TDIS mTPC update

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On behalf of TDIS collaboration

Outline

- Motivation to pion structure
- The experimental setup for TDIS

    -Super Big Bite Spectrometer (SBS)

    -multi-Time Projection Chamber (mTPC)

- The mTPC prototype

    -Design

    -Construction

- Summary and future work

Motivation to pion structure

- Parton distribution function for pions

  -Is not well understood as for protons

  -Easier to compute in LQCD and models than nucleon due to its simpler $q\bar{q}$ structure

  -But data is necessary to validate such models

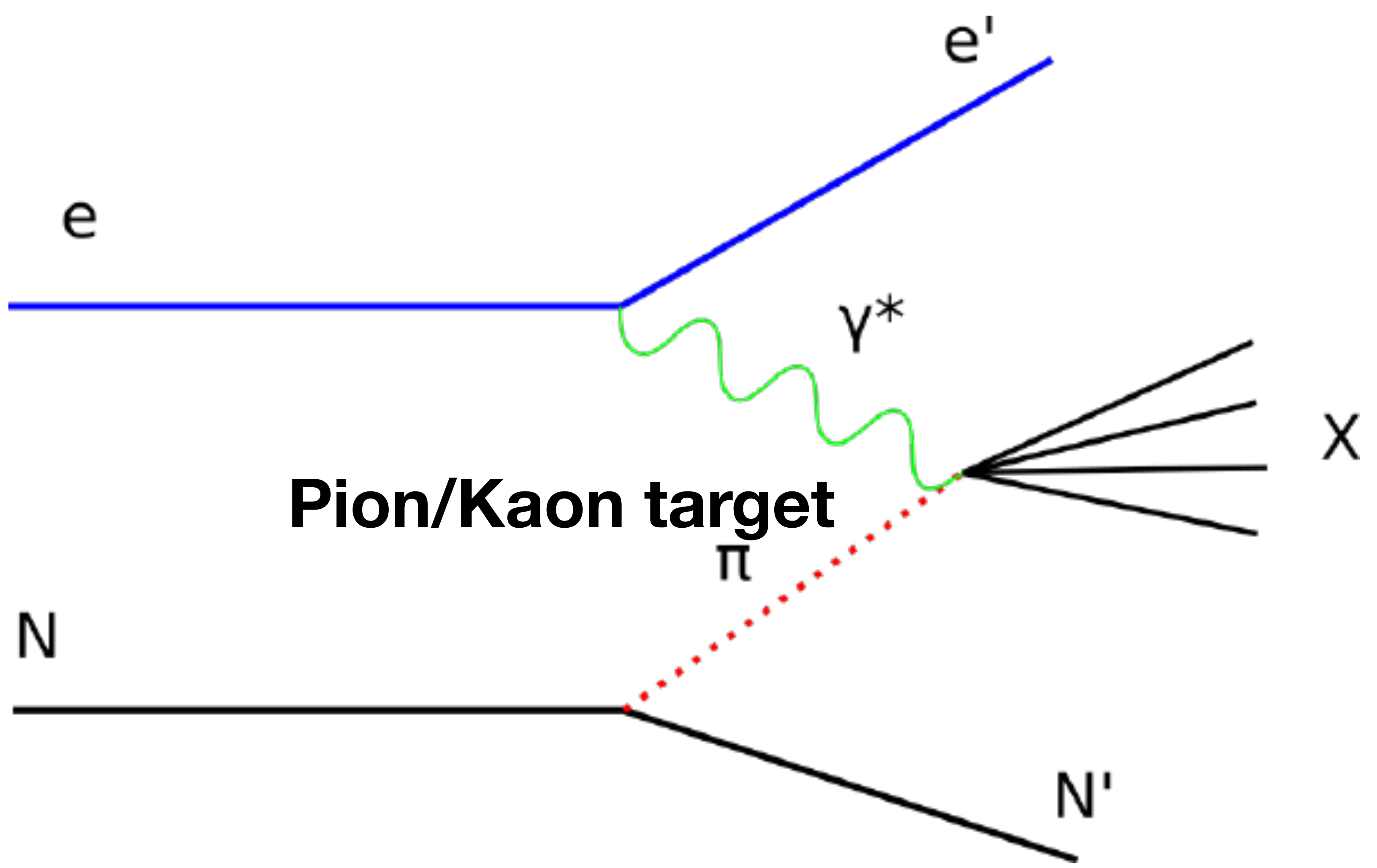
- Different processes allow access to the Pion structure information, like

  -Drell-Yan

  -Sullivan

Physics Objects for Pion Structure Studies

Sullivan process – scattering from nucleon-meson fluctuations

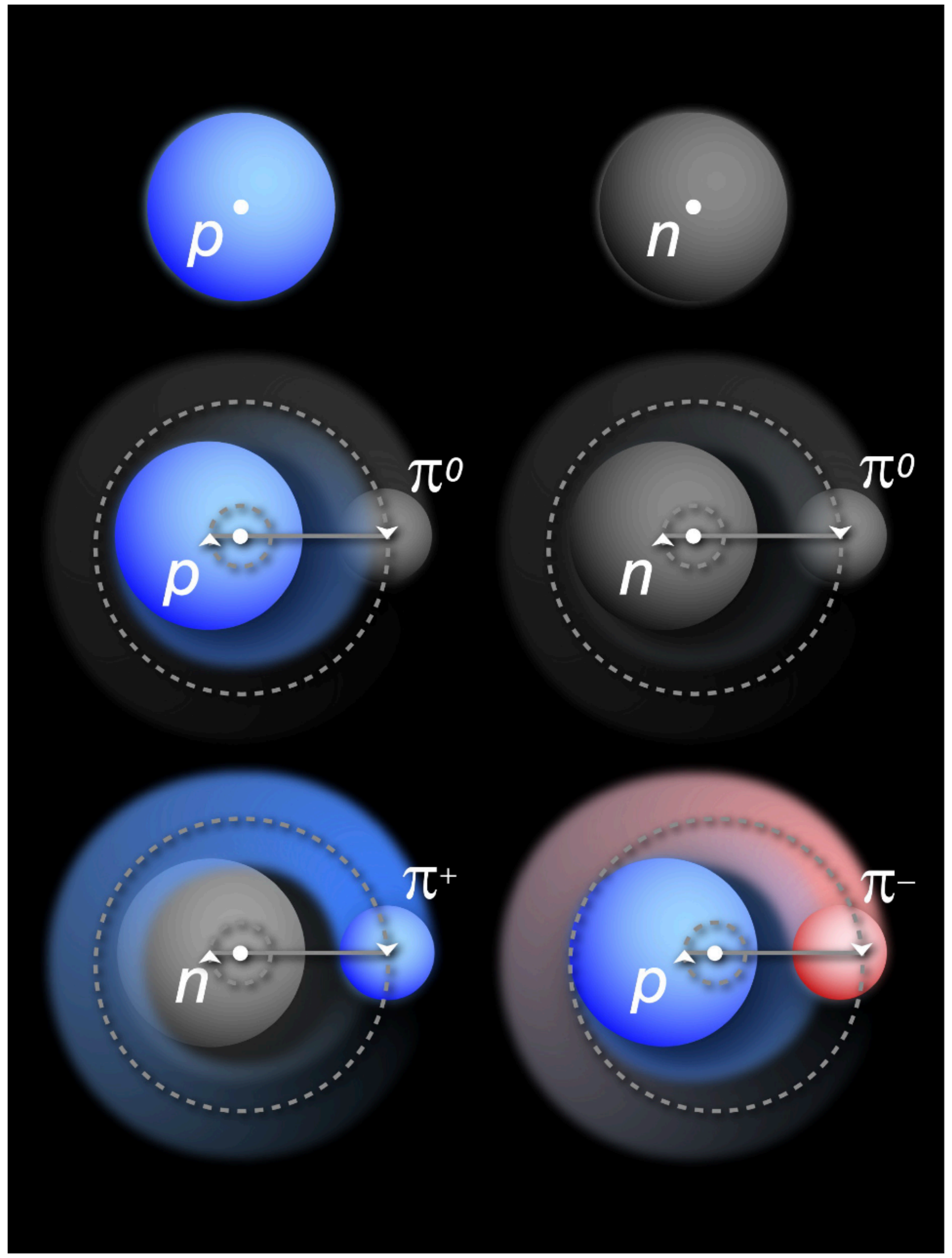


DIS event –
reconstruct x,Q2,W2
Undetected recoiling
hadronic system

Detect "tagged" proton/neutron/lambda

$$F_2^{LP(3)} = \sum_i \boxed{\left[\int_{t_0}^{t_{min}} f_i(z,t)dt\right]} F_2^i(x_i, Q^2)$$

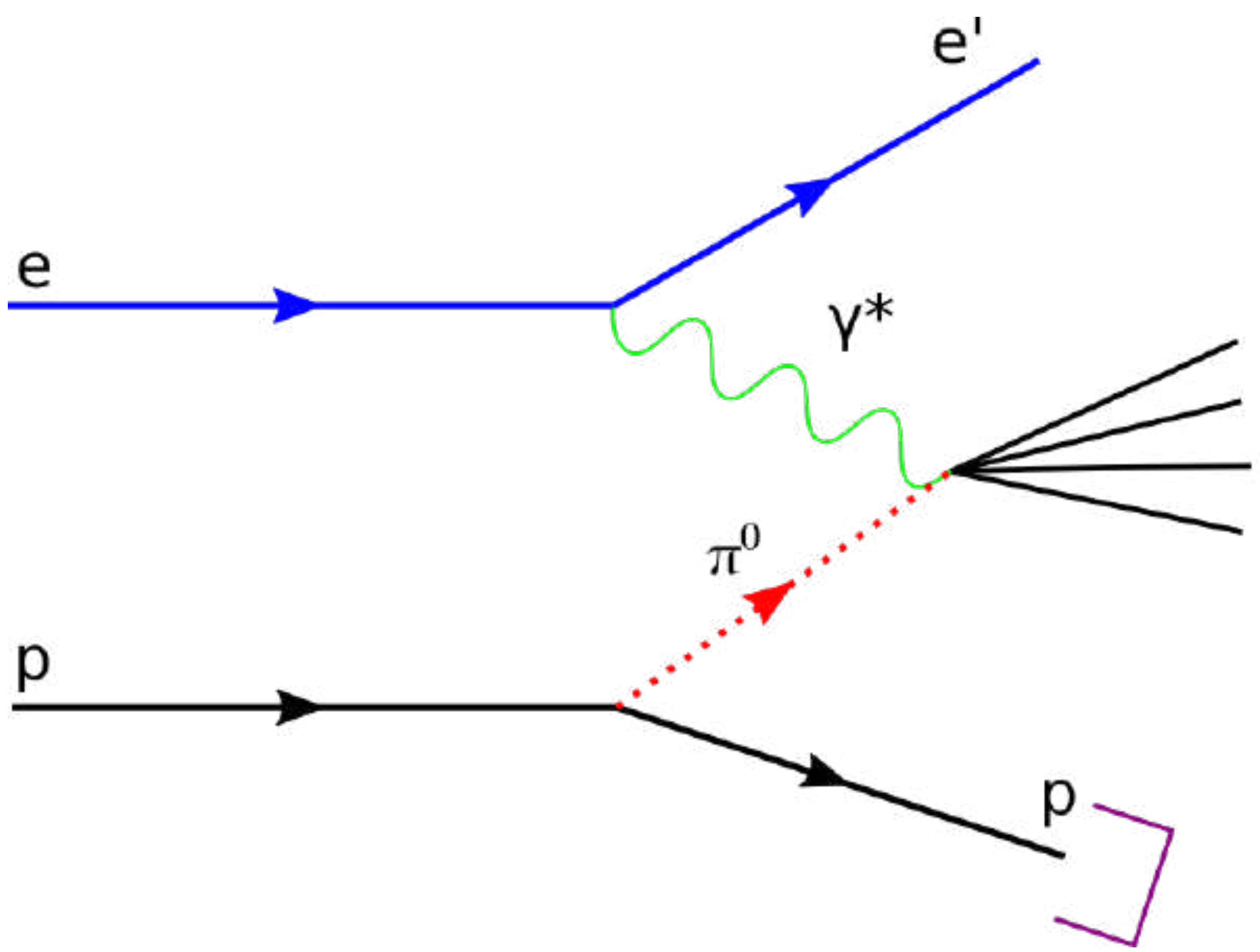
Flux factor



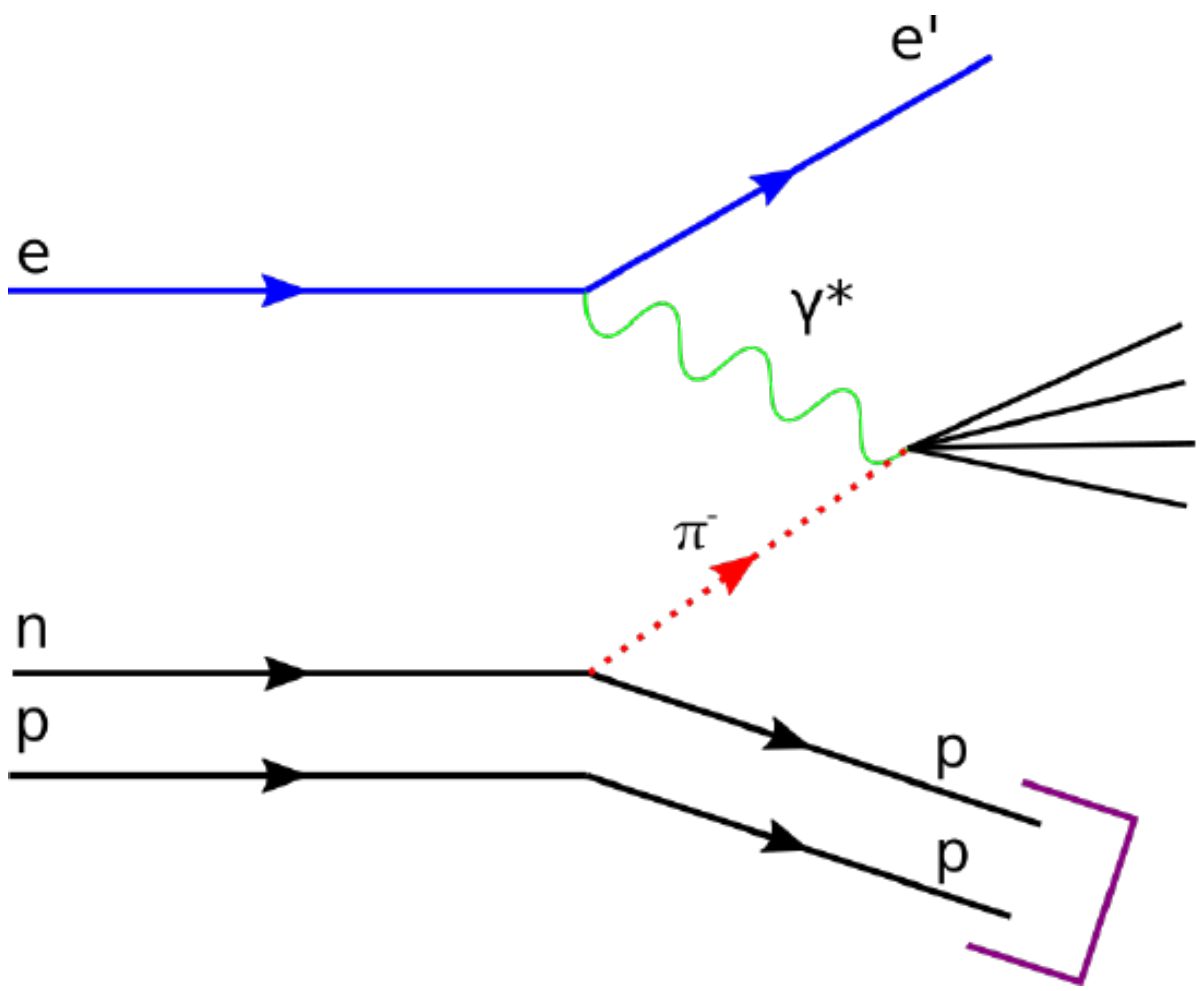
Credit: Joshua Rubin, Argonne National Laboratory

Pion structure from Sullivan process (TDIS)

More details Carlos talk tomorrow



Recoil proton
(Backward going slow proton)
TAG



detecting two protons with common vertex
Spectator proton

Effective π^0 target

$H(e, e'p)X$

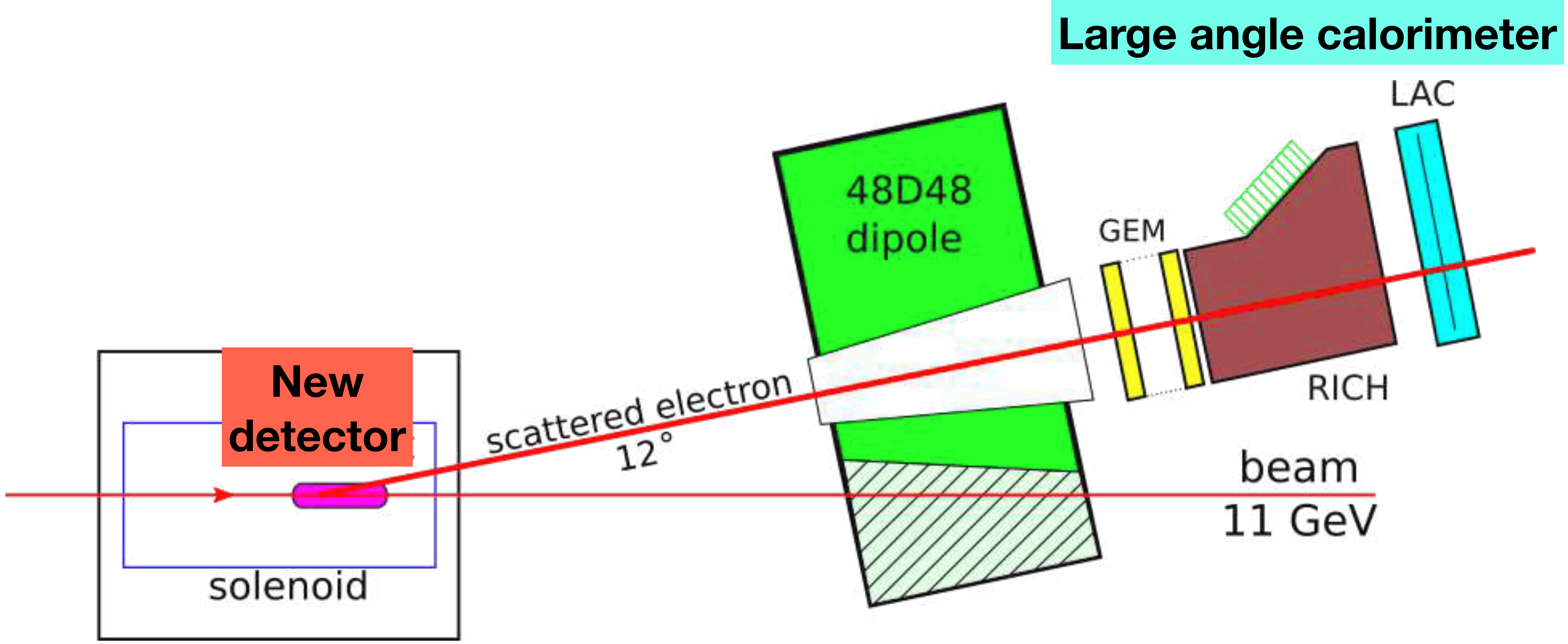
Effective π^- target

$D(e, e'pp)X$

This experimental technique is to measure the low-energy outgoing "recoil" proton (as well as a very low energy spectator proton in the D case) in coincidence with a deeply inelastically scattered electron

Experimental setup for TDIS experiment

- 11 GeV electron beam
- $8 < W^2 < 18$ GeV
- $1 < Q^2 < 3$ $(GeV/c)^2$
- $0.05 < x < 0.2$
- High luminosity is required $\sim 10^{36}$Hz/cm



SBS spectrometer

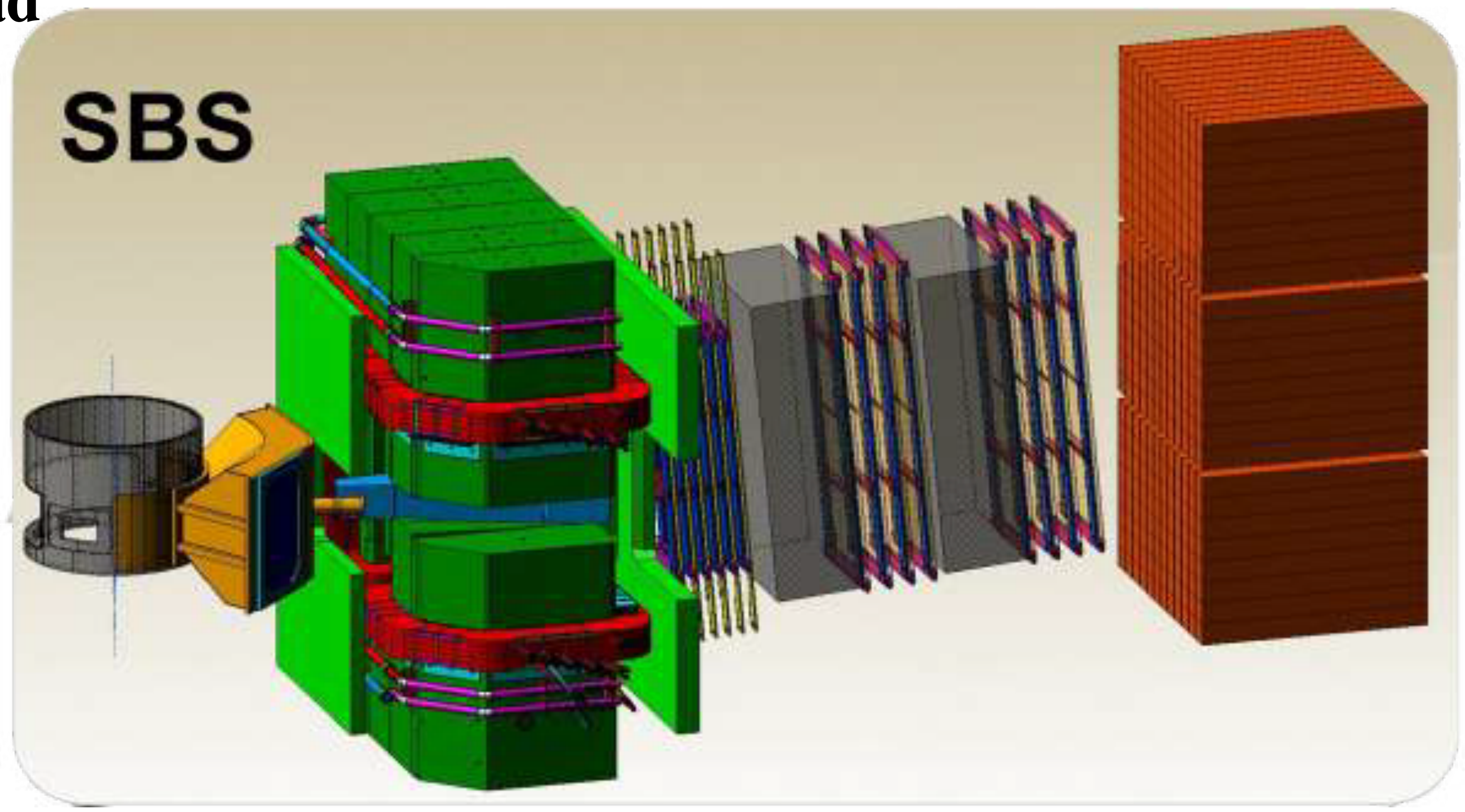
eH ⟶ **One proton**

eD ⟶ **Two protons with common vertex**

e' detection:Super BigBite Spectrometer

- $\Delta\Omega$ 76 msr @15^0,5 msr @3.5^0 (forward/small angle hadrons detected)
- Δp 2-10 GeV/c
- σ_p/p -1 $\times 10^{-4}$
- Angular resolution 0.5 mrad

Hadron detection configuration



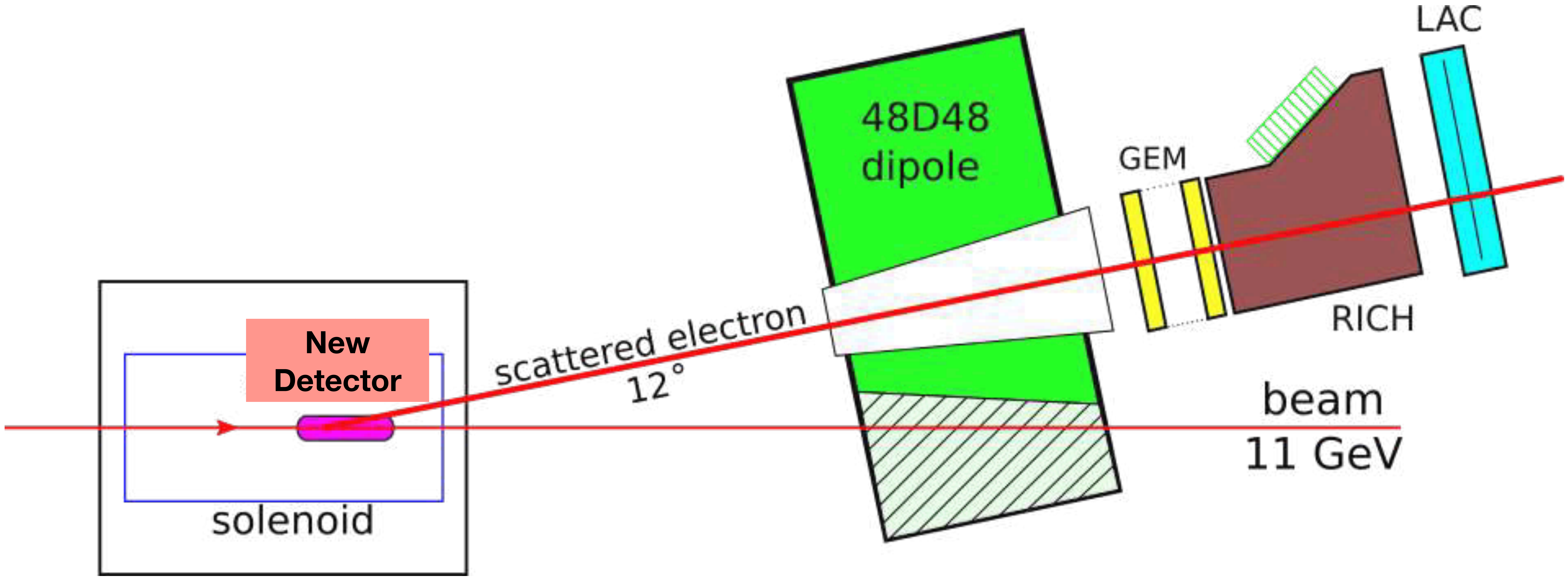
LAC at ESB

RICH at ESB

SBS configured for e' detection

- 12^0 scattering angle (large acceptance, -50 msr)
- 5 GEM tracker planes (70 μm resolution)
- Threshold CO_2 Cherenkov detector (modified HERMES RICH)
- Large angle calorimeter (From Hal B CLAS)
- e^- PID and e^- trigger (L2) = Cherenkov + calorimeter (combined π rejection factor)

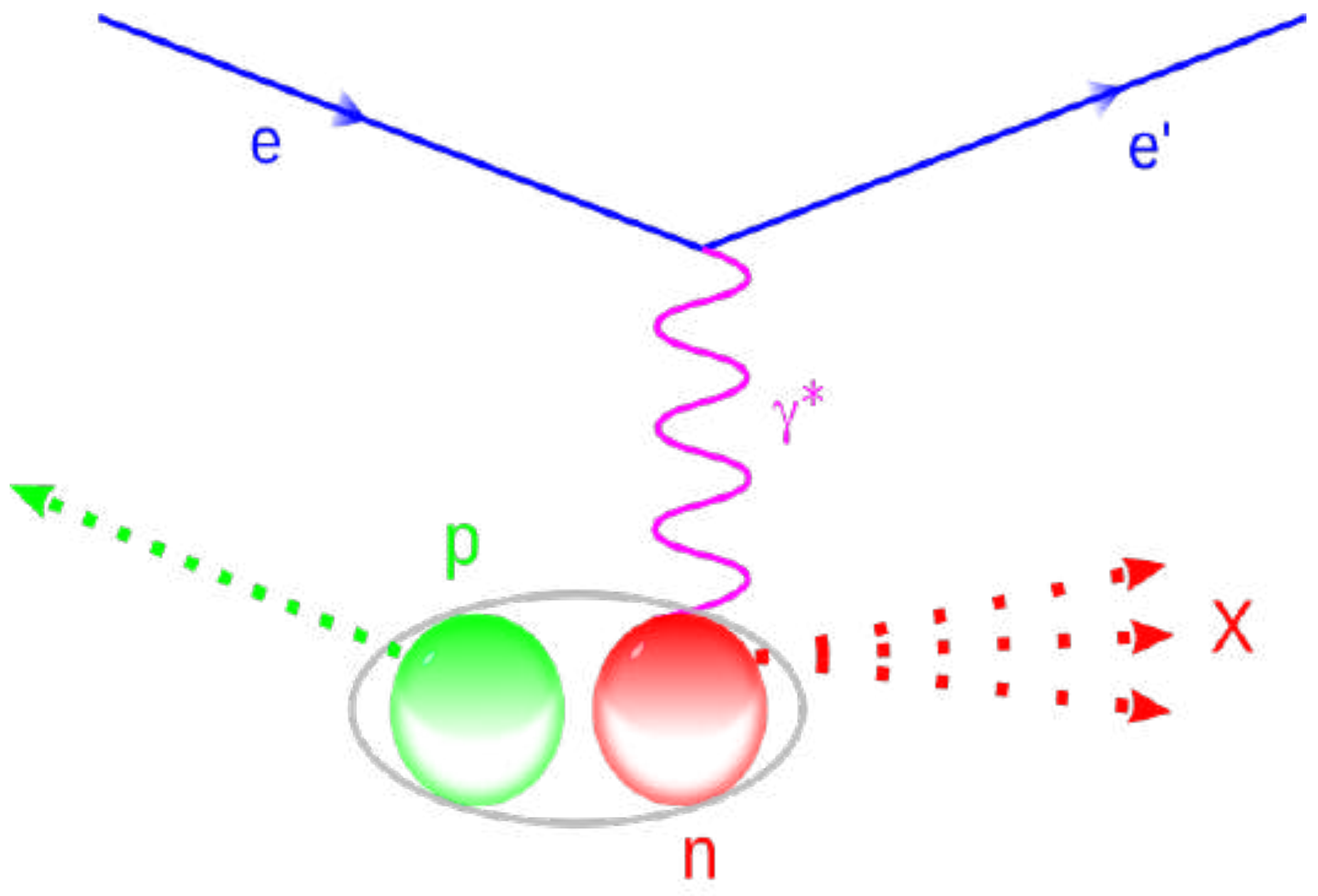
TDIS experimental layout in Hall A



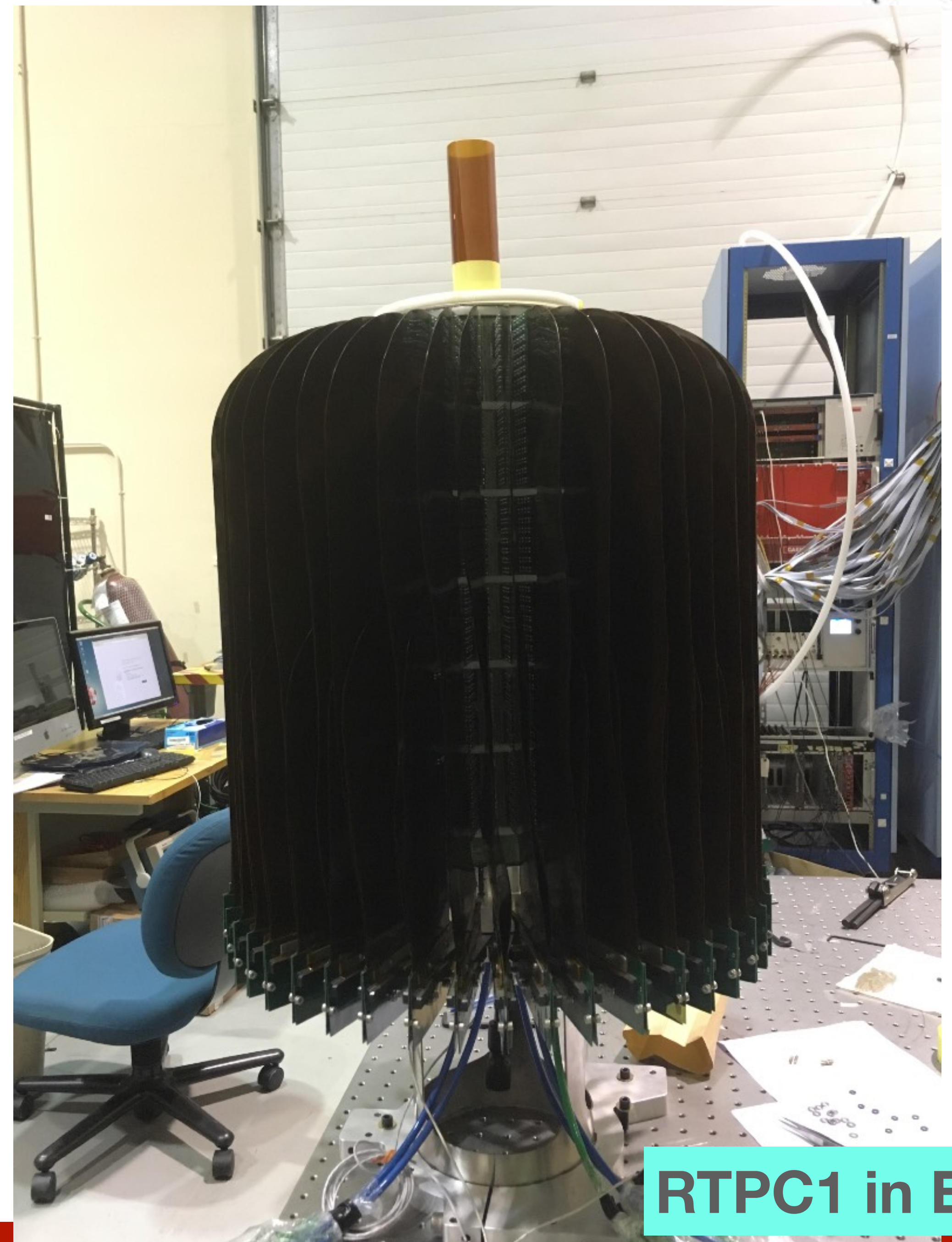
A new detector mTPC :multi-Time Projection Chamber to measure low-momentum recoil protons

BONuS12 RTPC

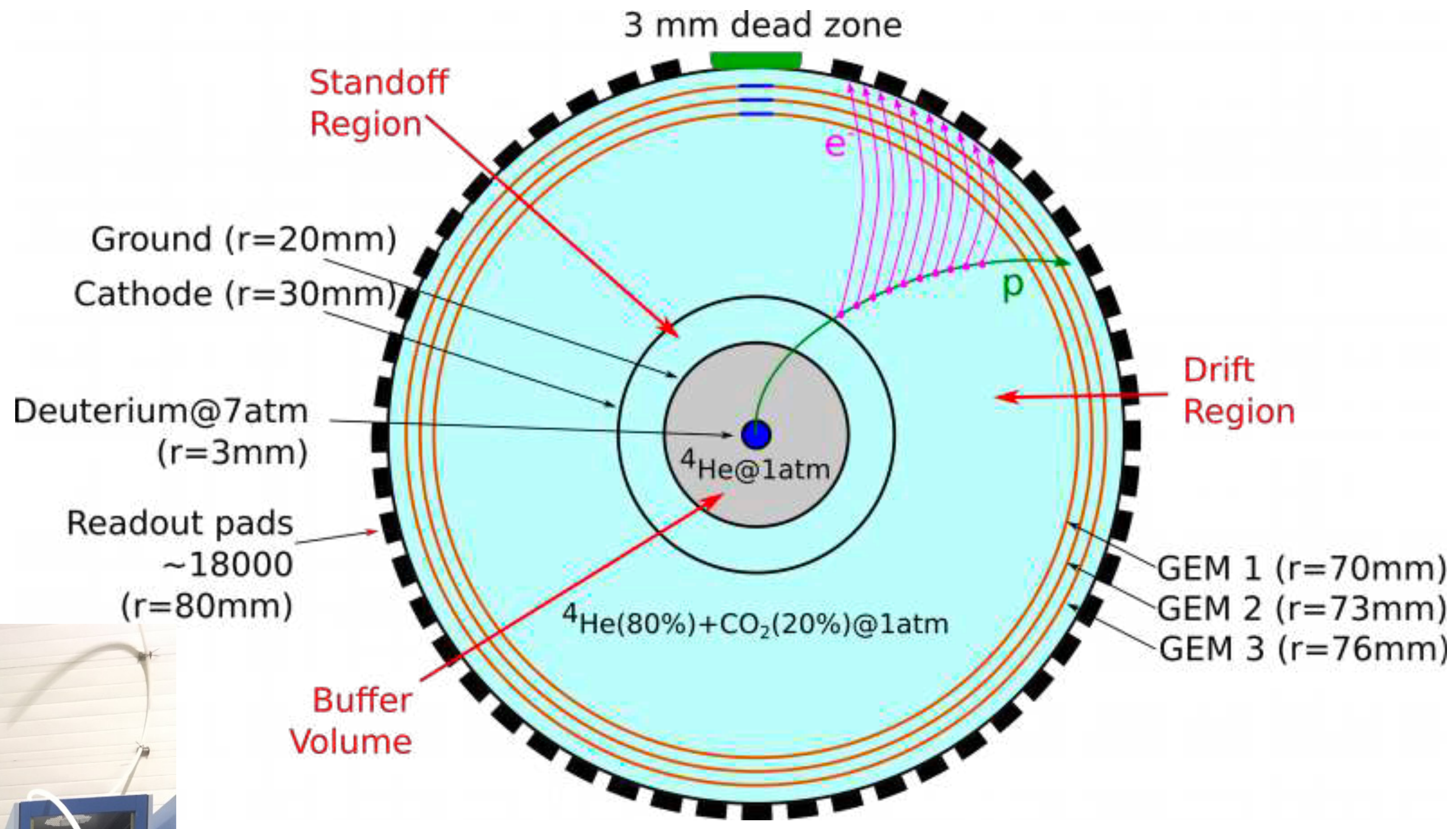
- BONuS and TDIS both use TPCs to detect tagged protons in the low momentum 70 <Ps<400 MeV/c
- BONuS12 done with the Radial Time Projection Chamber (RTPC)



BONuS12 reaction



RTPC1 in EEL building before move to HallB



Why mTPC?

- The idea of RTPC is good for BONuS12 . But for TDIS we need to optimize the RTPC idea….

- High luminosity (50 μA, L = 3 x 10 ^{36} Hz/cm^{2}) → higher background

Increase of occupancy

- long electron drift path→ wider time window

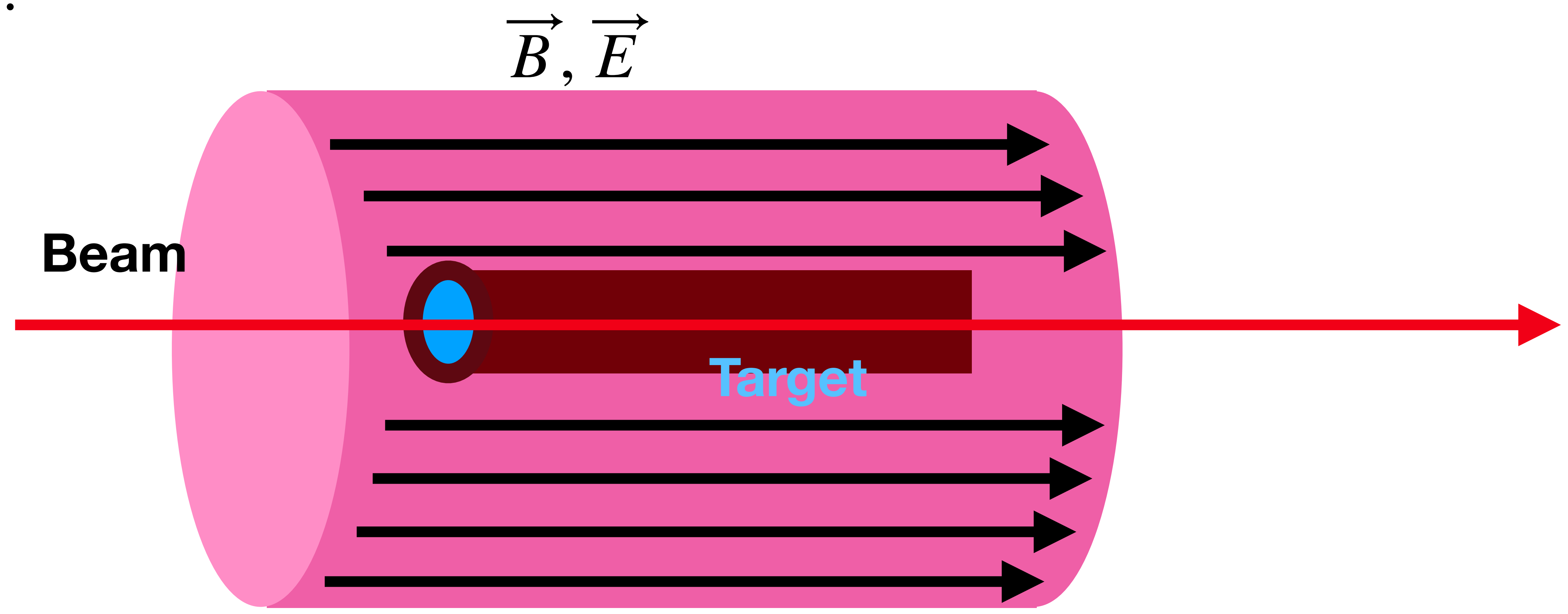
Multiple Time Projection Chamber

Features proposed to meet this high rate

- The use of a composite TPC device consisting of multiple TPC modules instead of a single TPC detector. Each TPC unit of the composite mTPC will be exposed to a fraction of the background rate, unlike a single TPC exposed to the full rate.

- The drift electric field will be parallel to the solenoidal magnetic field, as opposed to the perpendicular field configuration used in a radial TPC. The longitudinal electron drift parallel to the magnetic field minimizes the Lorentz force on the drift electrons leading to significantly simplified track reconstruction and reduced drift times.

- A strong solenoidal magnetic field to confine most of the background -electrons created in the target outside the TPC ionization region.



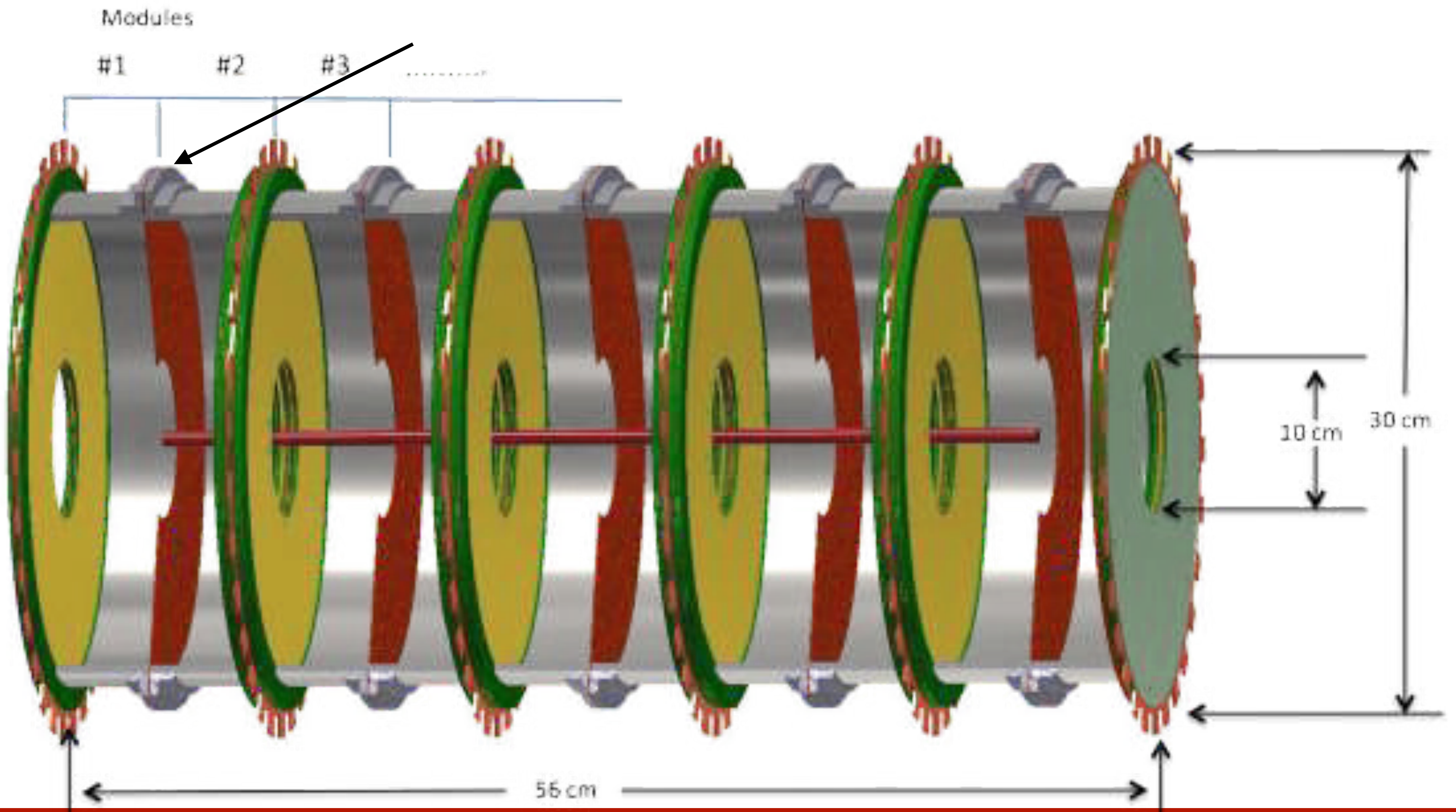
The multiple- Time Projection Chamber (mTPC)

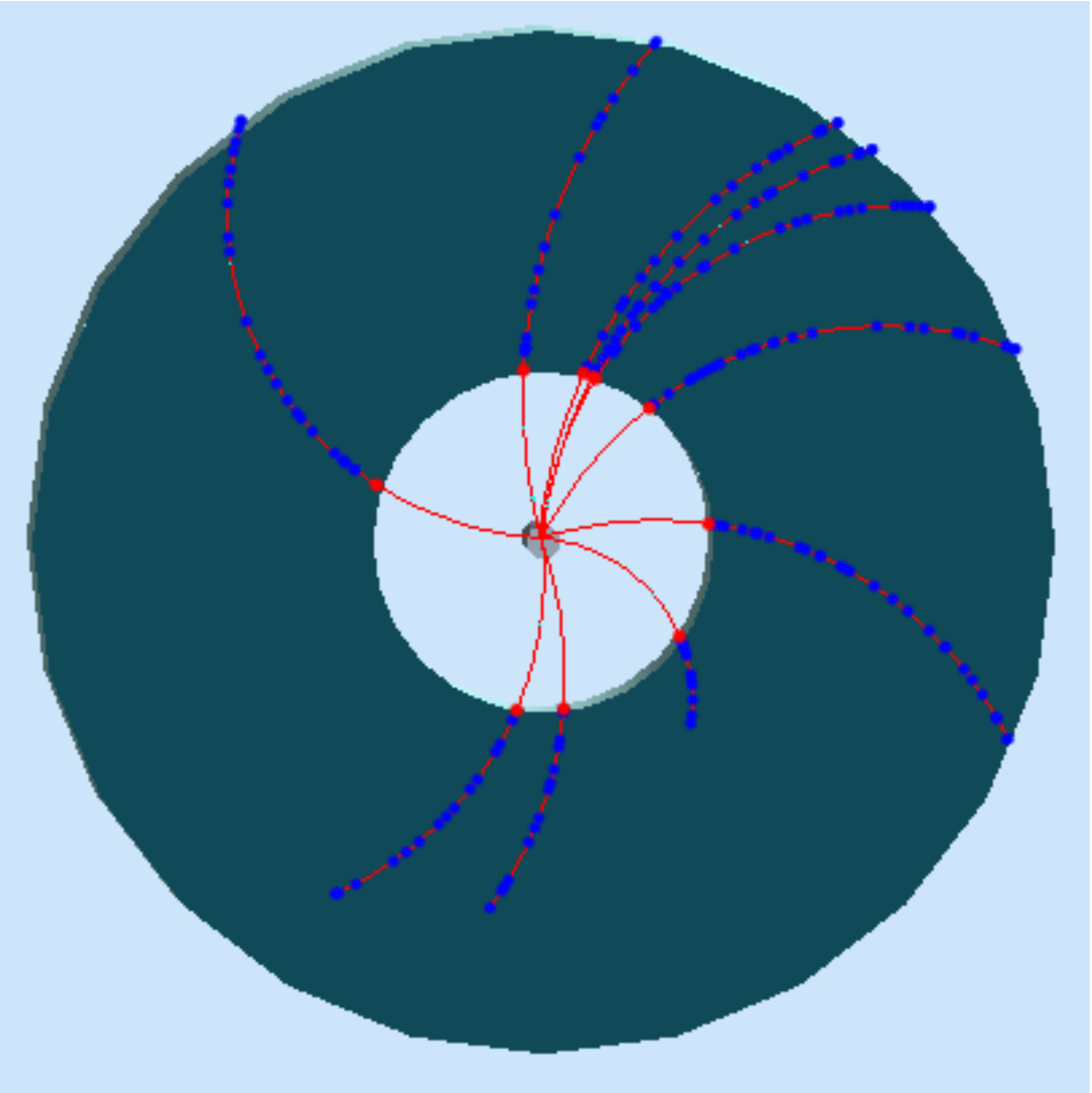
- Will be placed in the bore of the UVa superconducting solenoid magnet (L=152.7 cm, $\vec{B}$= 4.7 T) to fit the requirement of strong magnetic field parallel to $\boldsymbol{E}$

- Consist of 10 TPC modules to form one composite mTPC à takes care of high rates compared to single radial TPC

Dimension :55 cm long, Inner radii =5 cm , Outer radii =15 cm

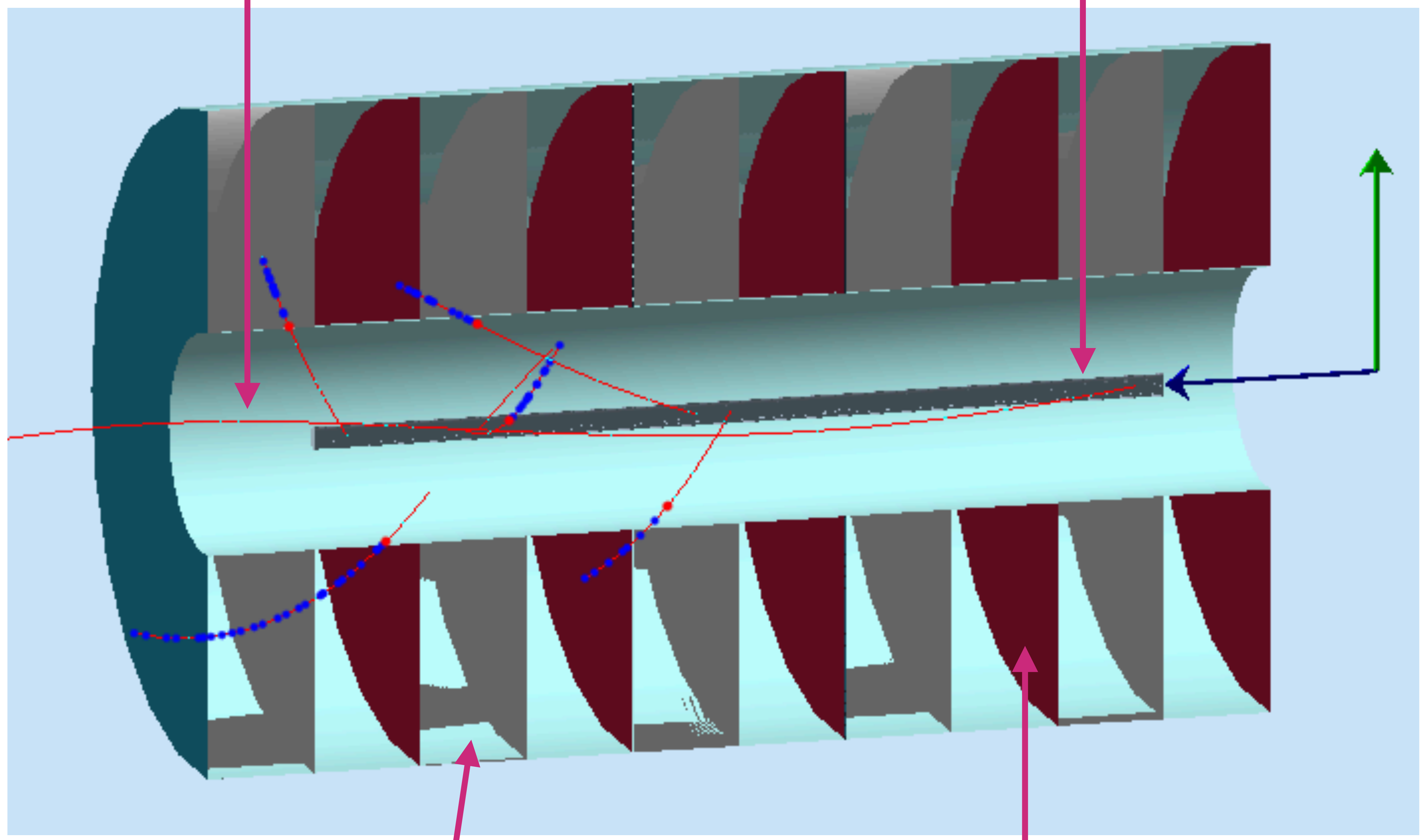
Module coupling locations

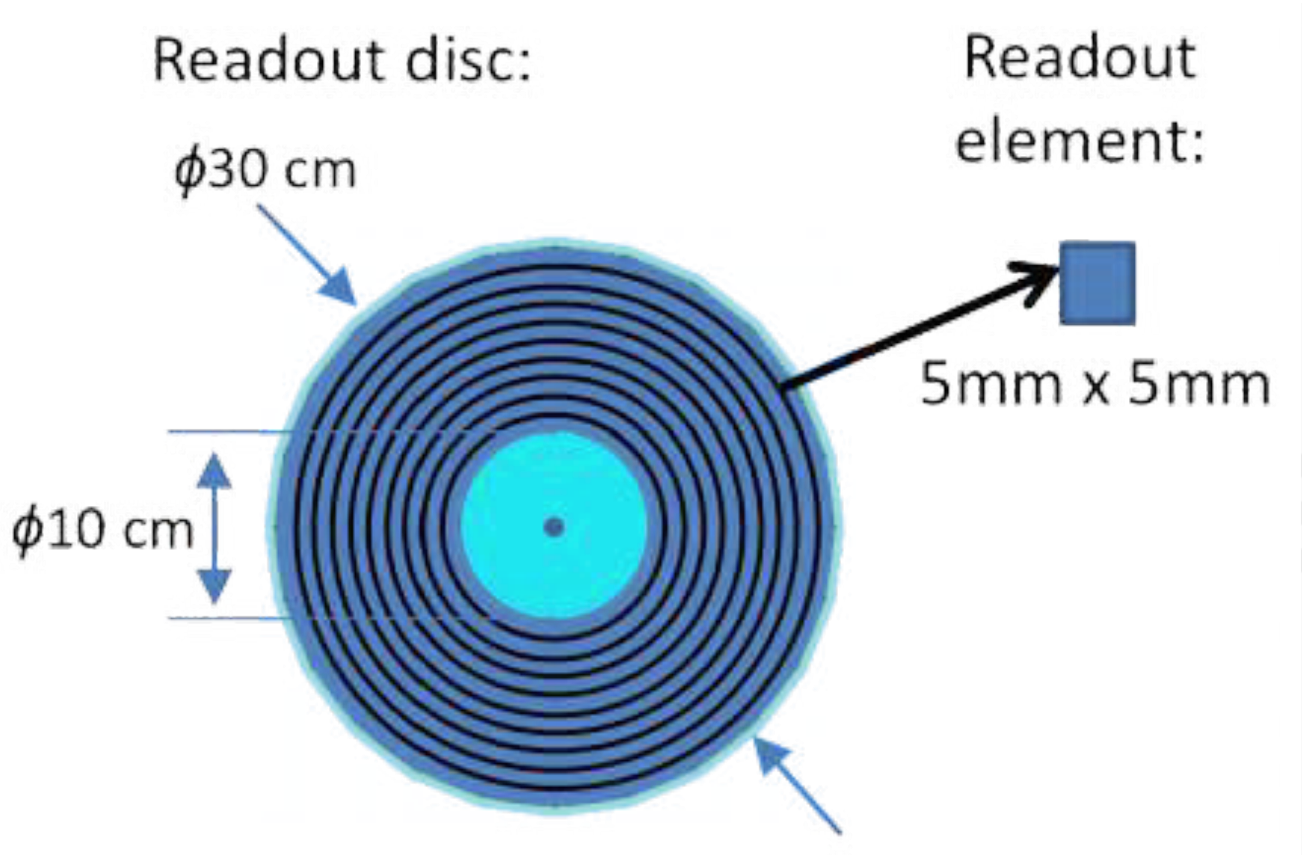


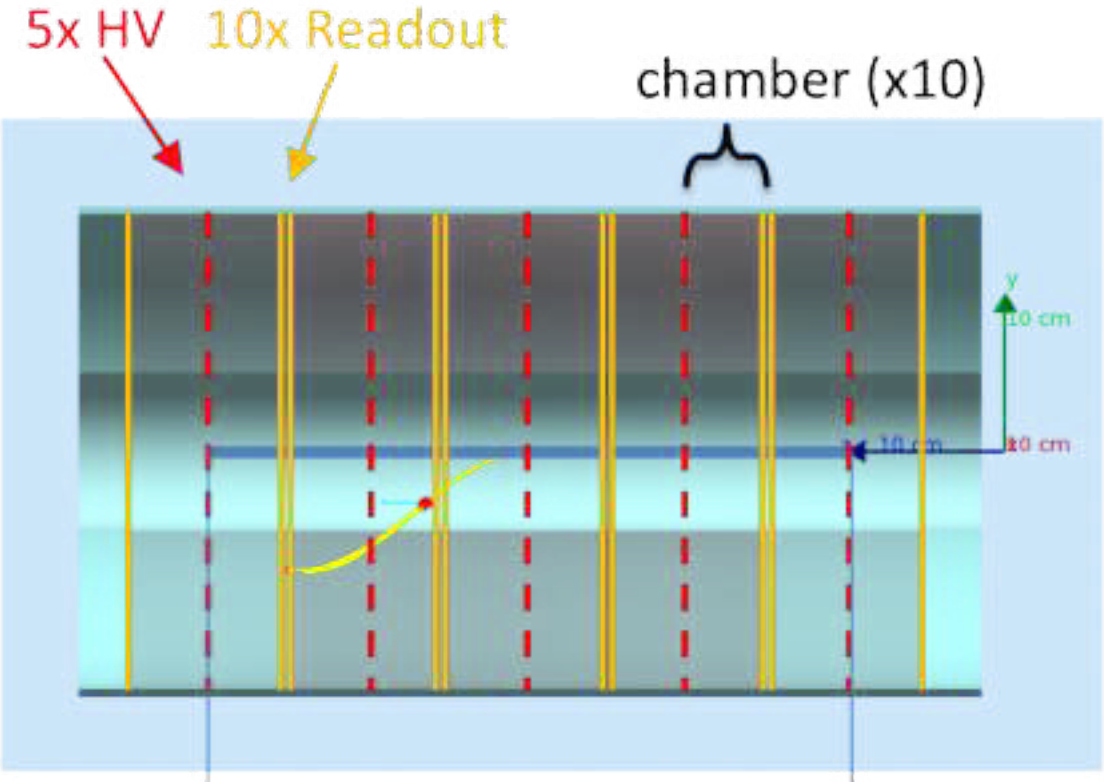


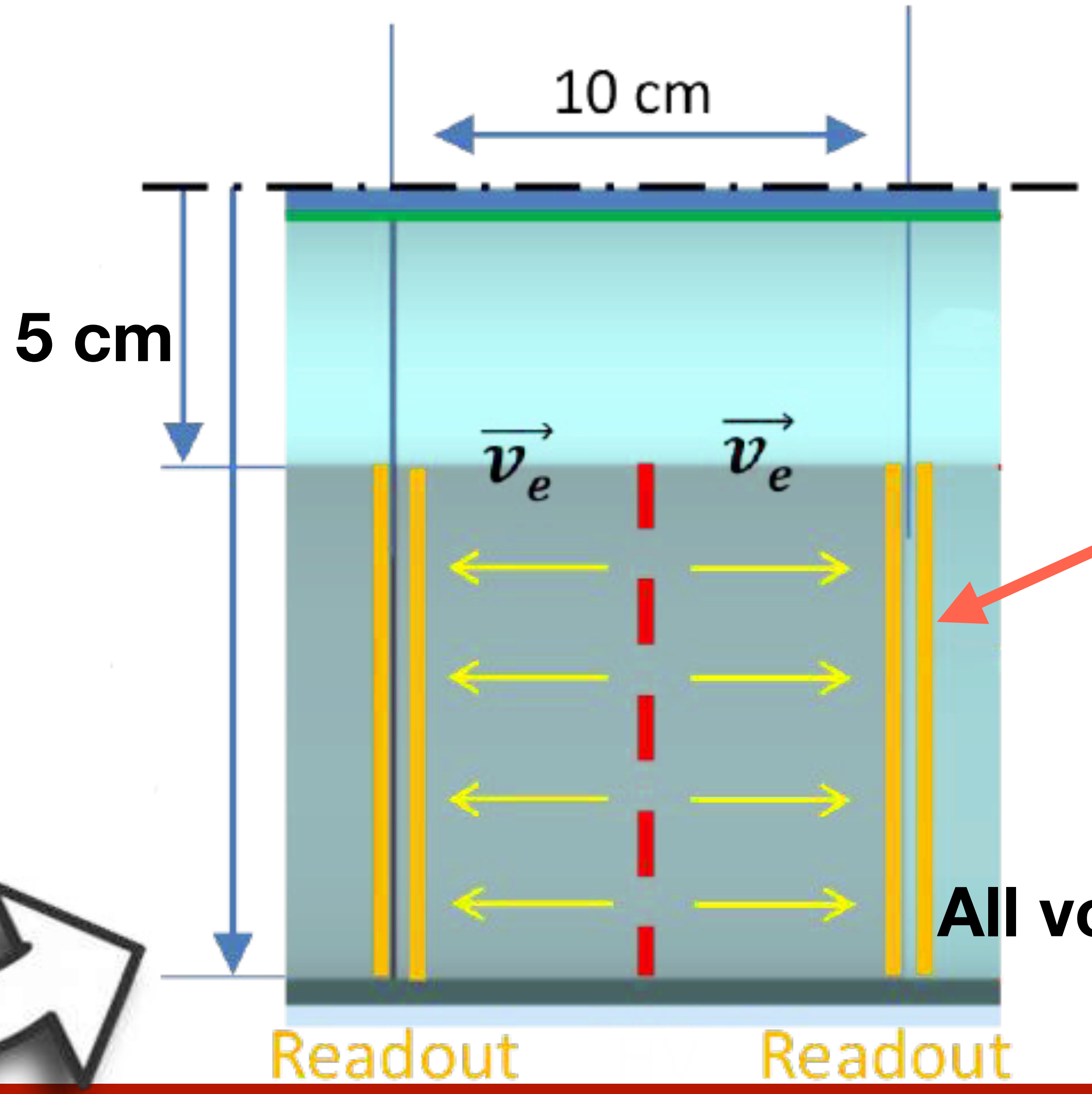
Particle tracks projection in readout plane

Design of mTPC in TDIS









Each readout disc
1.readout
2.GEM

All volumes filled with He (under study)

Streaming Data Acquisition

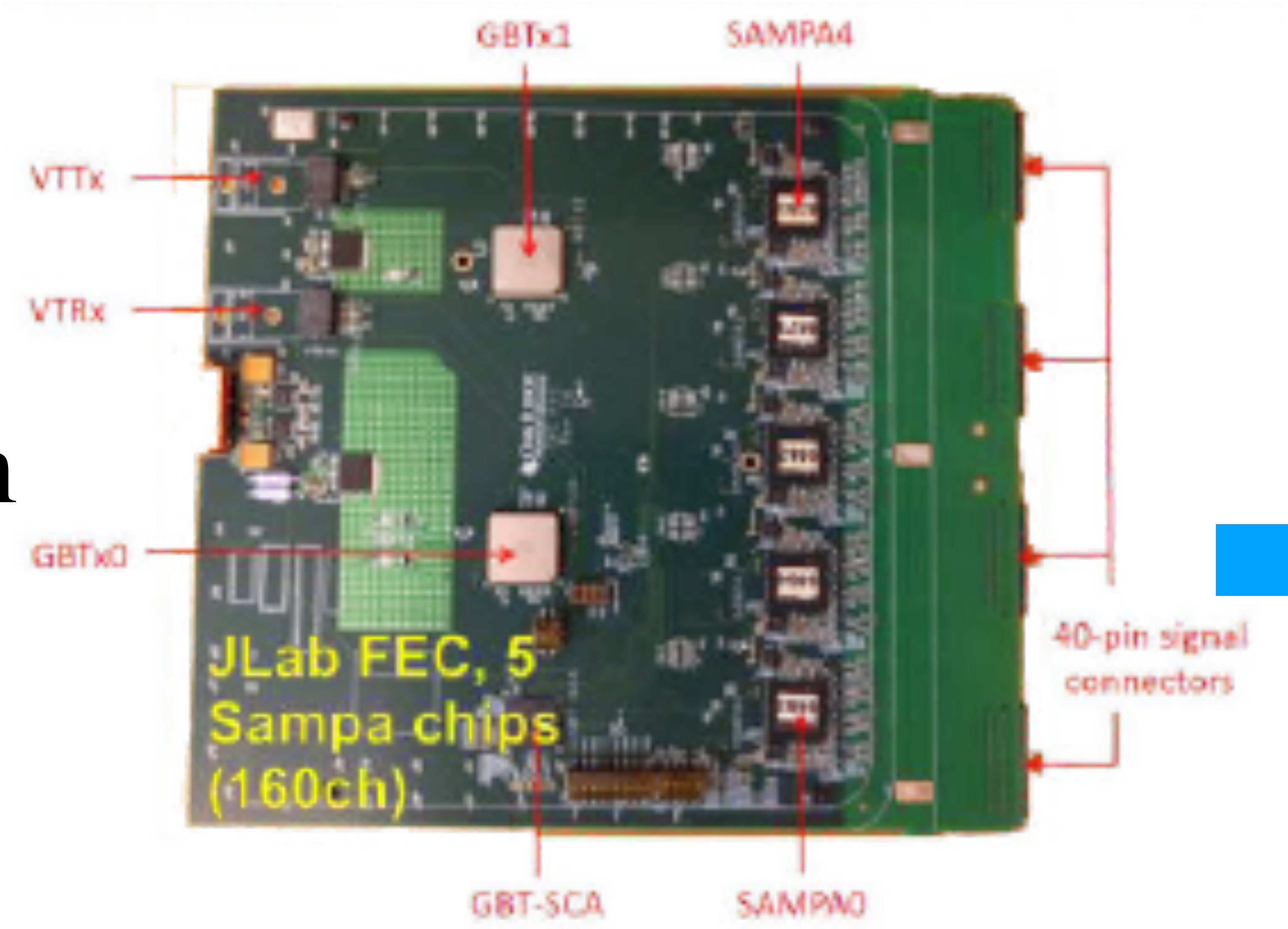
- Readout electronic updates

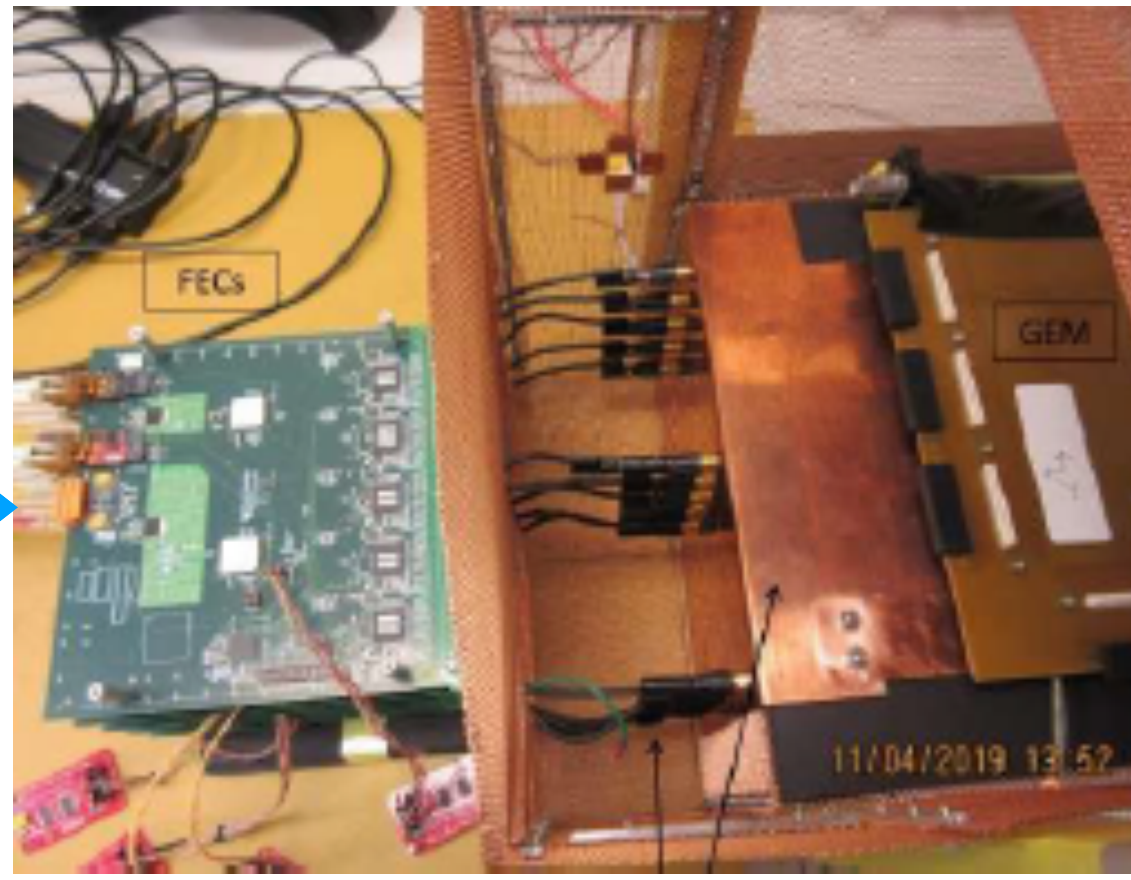
- Obtain radiation hard components from CERN

- 2nd generation data transmission and power conversion components

•lpGBT, VTRX+ (for High Luminosity LHC)

•bPOL12V, bPOL2V5, linPOL12V (for HL LHC)





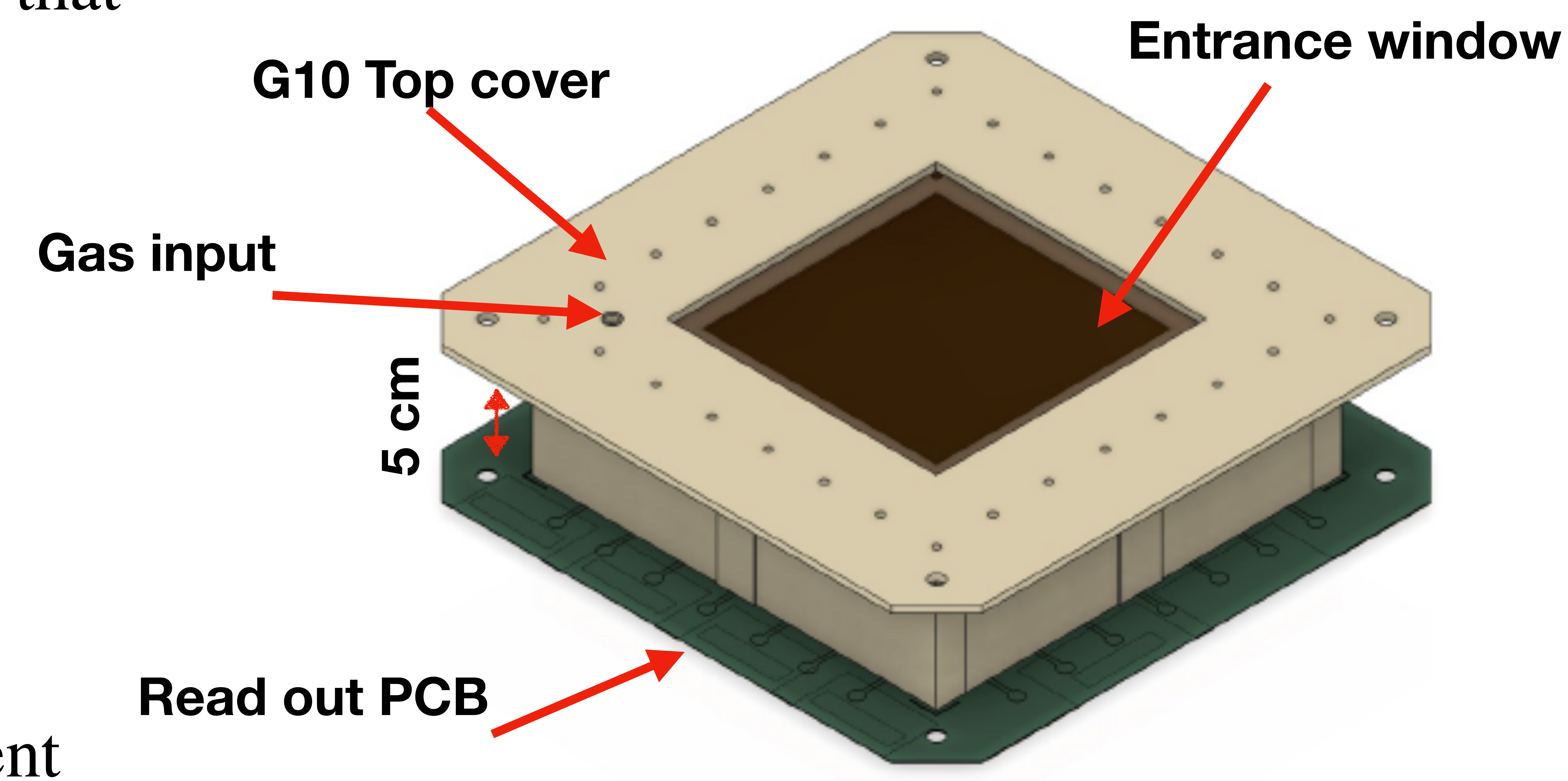
SAMPA - charge-sensitive pre-amp, ADC, DSP (zero-suppresion e.g.)

Design/prototyping/testing
E. Jastrzembski, E. Pooser,
G. Heyes (JLab)
SAMPA chip
M. Bregant (U. Sao Paulo) and streaming readout developed for ALICE TPC upgrade

mTPC prototyping and development

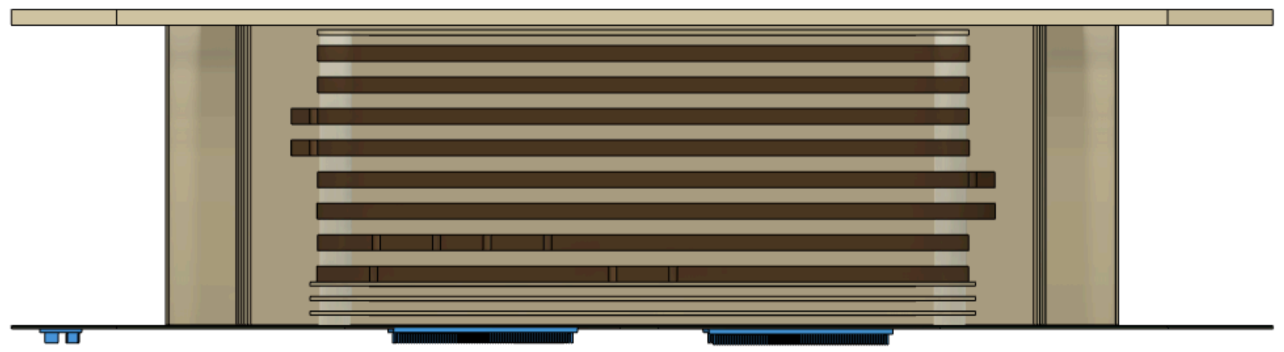
Square shaped prototype TPC to validate and test concepts of the larger cylindrical shaped mTPC. The concepts that will be evaluated using this prototype include

1. The pad readout configuration
2. Drift region
3. Time projection field cage,
4. Track reconstruction with the 5 cm drift arrangement under high rates
5. Cable lengths for the electronics.

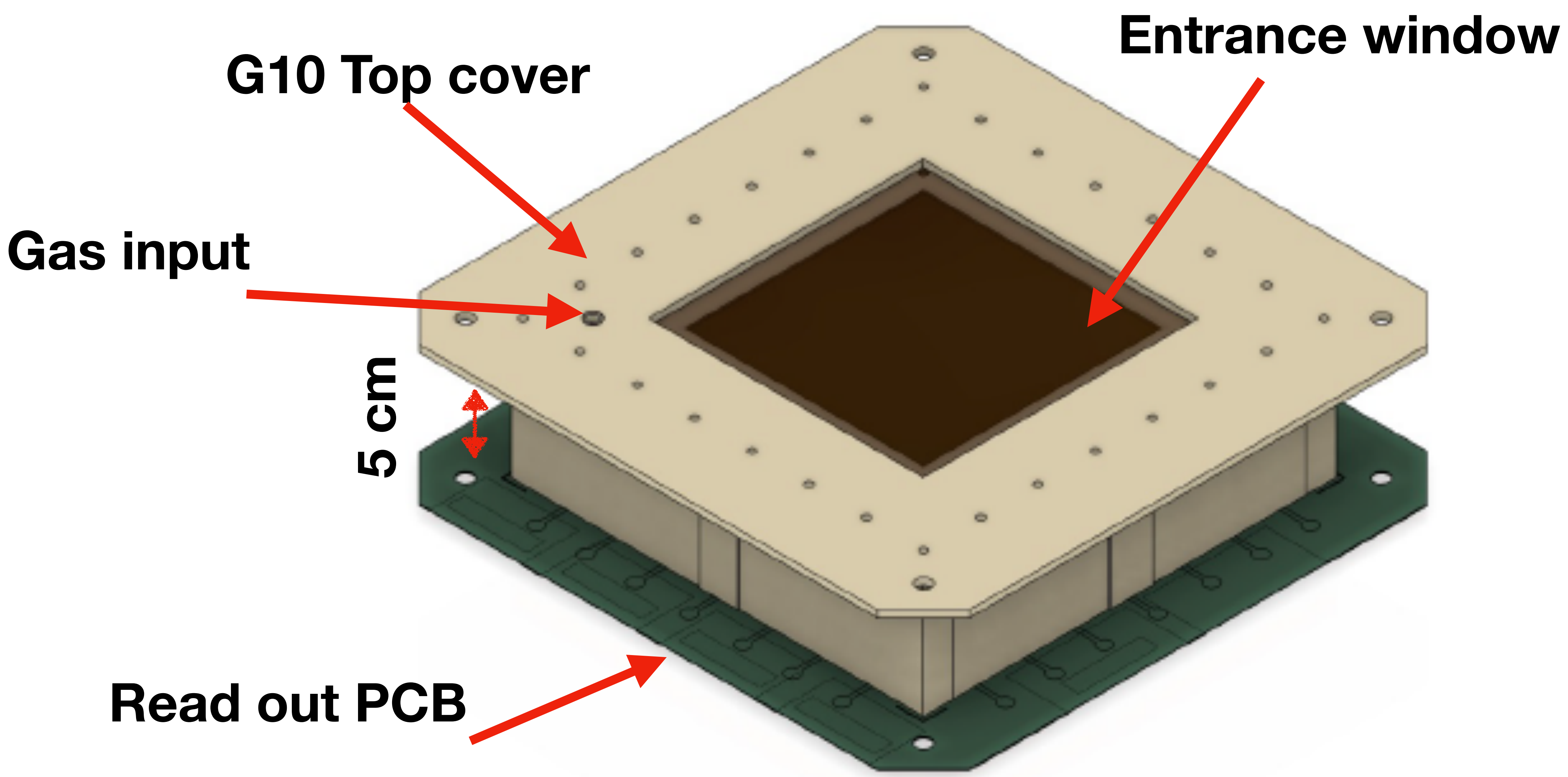


mTPC prototyping and development

- Design small prototype with 10 x 10 cm^2 GEM active area
- Anode (Read Out plane),
- Three GEMs stacked with 2 mm spacing (provided by spacers)
- Aluminized Kapton to act as cathode
- 5 cm space between anode and cathode endplates



a side view perspective of the readout, 3 GEM layers, 8 layer field cage, cathode layer and the spacers between the layers.

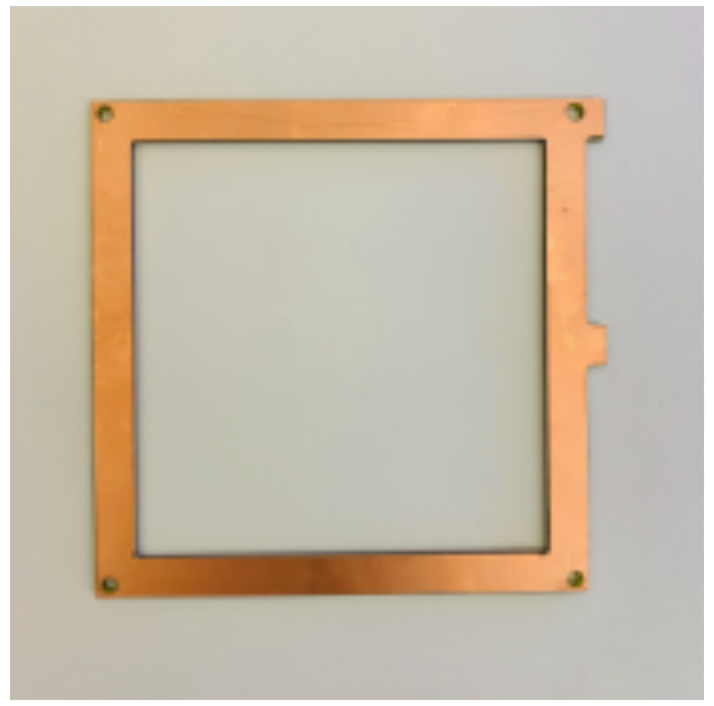


mTPC prototyping and development

- The height of the prototype is approximately 6 cm, with a 5 cm drift region to realize the time projection concept and uniform electric field.

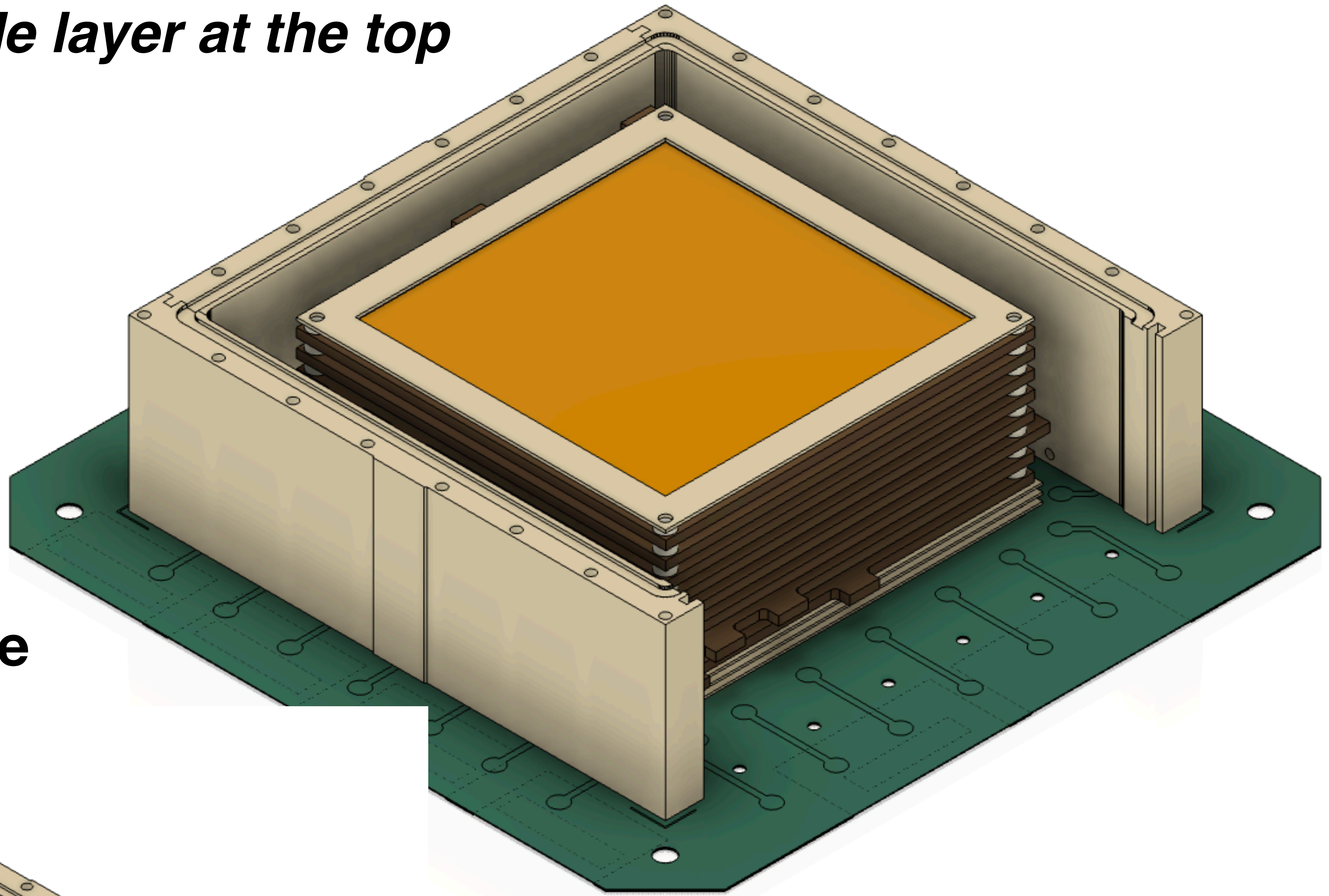
- The cathode layer of the prototype consists of 50 micron thick Aluminized Kapton glued to a 0.5 mm thick G-10 frame, and is placed 2 mm above the top field cage frame

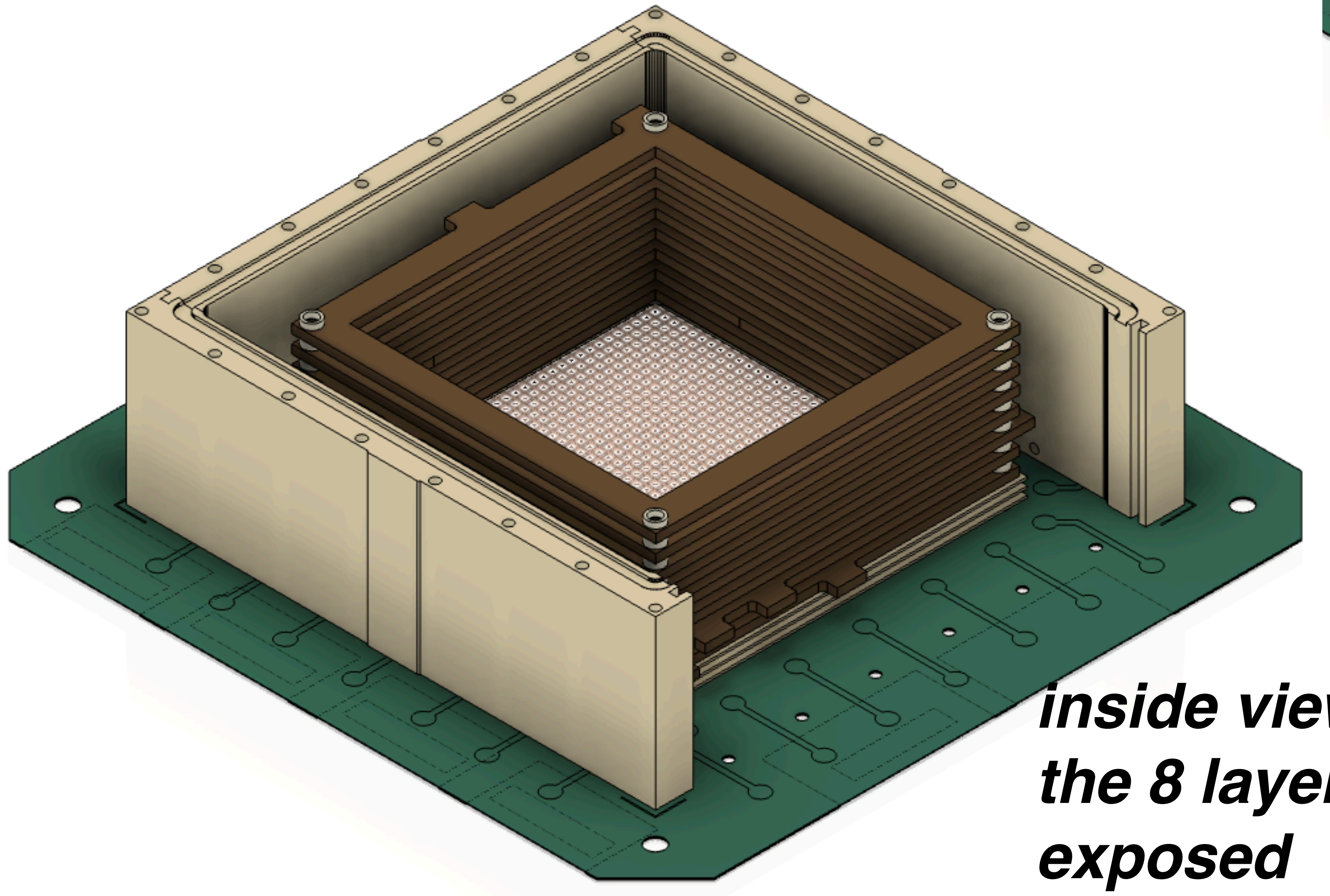
- The entire prototype structure is enclosed in a gas box with the gas input located on the top cover, and the gas output is toward the bottom on one side of the gas box to accommodate a uniform distribution of gas. This arrangement allows testing the prototype with different drift gasses to optimize the gas mixture for the final mTPC.



Top view of field cage frame

side view showing 3 GEM layers, 8 layer field cage, and cathode layer at the top



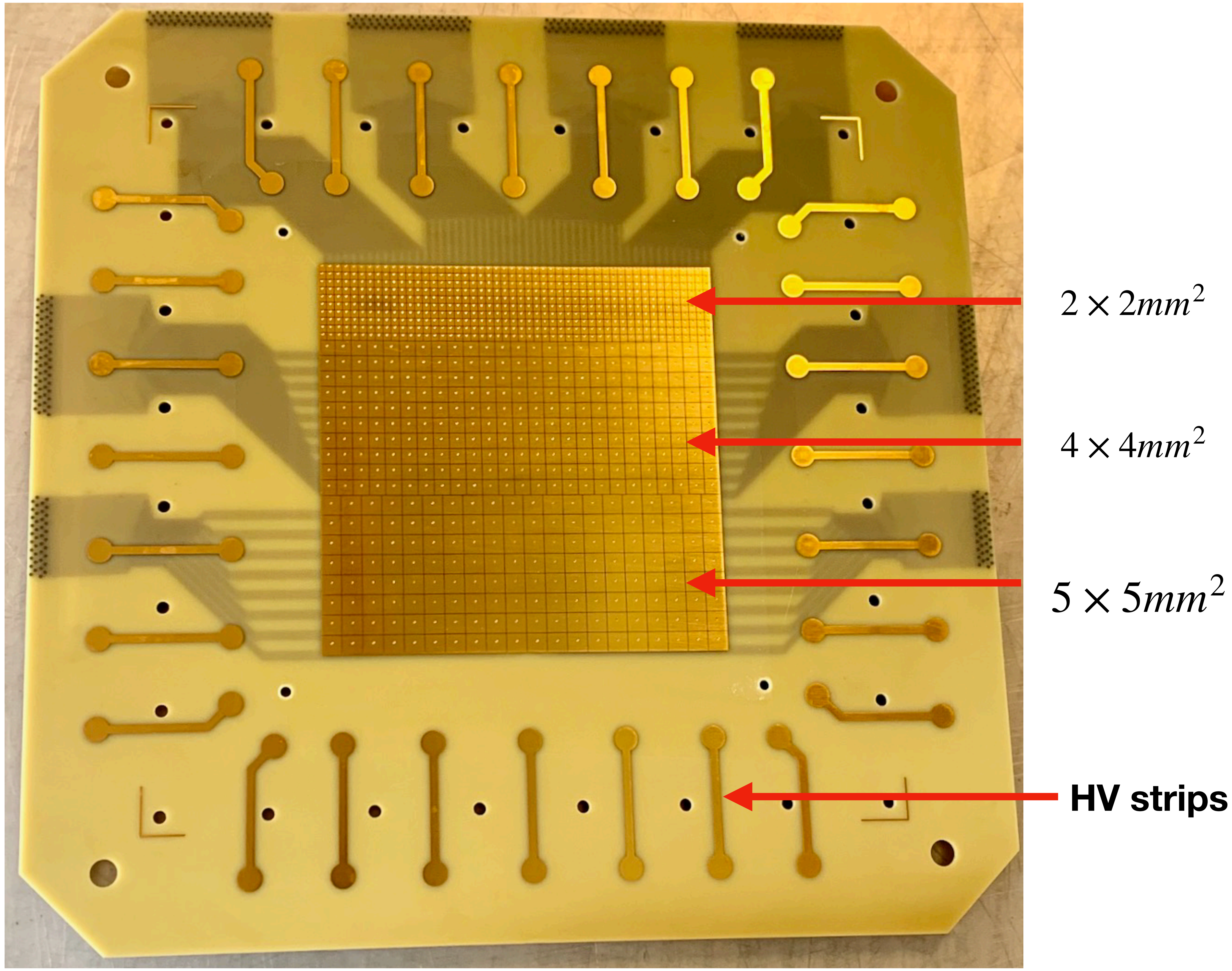


inside view without the cathode layer showing the 8 layer field cage with the top GEM layer exposed

Readout board design

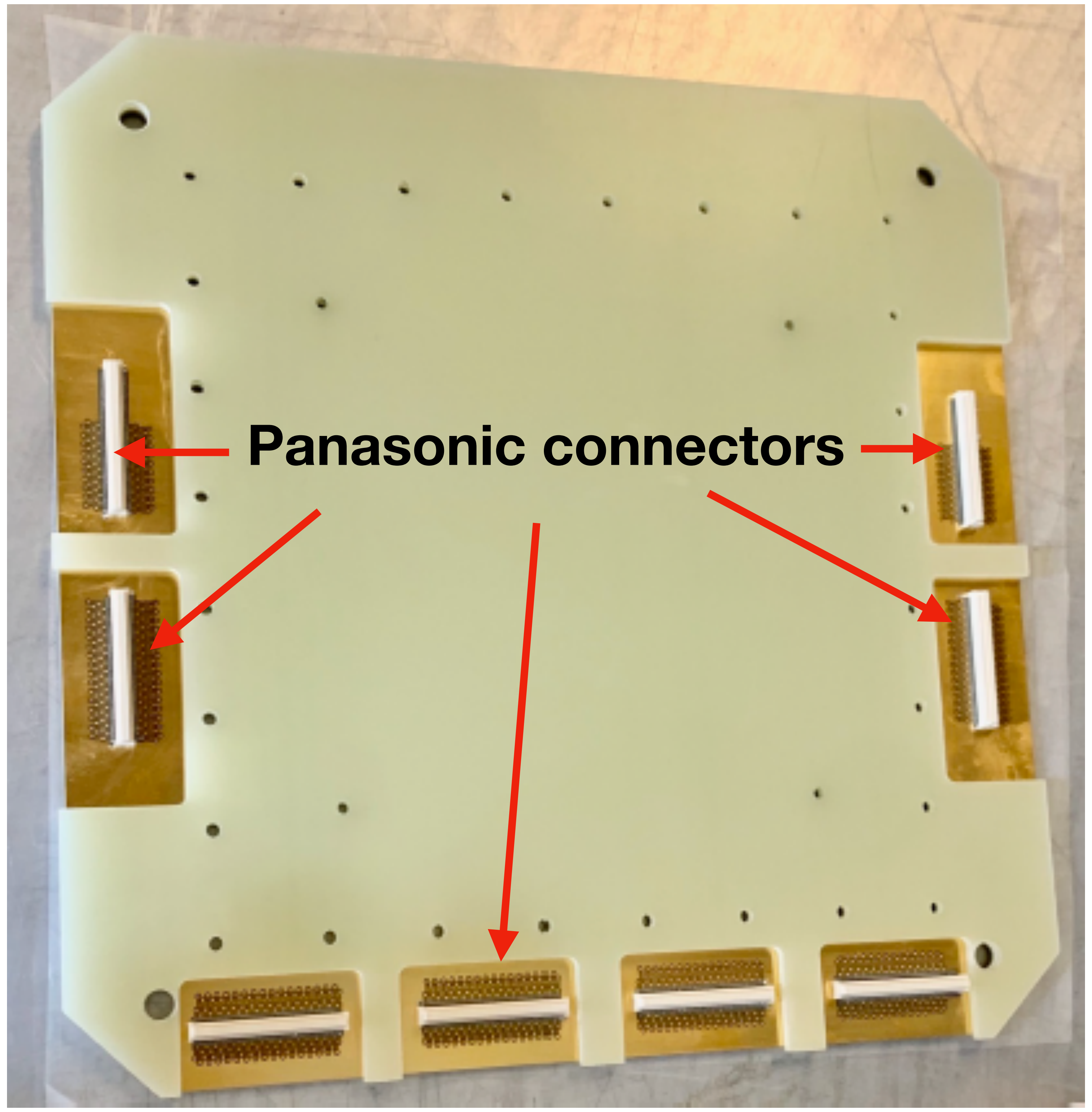
- To validate the readout pad configuration of the cylindrical mTPC, pads of different sizes were implemented in the readout of the square prototype within the limits of the 10× 10 cm^2 GEM active area.

- 910 total readout pads of three different sizes

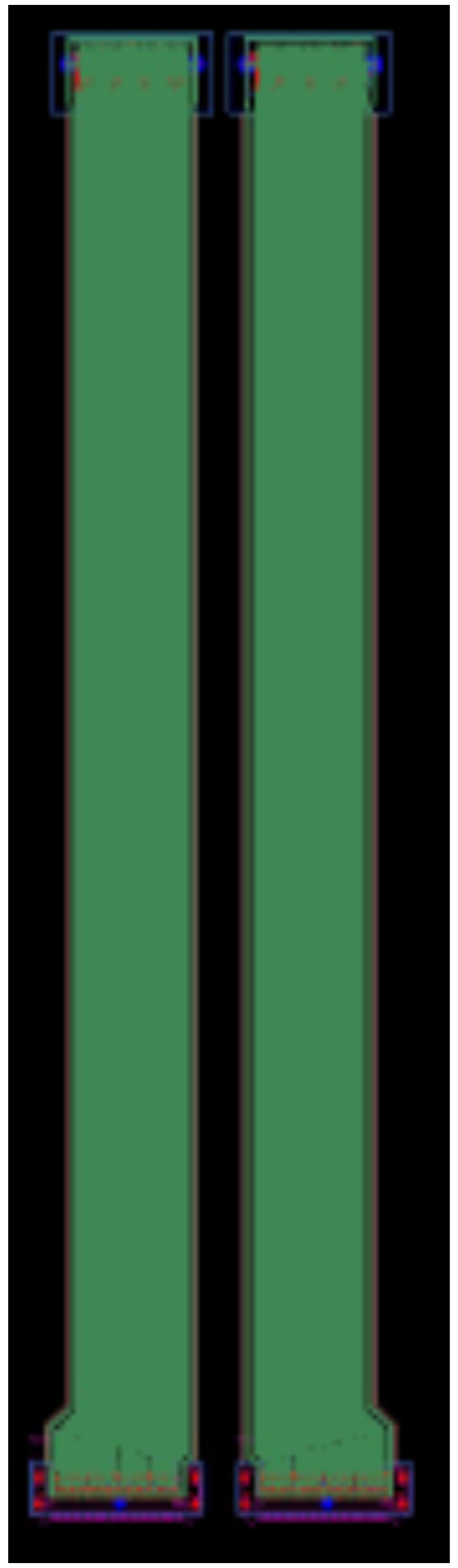


Readout board design

- Panasonic connectors (130 pins each) connected to signals from readout pads (910 channels).
- APV25 chip will be used to readout signals in initial testing
- APV25 to SAMPA flex circuit: Signals will be mapped via 40 cm long flex circuit adapter



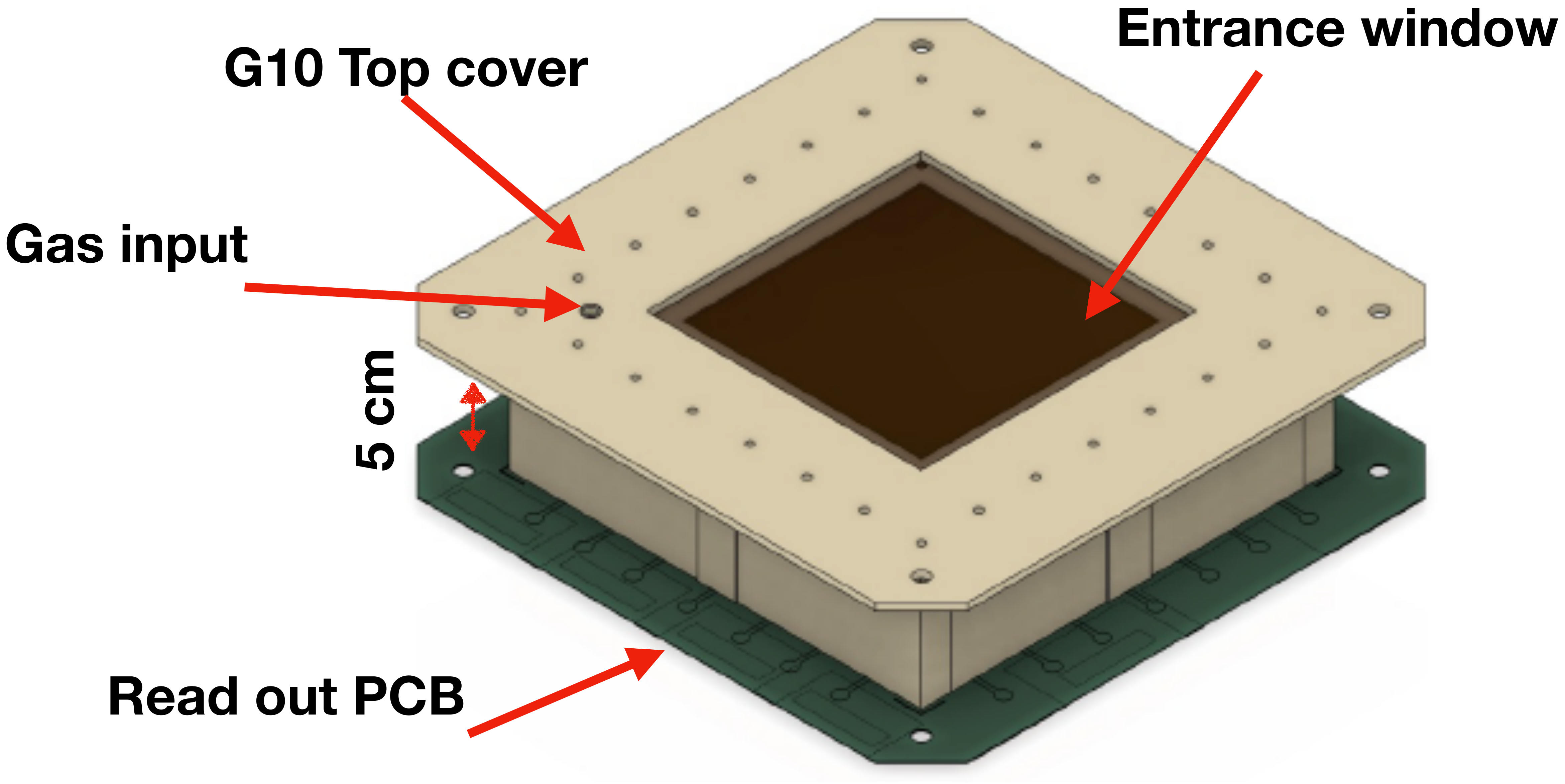
Back of the readout board



40 cm long flex adapter (GBR)

Timeline for Assembly & Commissioning

Task Description	February			March			
	2nd week	3rd Week	4th week	1st week	2nd week	3rd week	4th week
Training	UVA						
Square prototype assembly		UVA					
HV tests			UVA				
Cosmic test				Jlab			
Testing DAQ and SAMPA with prototype					Jlab		



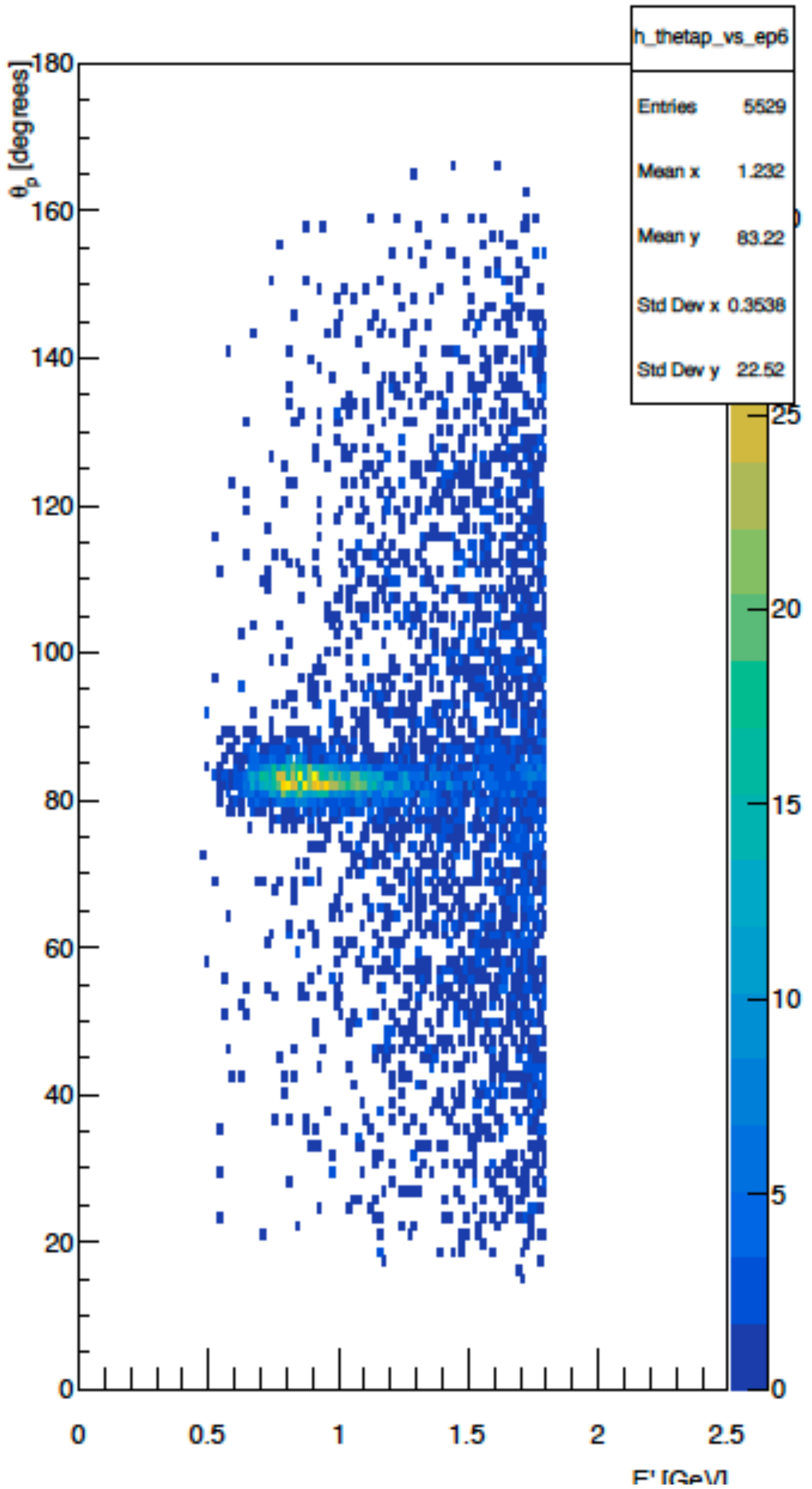
Short term plan:

- After the assembly, preliminary testing (cosmic) will be done at Jlab with APV25.
- High rate tests of prototype will utilize flex circuit adapter (APV25 to SAMPA) and will be done parasitically in Hall A in the next few months

Background studies using BONuS12

- BONuS12 targets are Deuterium and Hydrogen.

- How many protons in the large angle range in BONuS12 with deuterium target -> background for TDIS (Obtain rate of DIS protons BONuS12 RTPC getting)



2-D histogram of scattered electron momentum in GeV versus polar angle of recoil proton for the target filled with hydrogen gas and a beam energy of 2.2 GeV.

Summary and future work

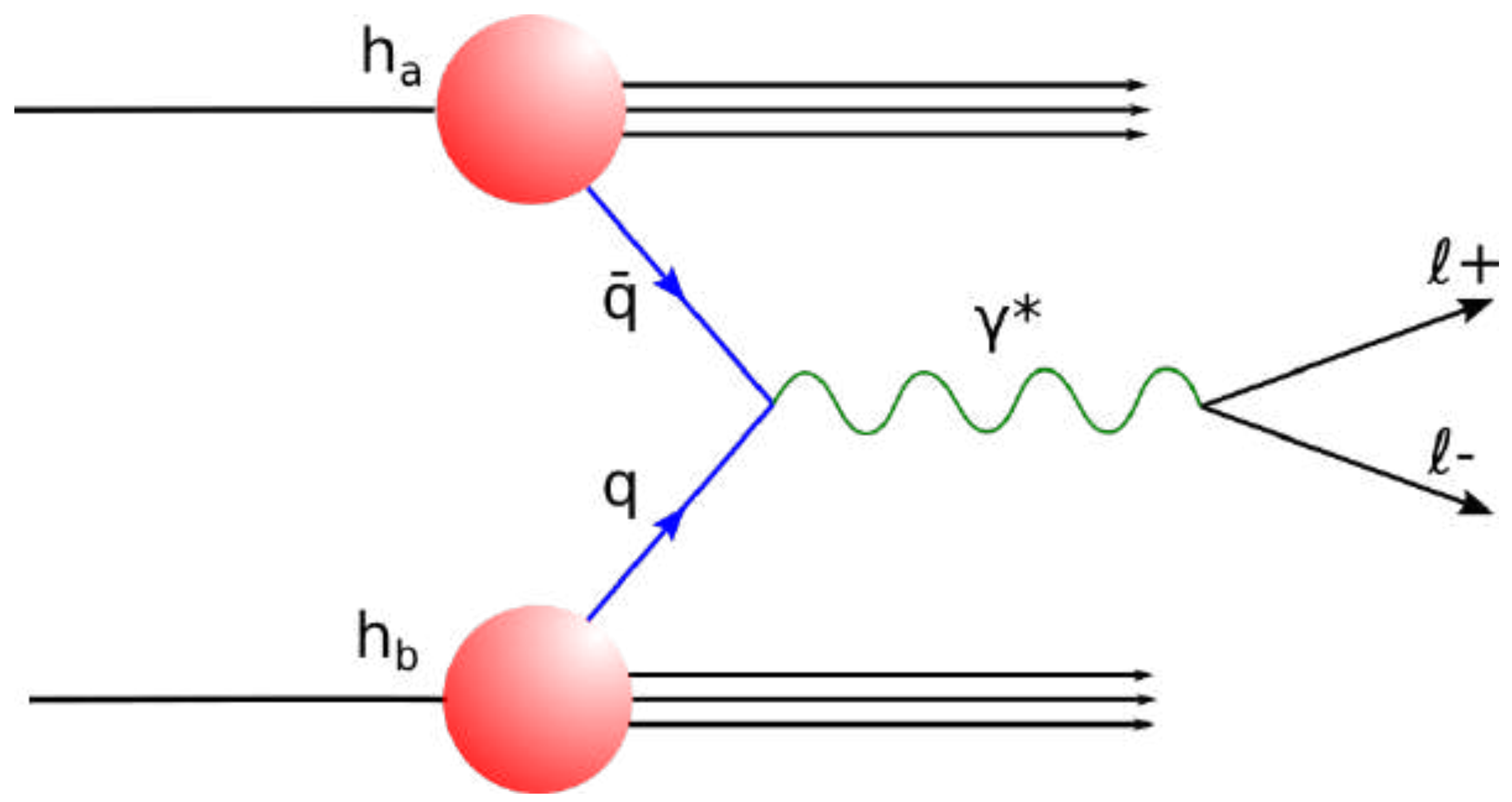
- The TDIS experiment at JLab Hall A (C12-15-006) will make use of the Sullivan process to measure the pion/kaon SF at low xBj through the spectator-tagging technique
- mTPC is a new type of detector to detect the low momenta recoil protons
- Obtaining radiation hard components from CERN for readout electronics for mTPC (will use the SAMPA chip)
- Simulation studies are underway: background studies of DIS and quasi-elastic, and track reconstruction efficiency studies
- Design a square prototype to test important features of the mTPC
- Fabrication of all prototype parts is complete. Currently in assembly phase.

Thank you

Back up slides

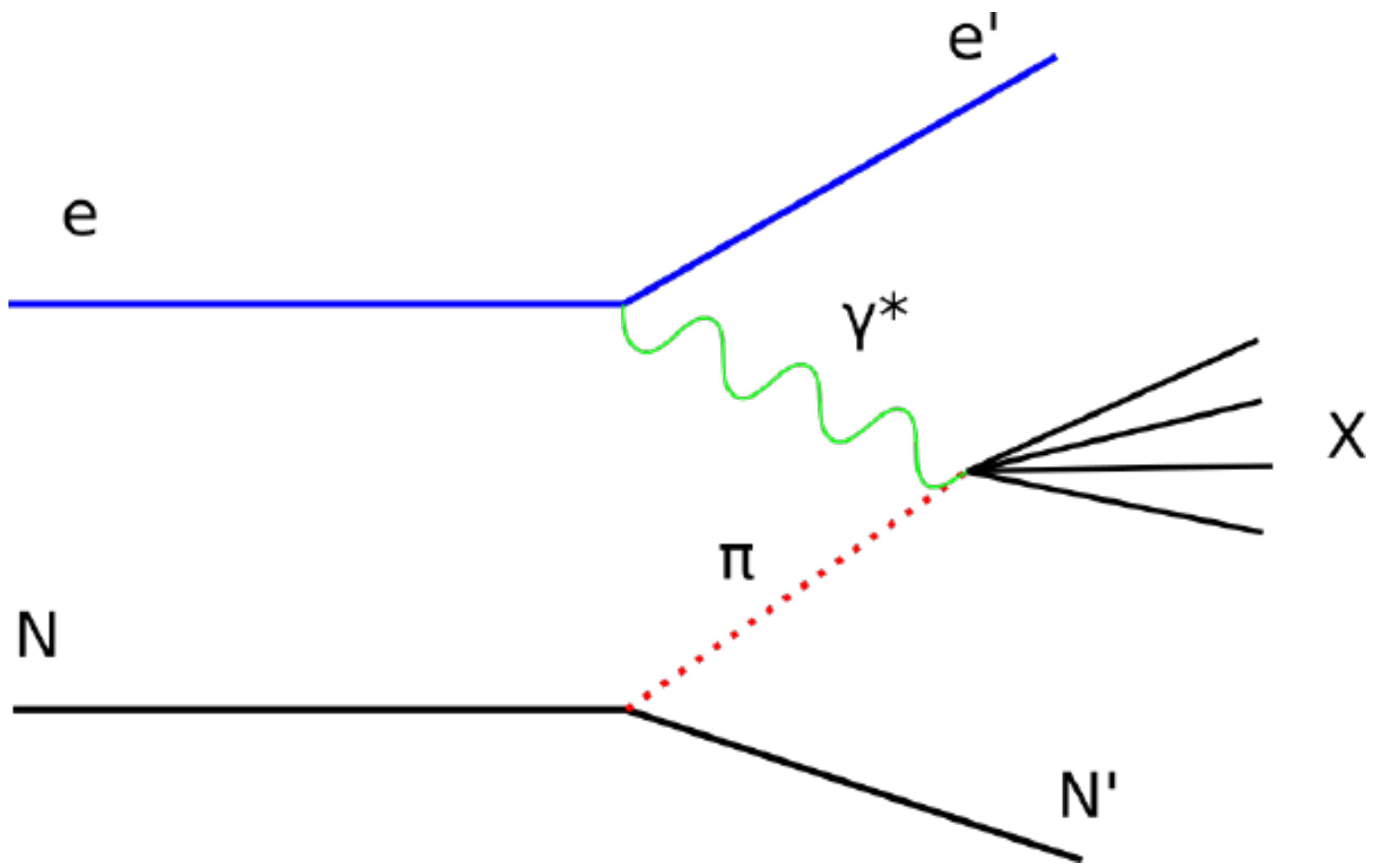
Pion structure

different processes allow access to the Pion structure information, like:



Drell-Yan

E615@Fermilab

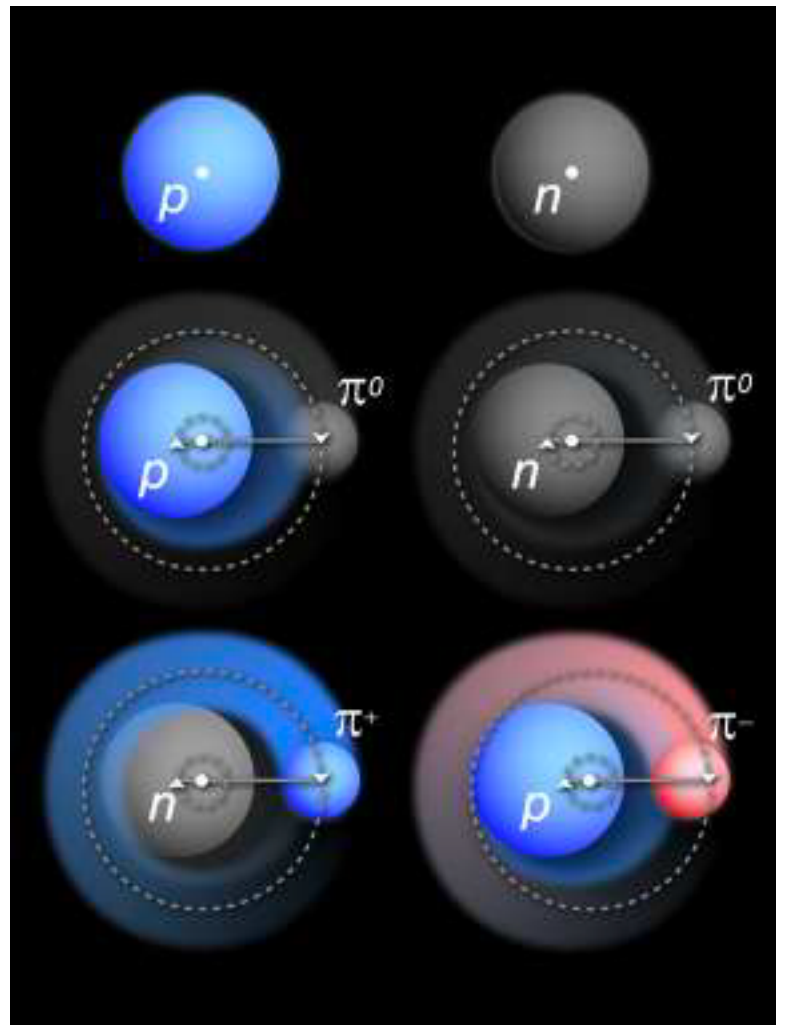


Sullivan

H1@HERA-DESY

Pion target

$$|p\rangle \rightarrow \sqrt{1-a-b}\,|p_0\rangle + \sqrt{a}\left(-\sqrt{\frac{1}{3}}\,|p_0\pi^0\rangle + \sqrt{\frac{2}{3}}\,|n_0\pi^+\rangle\right) + \sqrt{b}\left(\sqrt{\frac{1}{2}}\,|\Delta_0^{++}\pi^-\rangle - \sqrt{\frac{1}{3}}\,|\Delta_0^{+}\pi^0\rangle + \sqrt{\frac{1}{6}}\,|\Delta_0^{0}\pi^+\rangle\right)$$



- making use of the meson-cloud model, the asymmetry is explained →it suggests that meson-cloud could be considered as a virtual target

Geometry build into GEANT4

- V