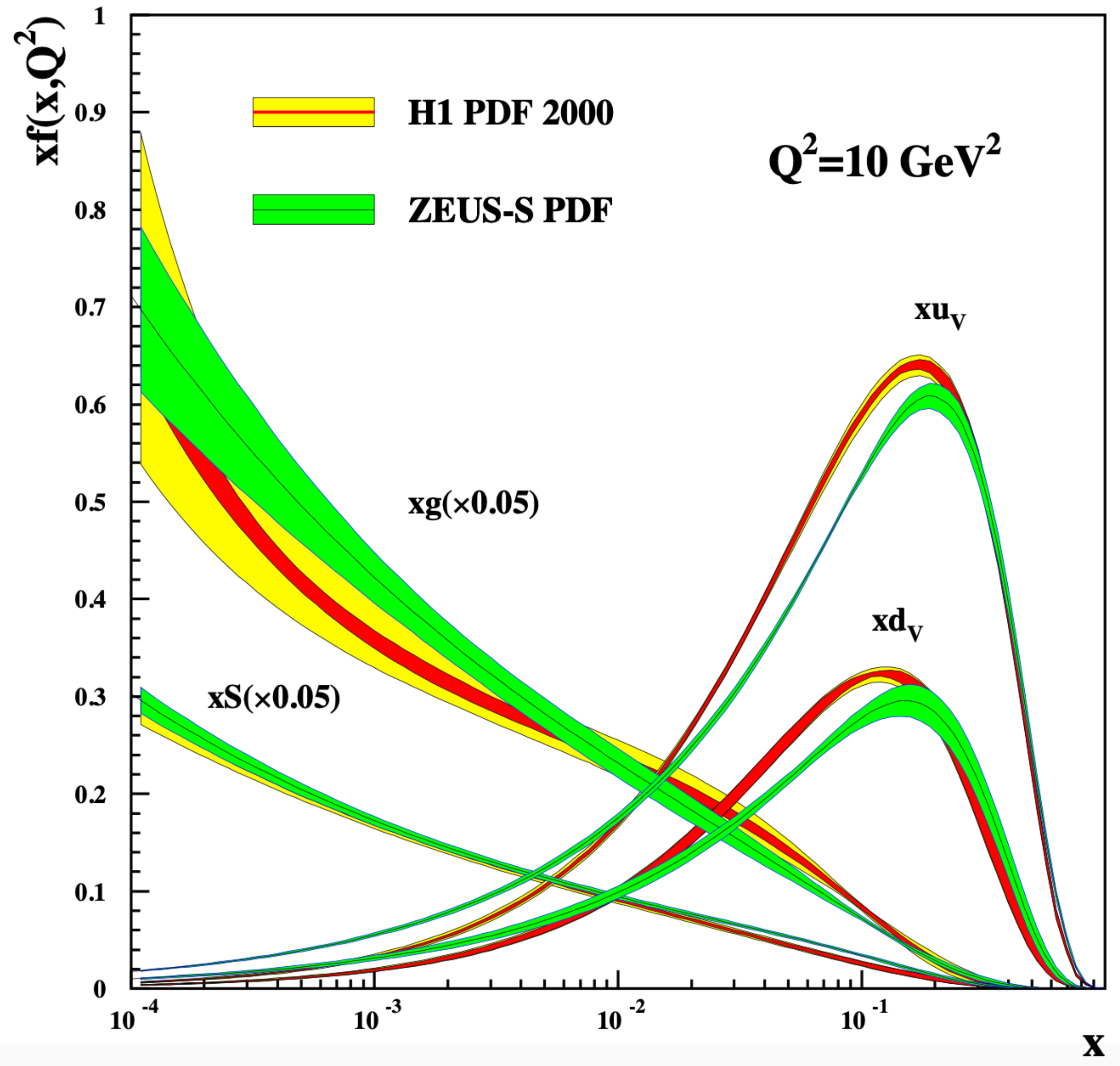
$$\frac{d\sigma^{\gamma^* p \to J/\Psi\ X}}{dt} \propto \sum_i \sum_{f \neq i} |\langle f | A | i \rangle|^2 = \sum_i \sum_f \langle i | A^* | f \rangle \langle f | A | i \rangle - \sum_i \langle i | A^* | i \rangle \langle i | A | i \rangle$$

$$= \sum_i \langle i | A^* A | i \rangle - \sum_i |\langle i | A | i \rangle|^2$$

$$= \langle |A^{\gamma^* p \to J/\Psi\ p}|^2 \rangle - |\langle A^{\gamma^* p \to J/\Psi\ p} \rangle|^2$$

Physically: we measure the fluctuations of the configurations of the proton

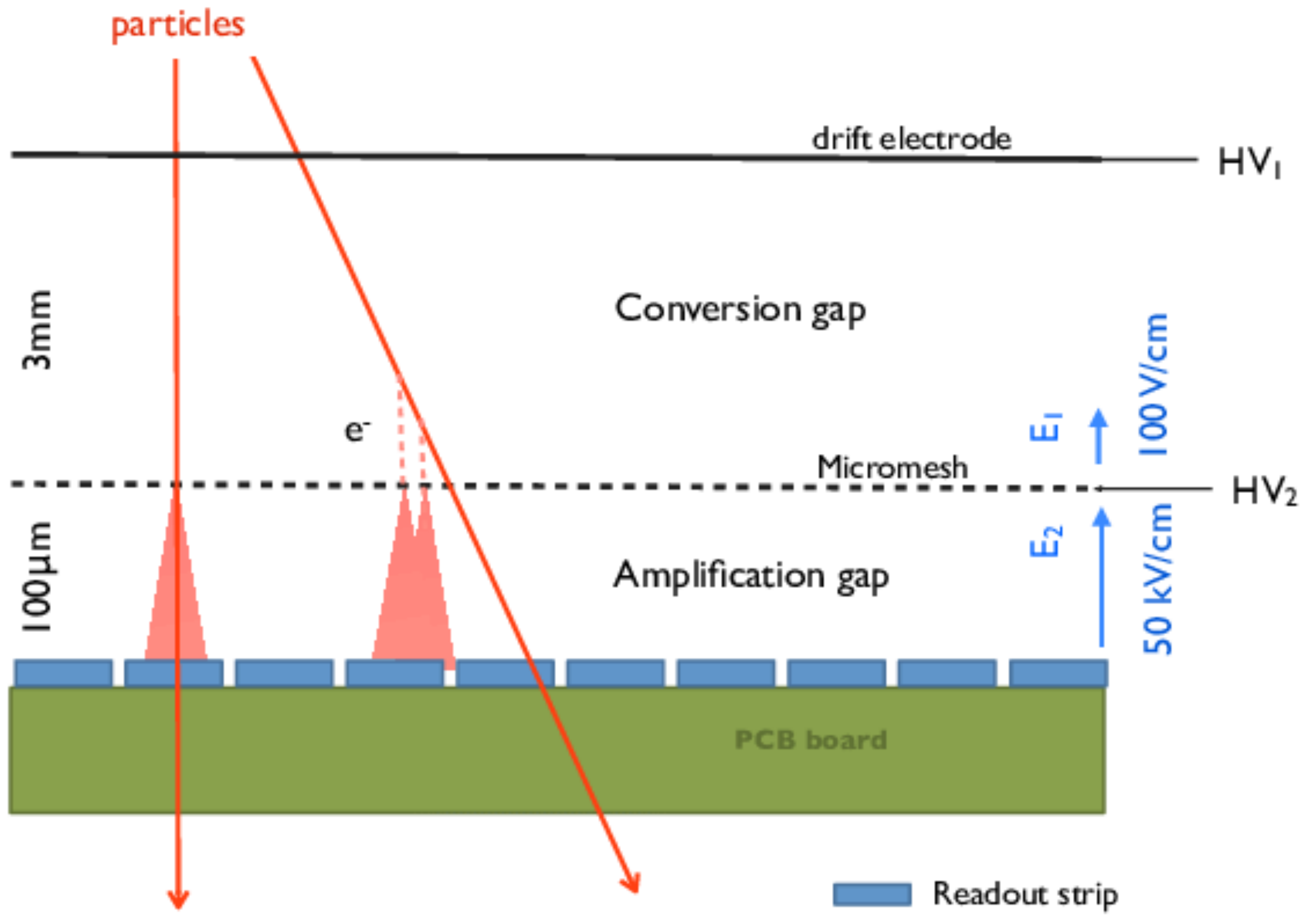
- The parton density increases with decreasing momentum fraction x
  - Saturation at low x?



Back-up R&D Micromegas

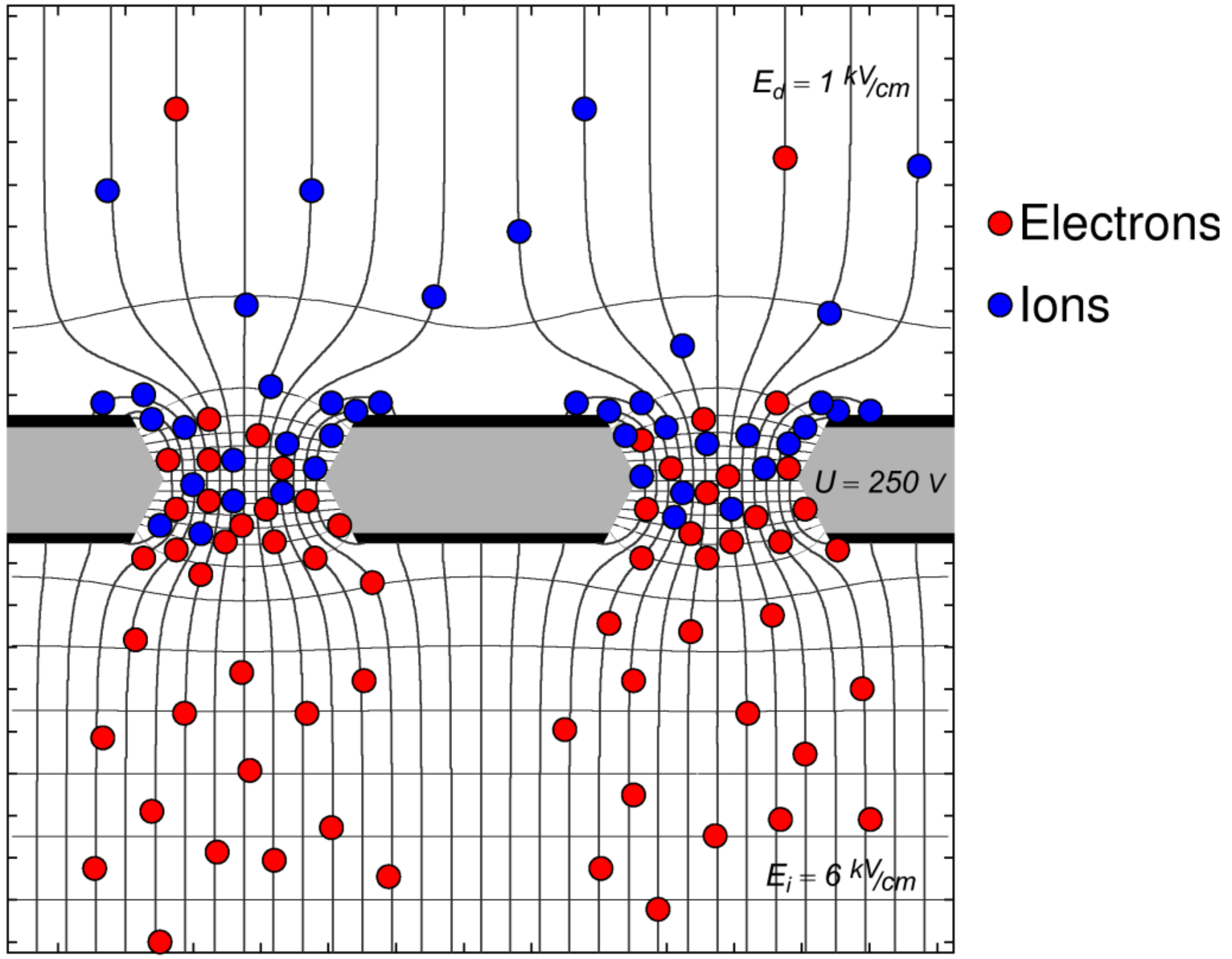
Micromegas / GEM

- MicroMEGAS : Micro-MEsh GASeous structure



Amplification below the mesh
(NIM A 376 (1996) 29-35)

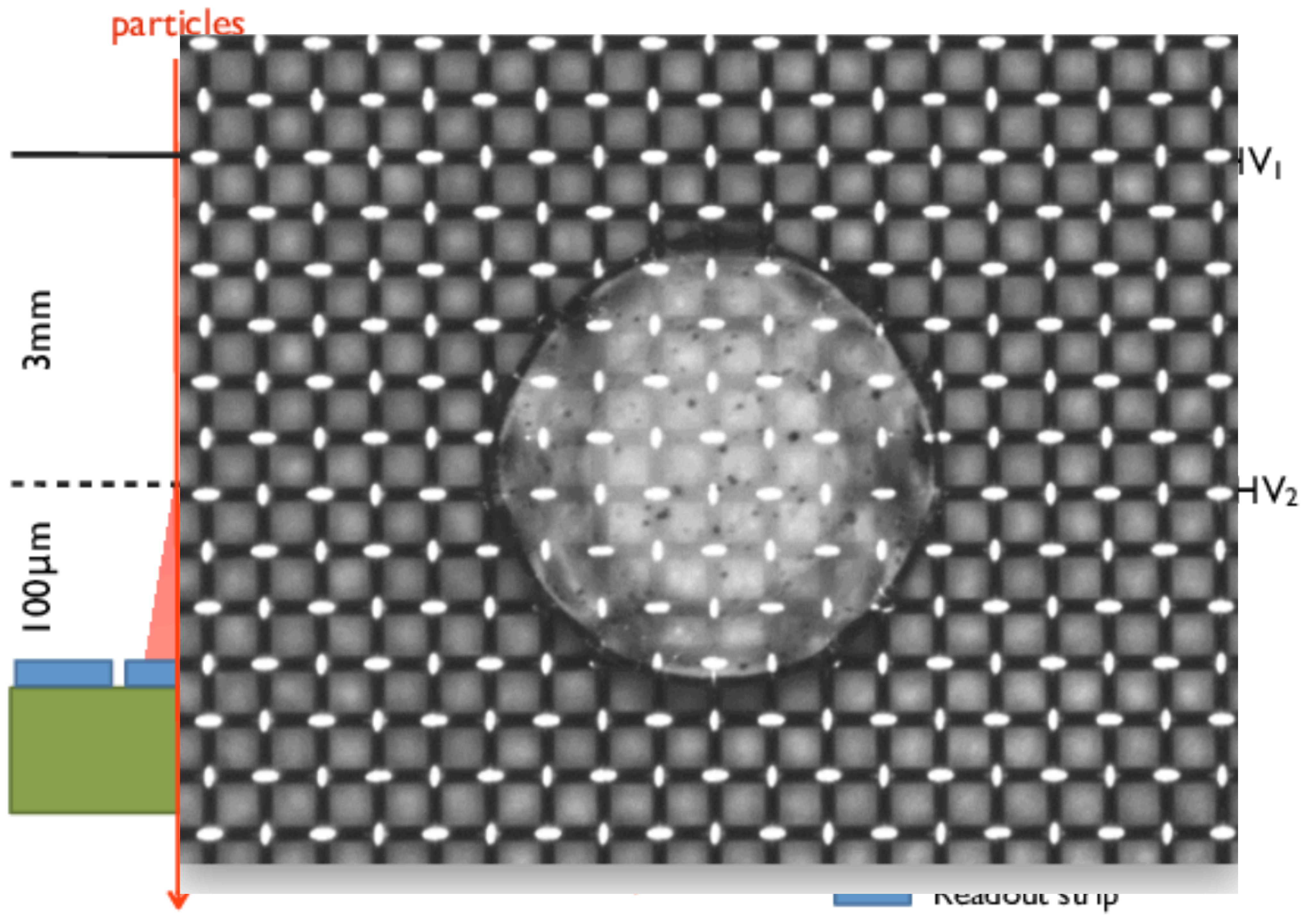
- GEM: Gas Electron Multiplier



Amplification in the holes
(NIM A 386 (1997) 531-534)

Micromegas / GEM

- MicroMEGAS : Micro-MEsh GASeous structure



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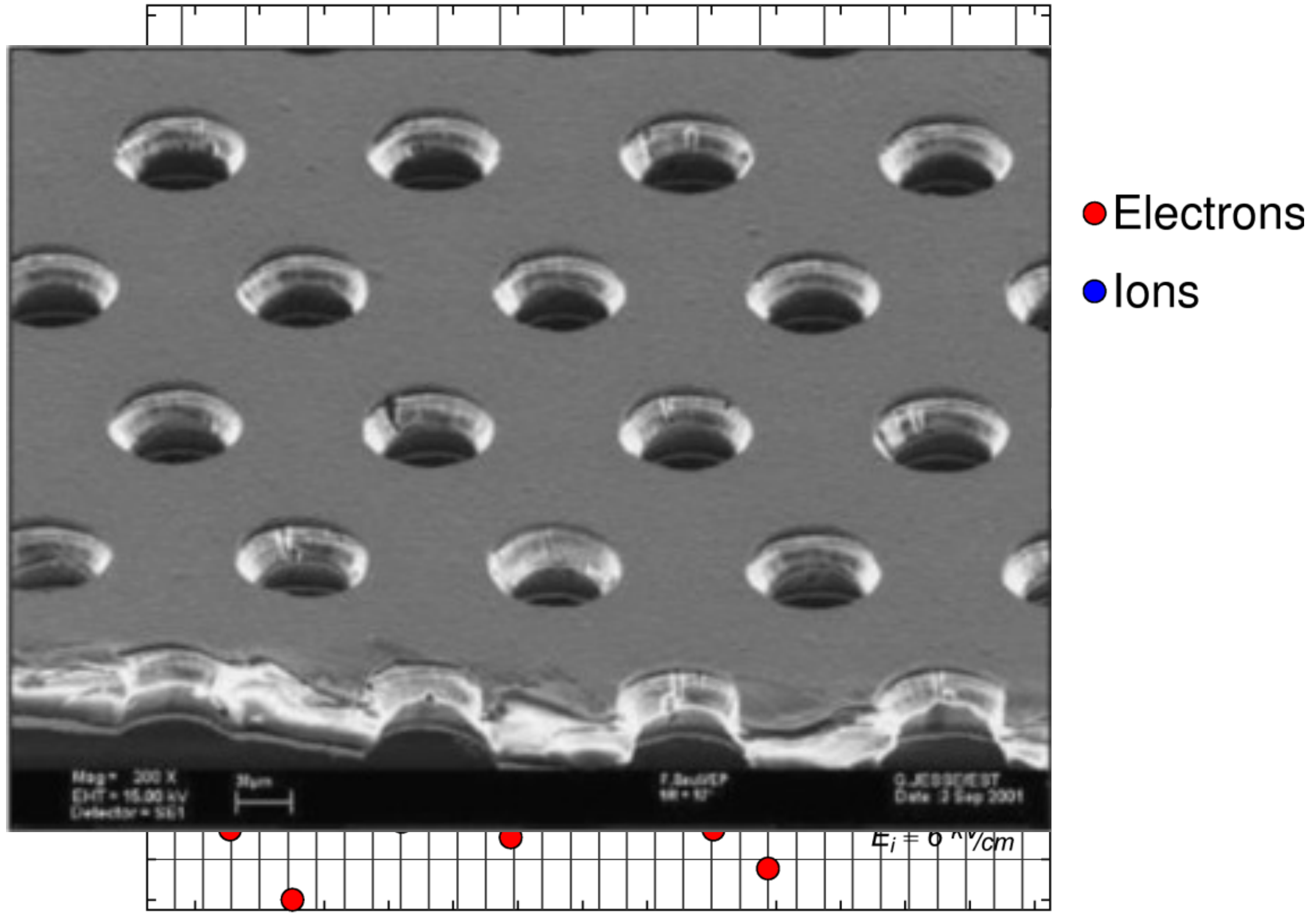

Amplification in the holes
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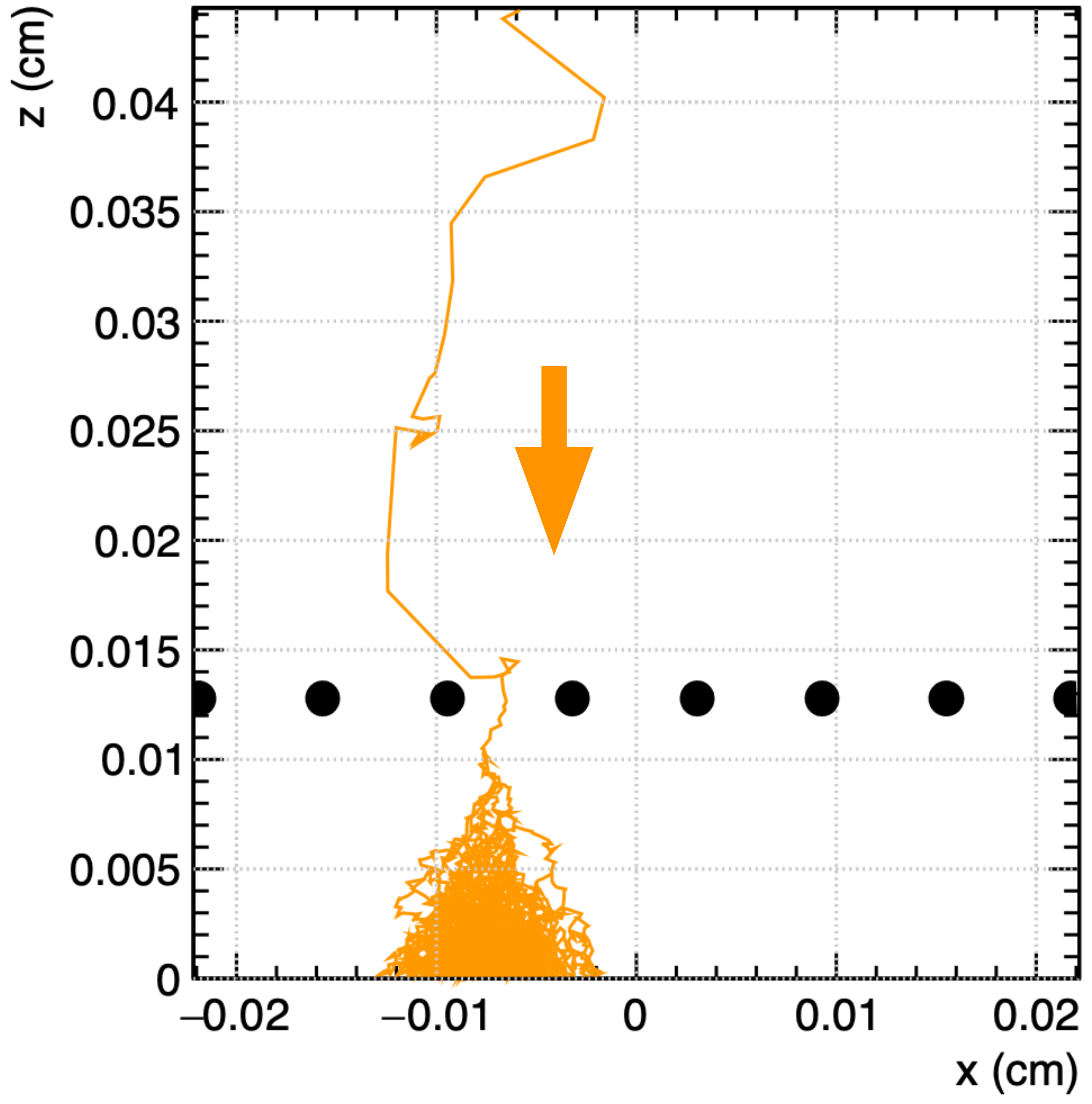
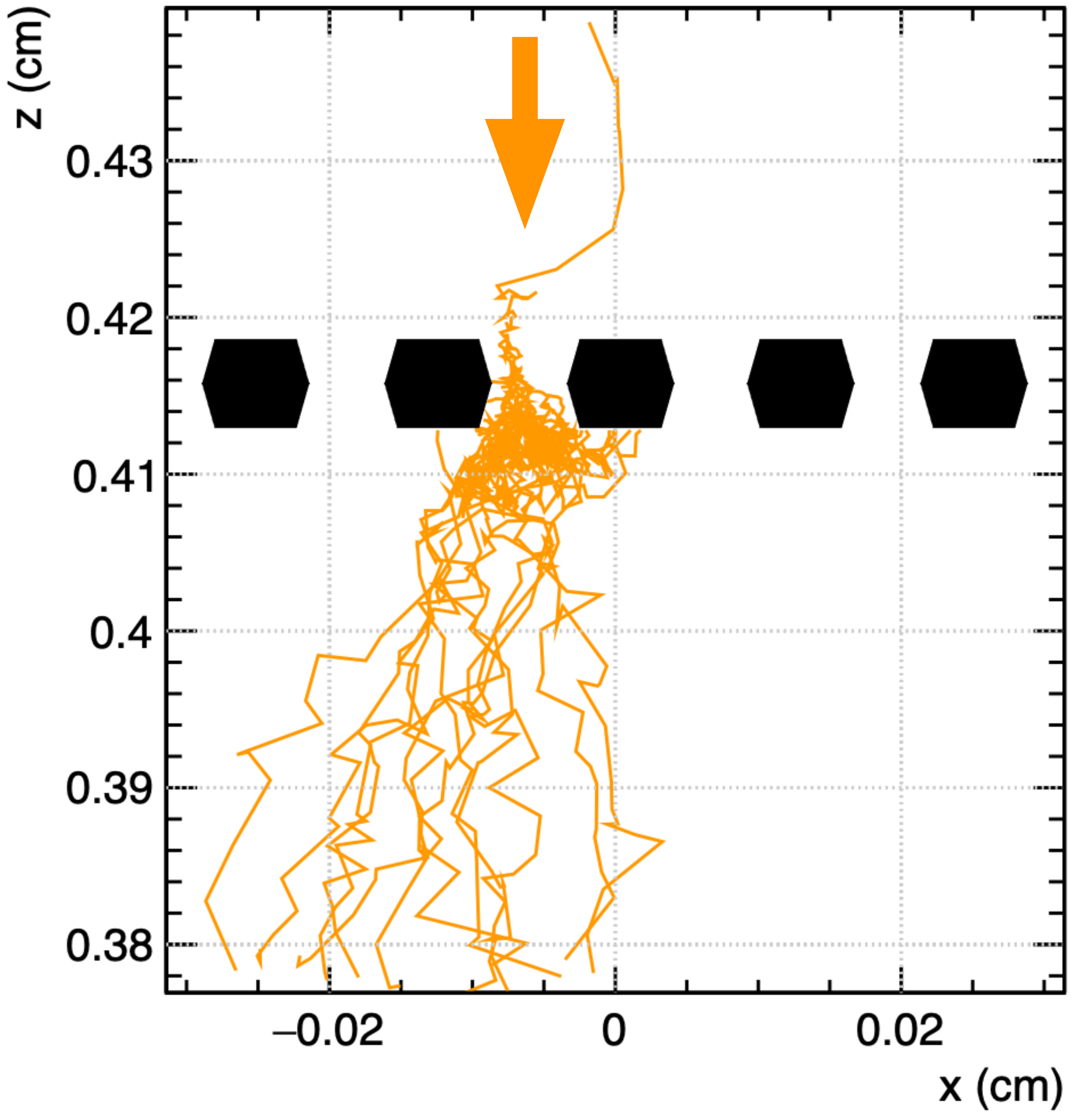
Electron avalanche simulations

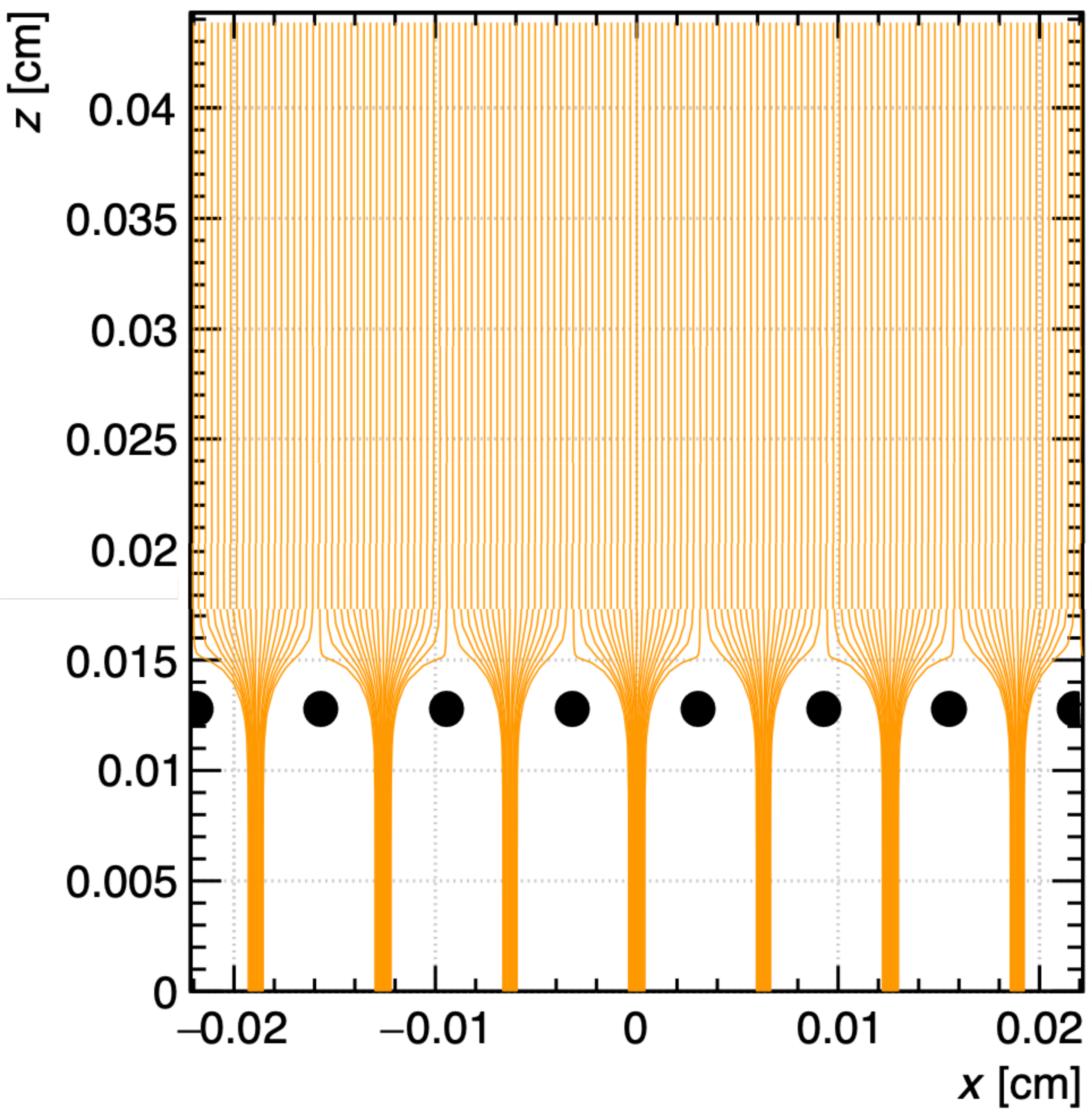


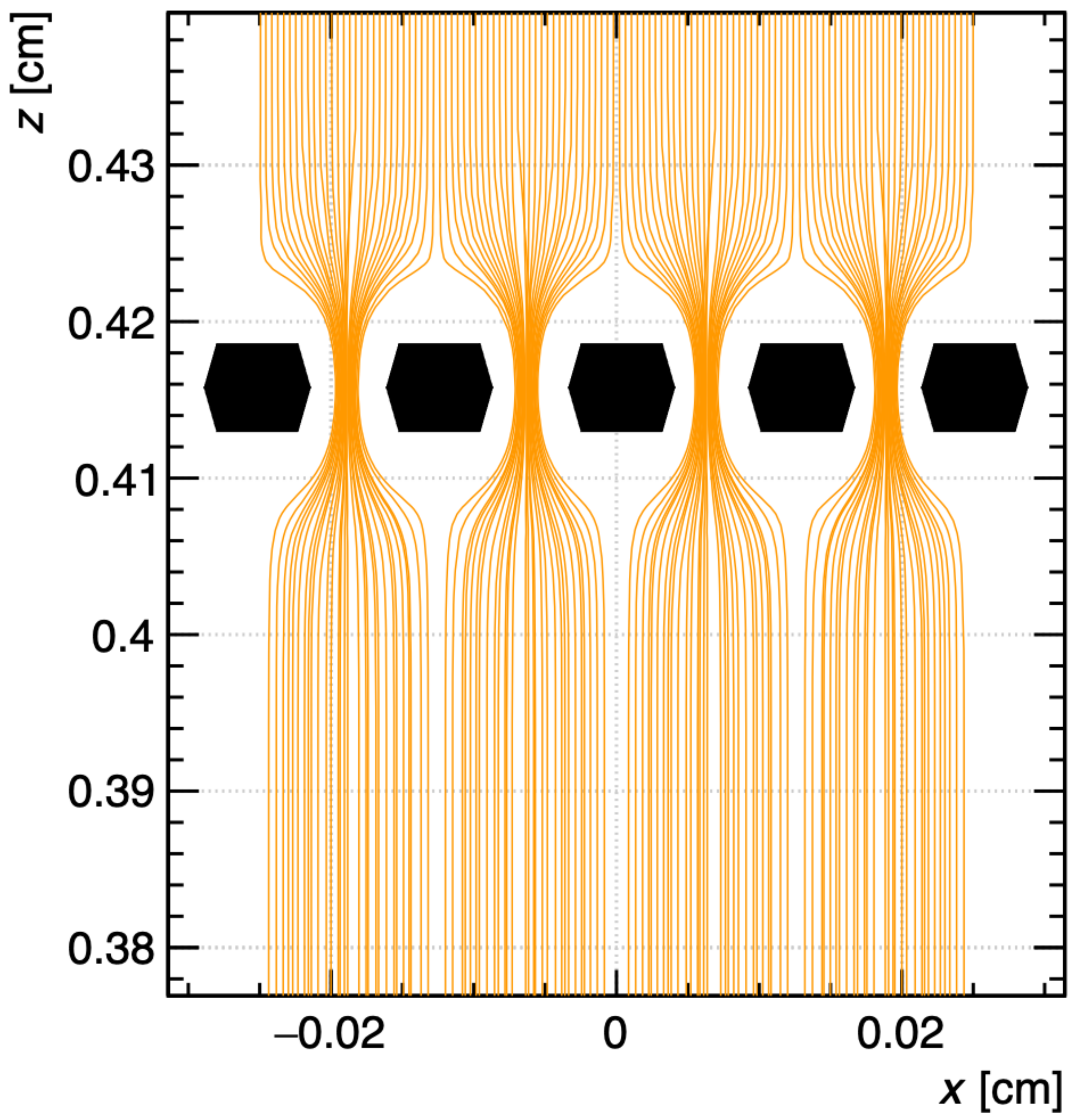


Gain = number of electrons that reach the bottom of the detector

Simulations for simple Micromegas

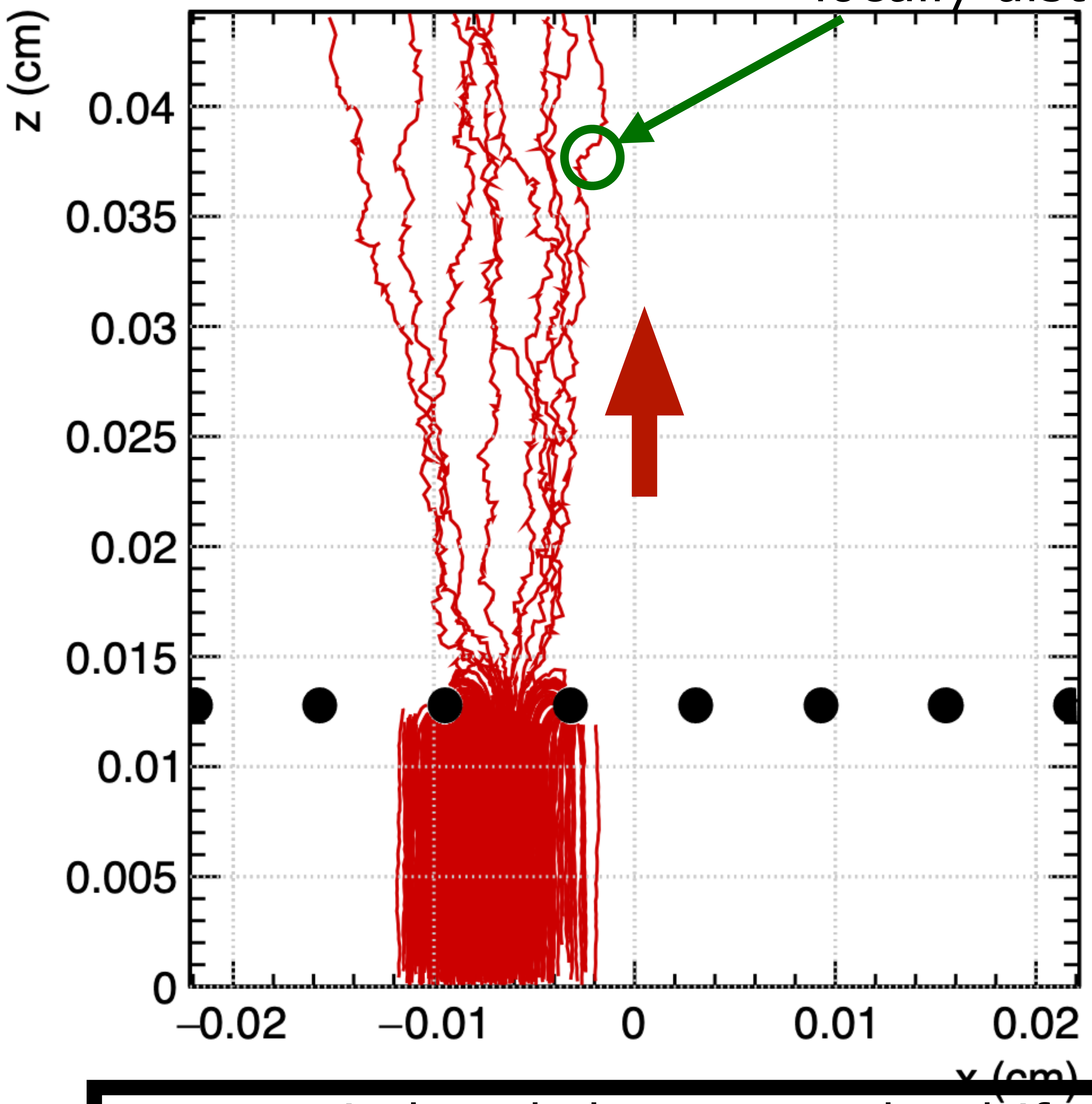
- drift lines

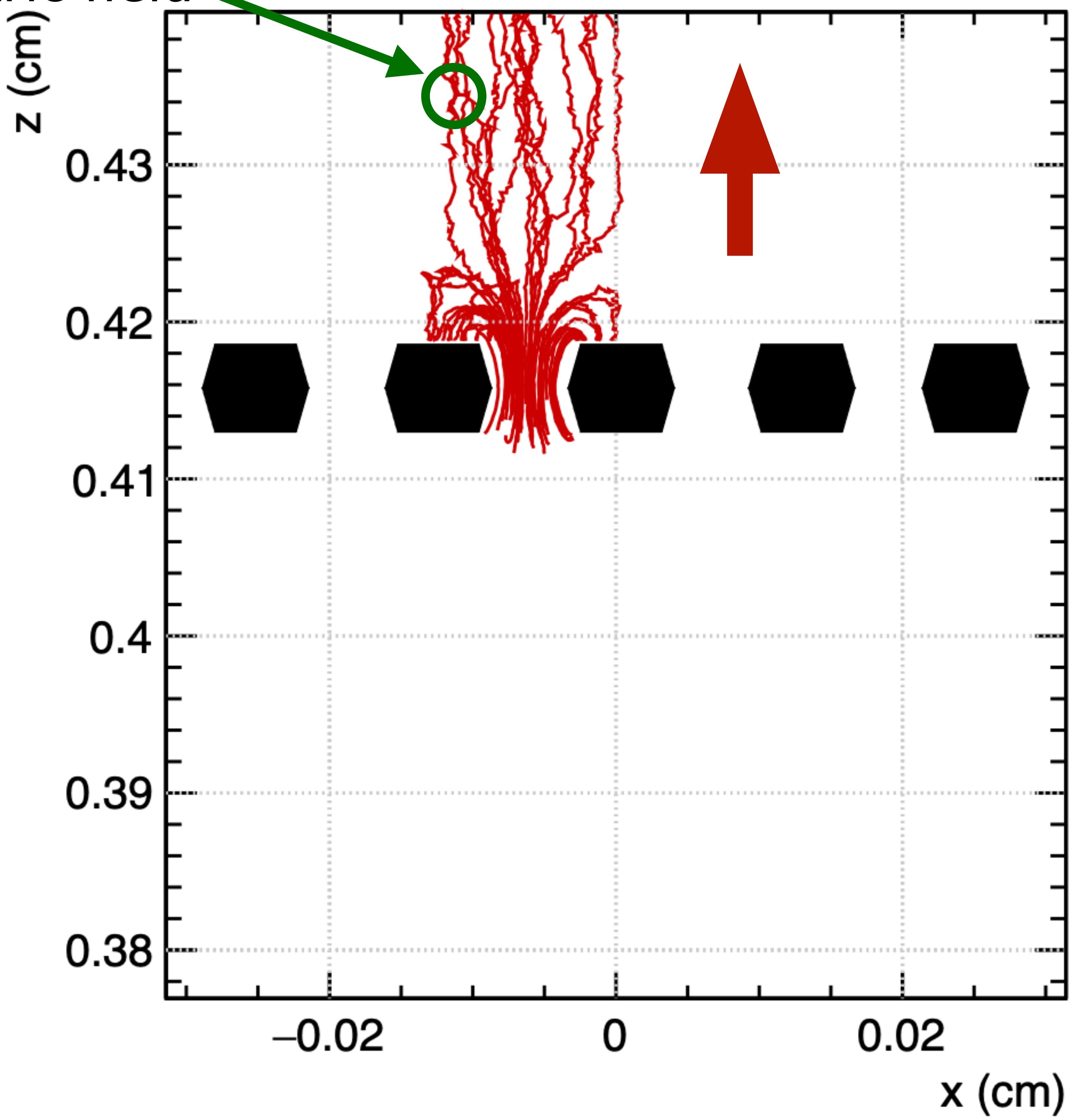




Backflowing ions

locally distort the electric field





$$\mathrm{IBF} = \frac{\#\text{ induced charges on the drift electrode}}{\#\text{ induced charges on the bottom plane}}$$

Goal: design hybrid detectors that would reduce this ion backflow while keeping a gain ~ 10^3