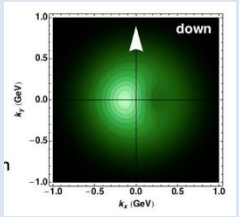
RG-H Status and Workshop Report

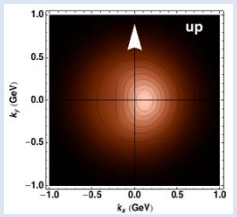
Contalbrigo Marco - INFN Ferrara

CLAS Collaboratino Meeting, JLab, 17th- 20th November 2026

TMD (x, k_T) quark polarisation

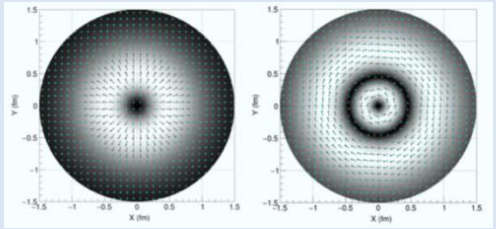
nucleon polarisation: N/q	U	L	T
U	f_1		$h_1^\perp$
L		g_1	$h_{1L}^\perp$
T	$f_{1T}^\perp$	$g_{1T}^\perp$	$h_1, h_{1T}^\perp$



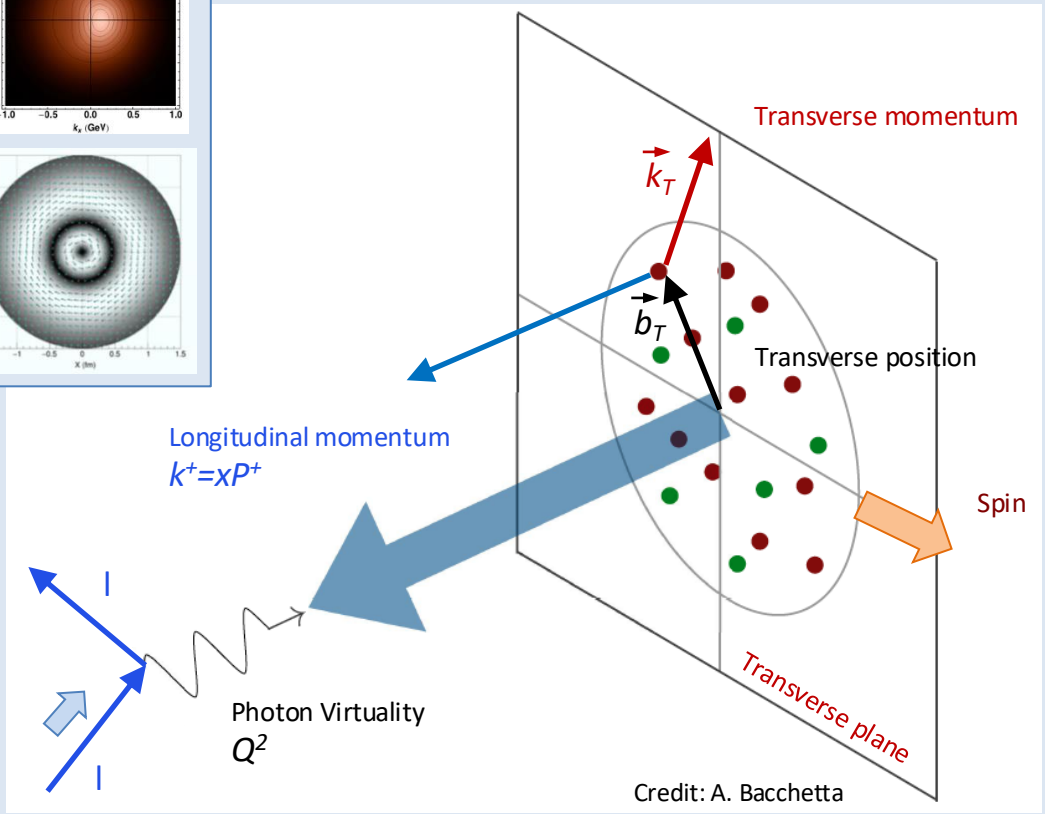


GPD (x, b_T) quark polarisation

nucleon polarisation: N/q	U	L	T
U	H		$\mathcal{E}_T$
L		$\tilde{H}$	$\tilde{E}_T$
T	E	$\tilde{E}$	$H_T, \tilde{H}_T$



Confinement Scale



High Energy Probe
Hard Scale

RGH approved with NH_3 target by PAC 53 - 2025

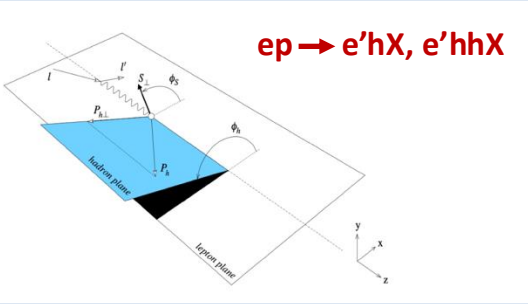
Experiment	Contact	Title	Rating	PAC days
C12-11-111	M. Contalbrigo	Transverse spin effect in SIDIS at 11 GeV with a transversely polarized target using CLAS12	A	100 + 25
C12-12-009	H. Avakian	Measurement of transversity with di-hadron production in SIDIS with a transversely polarized target	A	100 + 25
C12-12-010	L. Elauadrhiri	Deeply Virtual Compton scattering at 11 GeV with transversely polarized target using the CLAS12 detector	A	100 + 25
C12-11-111A	H. Avakian	Measurements of Single Spin Asymmetries in exclusive production of hadrons with RGH transversely polarized target		100 + 25

Access to unique observables in

- SIDIS hadron ep->ehX
- SIDIS di-hadron ep->ehhX
- DVCS ep->eγp
- DVMP ep->eV^0p

Gather unprecedented information on

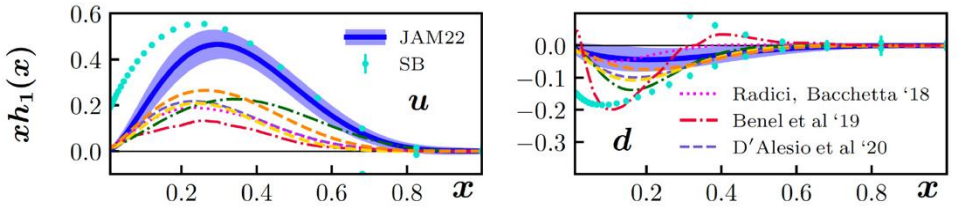
Transversity	**Sivers**, $h_{1T}^{\perp}$, $g_{1T}^{\perp}$, $H_1^{\perp}$	**GPD E**
Tensor charge	Spin-orbit effects	Quark OAM



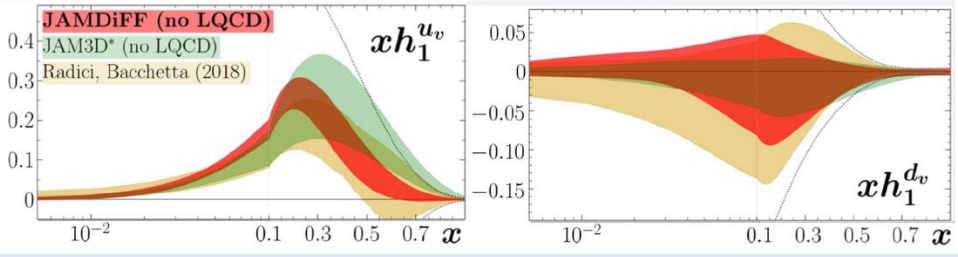
Large sensitivity expected in the valence region
Lack of data above x = 0.3 and no fully differential (4D) analysis available so far

CLAS12 can be the first experiment to achieve a 4D analysis in the valence region

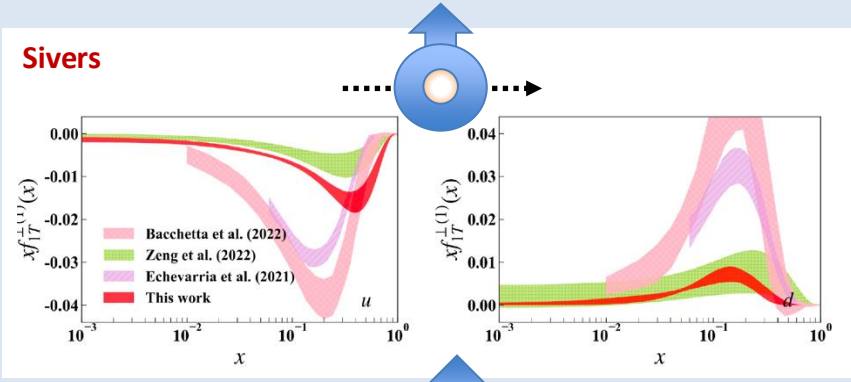
Transversity from single hadron SIDIS



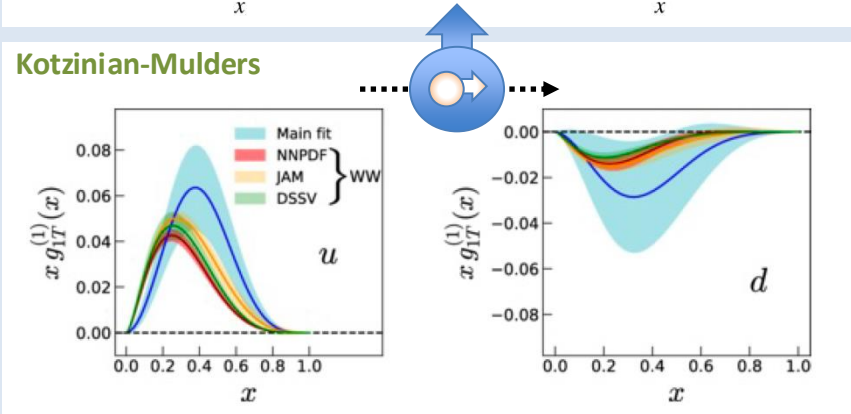
Transversity from di-hadron SIDIS



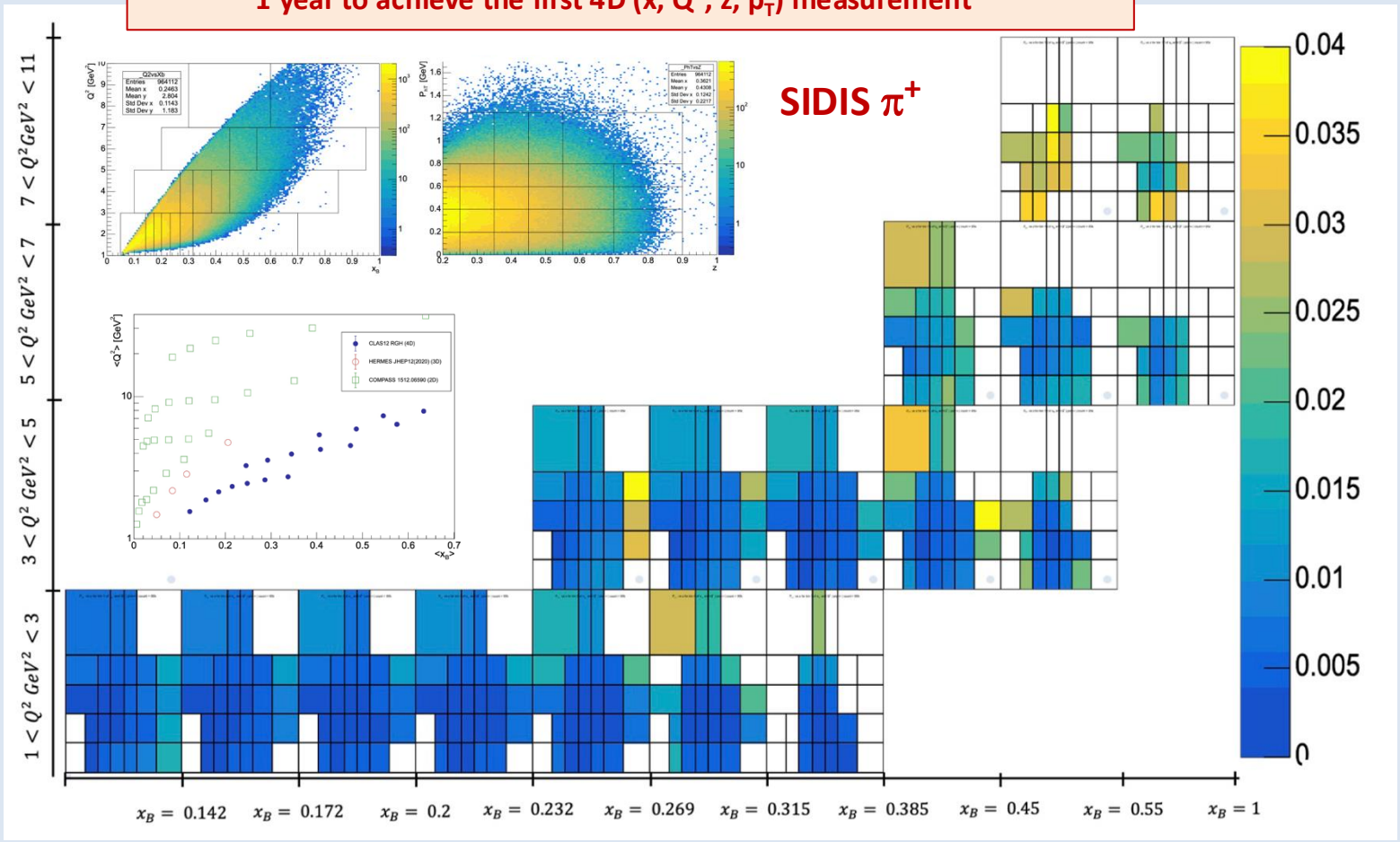
Sivers



Kotzinian-Mulders



~ 1 year to achieve the first 4D (x, Q^2, z, p_T) measurement



GPD E

$$\sum_q \int_{-1}^{+1} dx\, x[H^q(x,\xi,t=0) + E^q(x,\xi,t=0)] = 2\,J_q$$

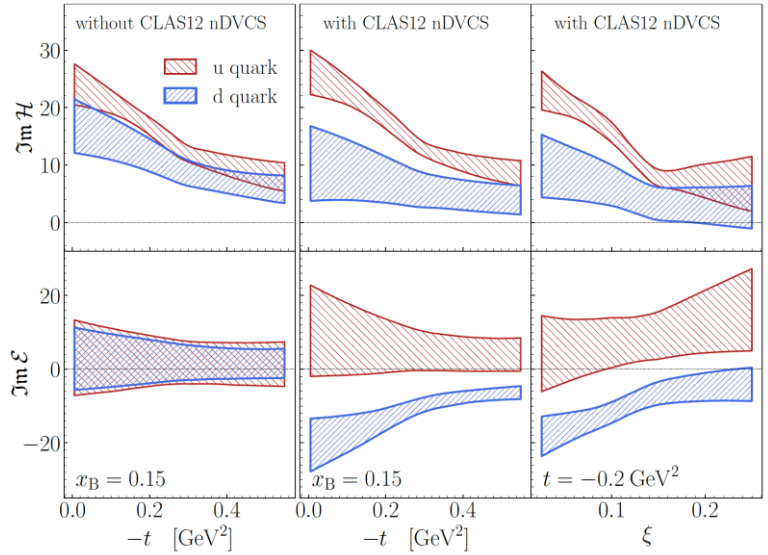
GPD E is essential to pin down the quark dynamics (OAM)
It is poorly known expecially for the u-quark flavor

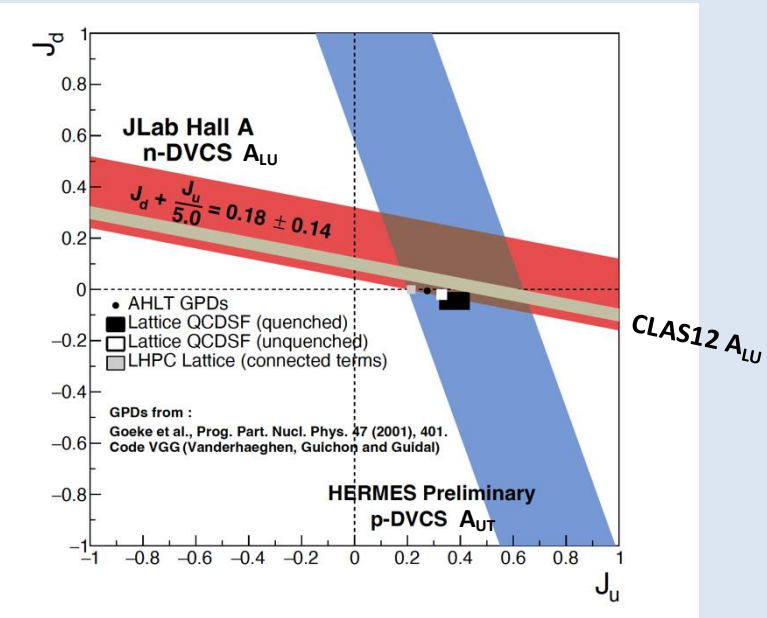
CLAS12 can be the first experiment in exploiting both
A_{LU} measurement on neutron with
A_{UT} measurement on proton

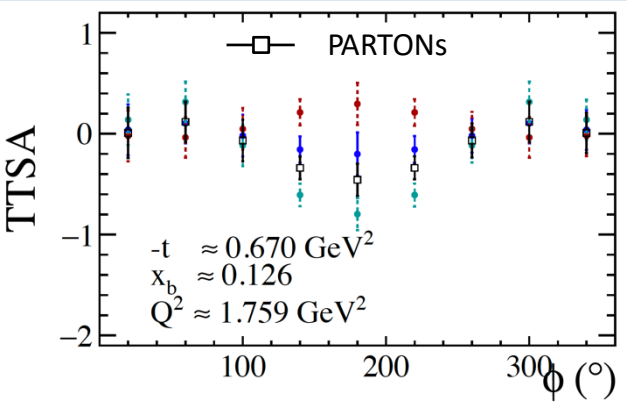
$$\Delta\sigma_{LU} \sim \sin\phi\ \mathrm{Im}\{F_1\mathcal{H} + \xi(F_1+F_2)\widetilde{\mathcal{H}} - kF_2\mathcal{E} + \dots\}$$

$$\Delta\sigma_{UT} \sim \cos\phi\sin(\phi_s-\phi)\mathrm{Im}\{k(F_2\mathcal{H} - F_1\mathcal{E}) + \dots\}$$

CLAS12 RGB measurement of A_{LU} on neutron, Phys.Rev.Lett. 133 (2024) 21, 211903



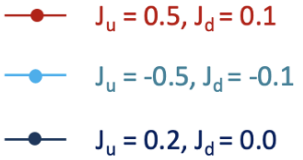




~ 1 year to get unprecedented access to elusive quark angular momenta

Supersede the only other A_{UT} measurement
Pair with A_{LU} measurement done by RGB on neutron

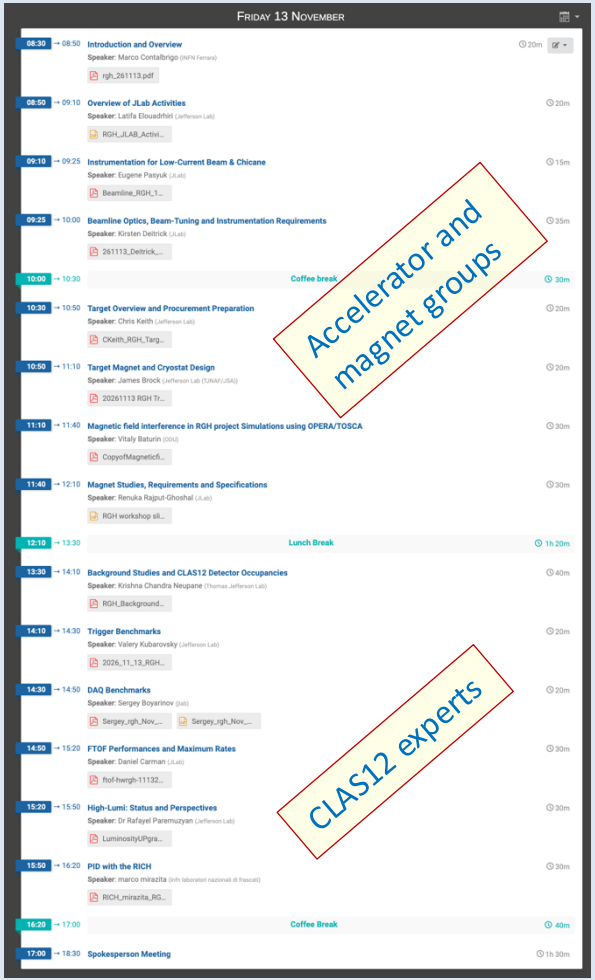
VGG



Superior discrimination power between various OAM model hypotheses

HERMES

RGH Workshop



Beam Line

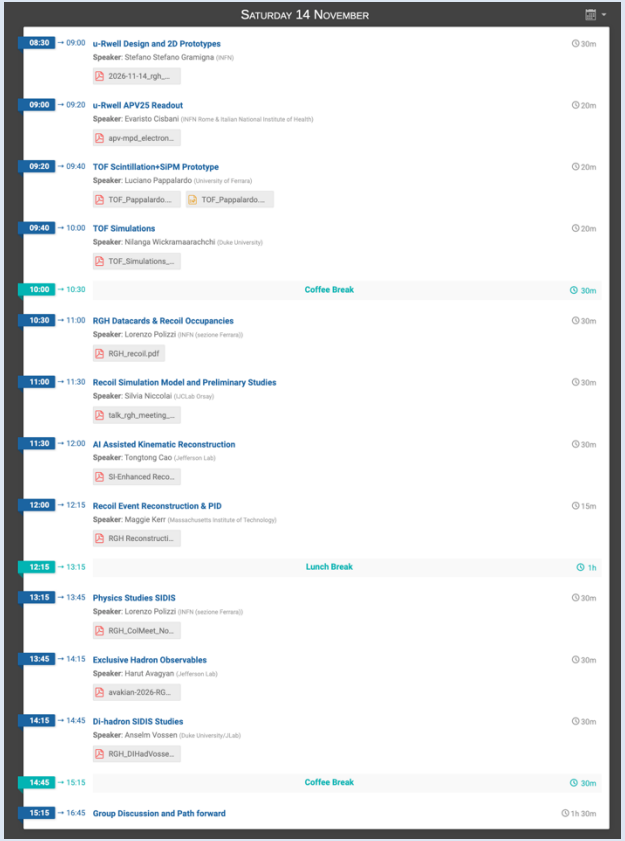
Target

Magnets

Background

CLAS12 Rates

CLAS12 Upgrades



Recoil Tracking

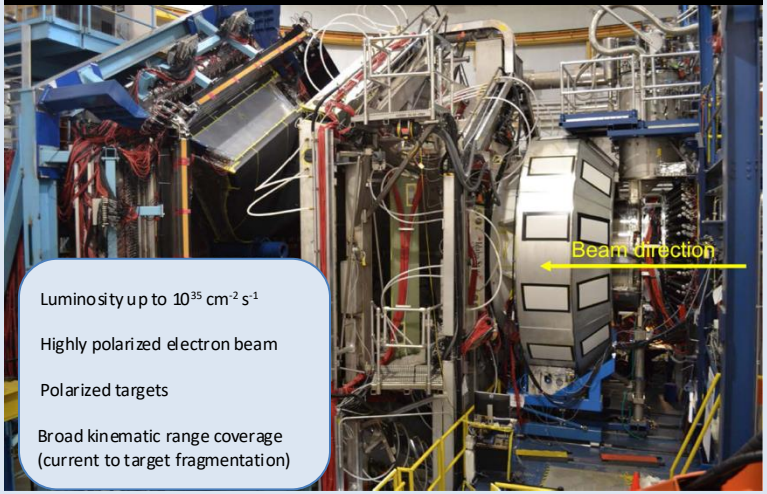
Recoil TOF

Recoil Simulation

Recoil Reconstruction

Physics Studies

Large acceptance spectrometer. Operational since 02/18

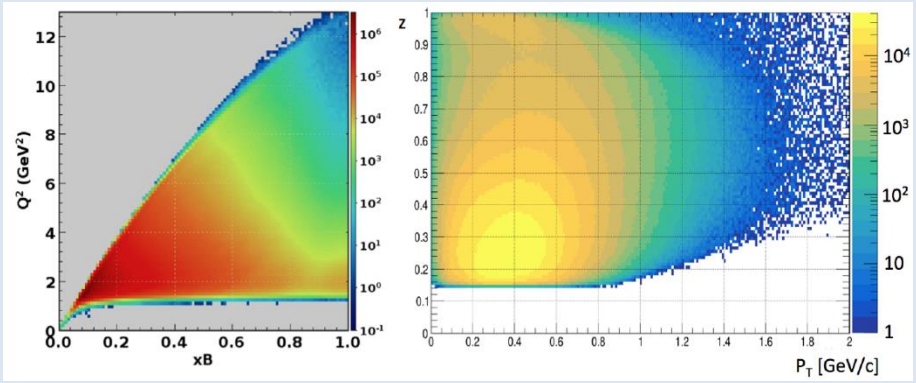


Luminosity up to 10^{35} cm^{-2} s^{-1}

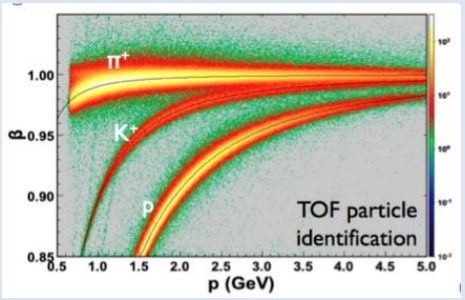
Highly polarized electron beam

Polarized targets

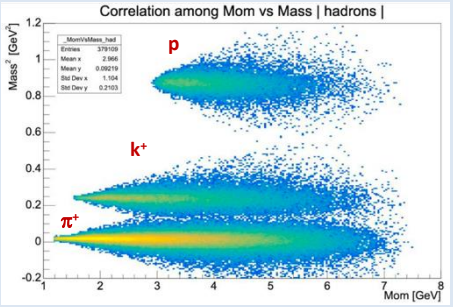
Broad kinematic range coverage (current to target fragmentation)



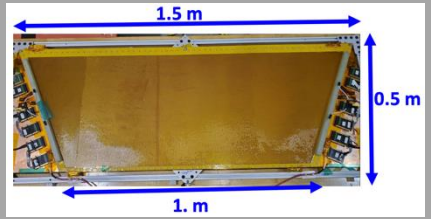
Time of flight

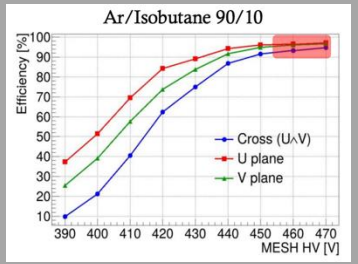


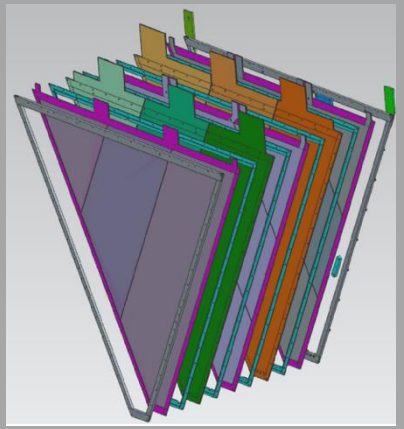
Ring-imaging Cherenkov



Luminosity upgrade Stage-1: 2x10^{35} cm^{-2}s^{-1}







Courtesy of R. Paremuzyan

RGH Target & Magnet

HD-ice: ruled out after beam tests at UITF

NH_3: Viable solution to prioritize physics over R&D

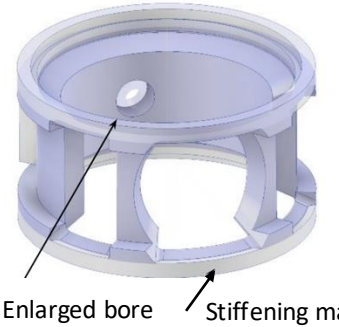
Consolidated dynamically polarized technology

Designed based on already successful realizations

Hall-A G2p-Gep target (replica optimized for HTCC)
Hall-C E12-15-005 magnet (replica optimized for recoil detection)

Magnet design being finalized for procurement

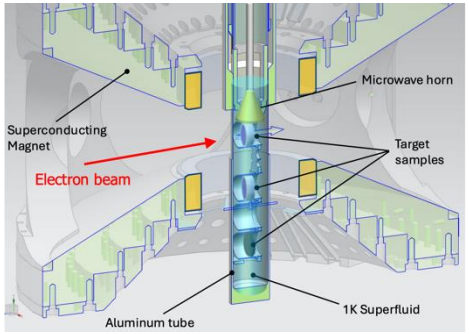




5T dipole acceptance:

$\pm 25^{o}$ vertical

$\pm 70^{o}$ horizontal



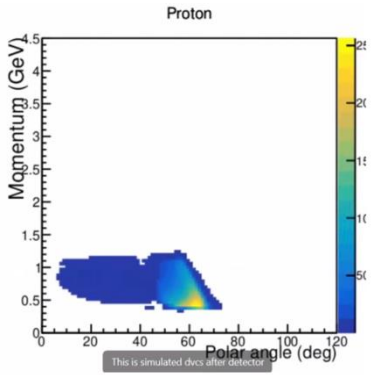
Target ladder details

An "ideal" week (21 shifts):
Ammonia 1: 8 shifts (+ pol.)
Carbon: 1 shift
Ammonia 2: 9 shifts (- pol.)
CH2: 1 shift
Empty: 1 shift
Annealing & NMR calibration: 1 shift

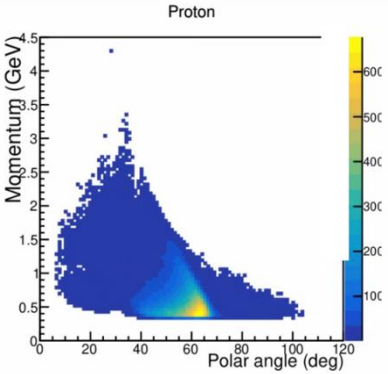
In this scenario, there is only about 5% overheard for target maintenance

We replace the target insert as few as three times (day 28, 56, & 84)

RGH (MC)

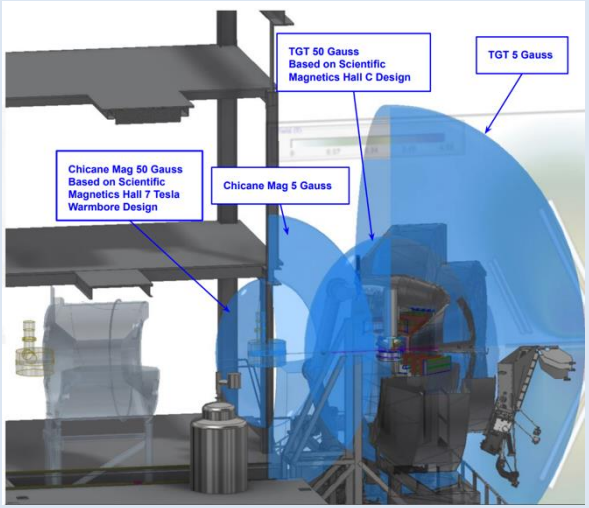


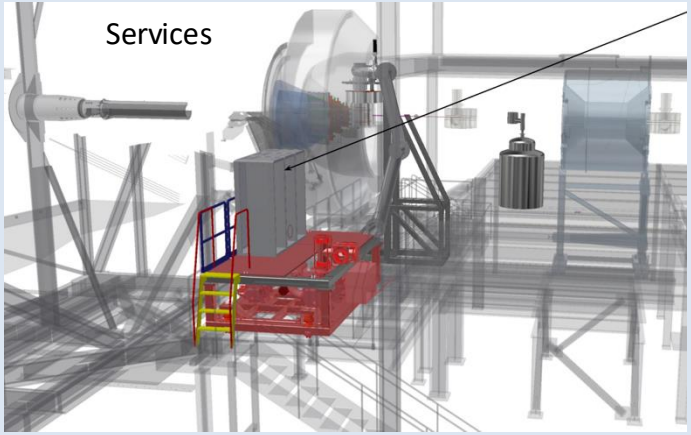
RGA (data)

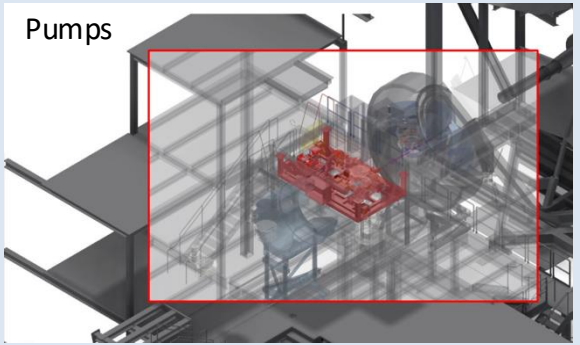


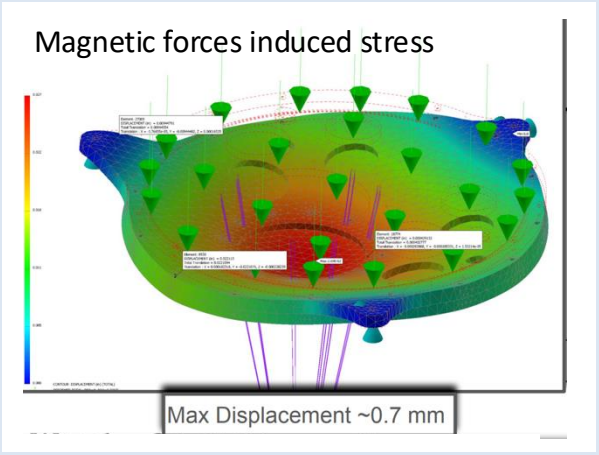
Courtesy of J. Brock

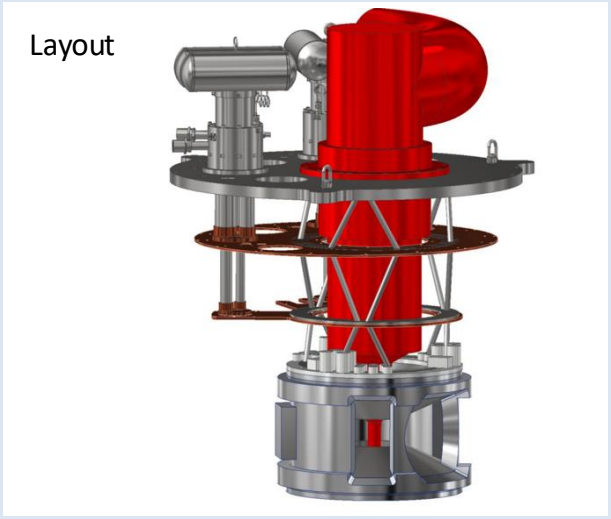
RGH Target & Magnet

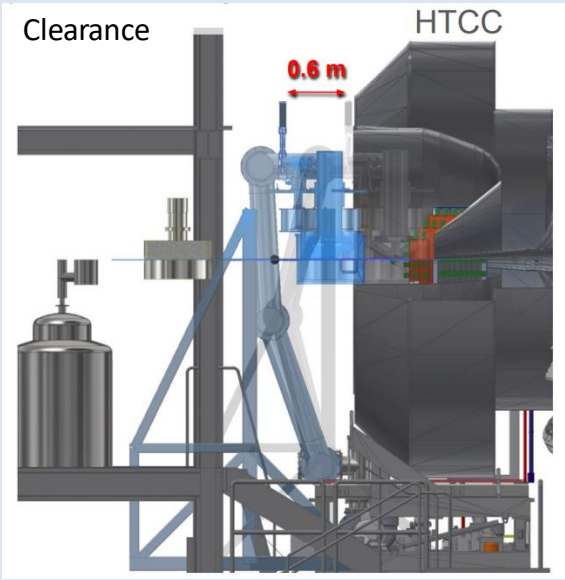












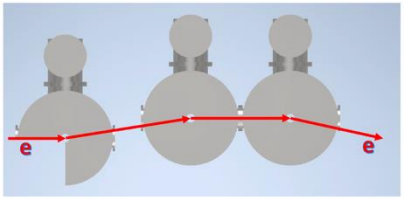
RGH Beam Line

Based on

existing 0.7 cm raster

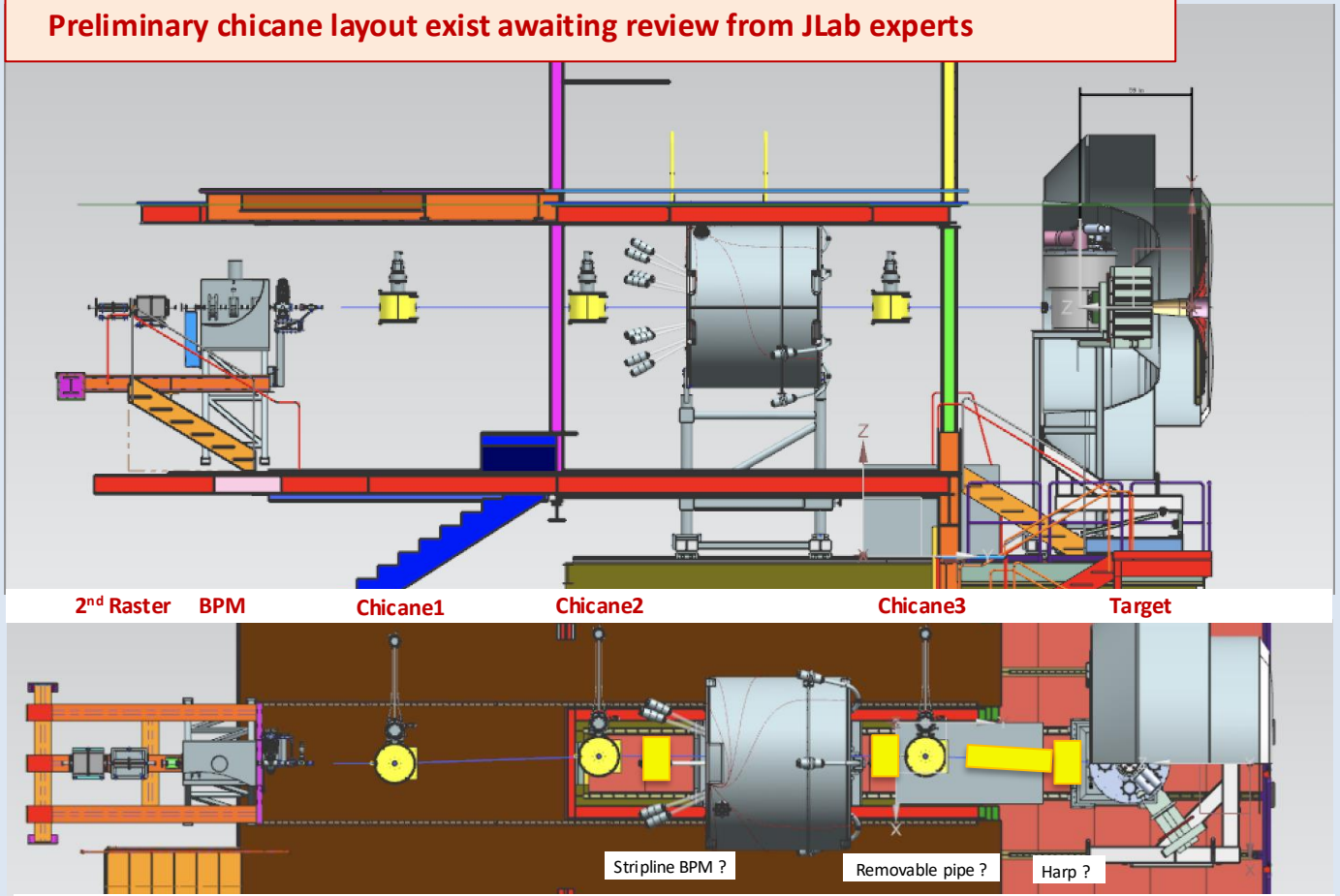
commercial 7.5T magnets





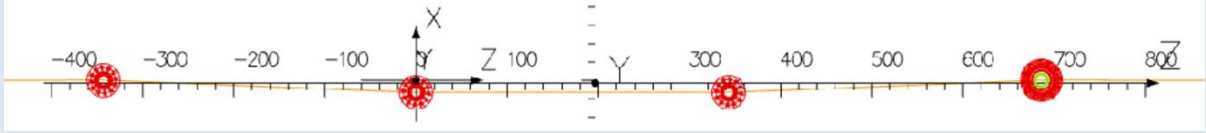
- ✓ space
- ✓ synchrotron radiation
- ✓ beam rastering

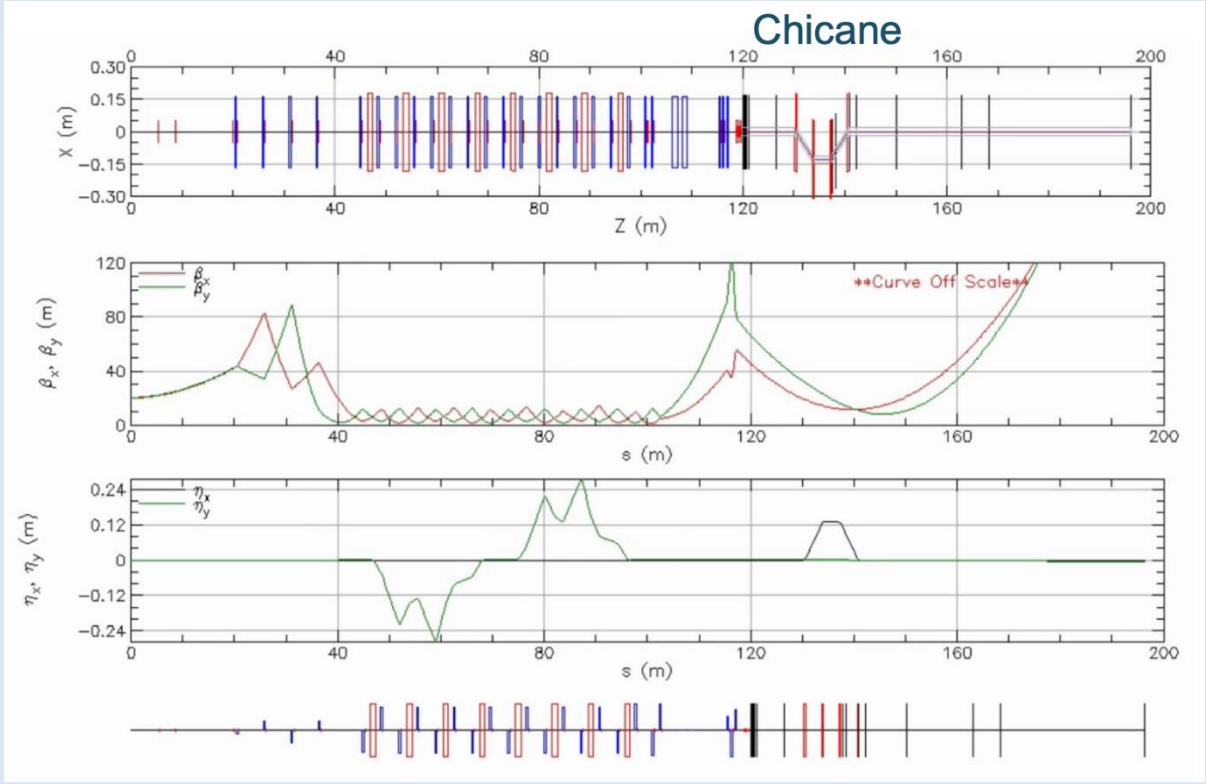
Preliminary chicane layout exist awaiting review from JLab experts



Beam pipe + 1 cm lead in the proper locations suppress synchrotron radiation to a negligible level

Beam Chicane



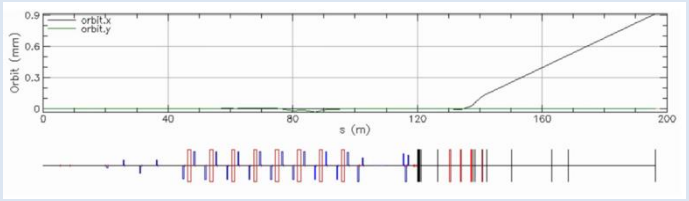


Full symmetric chicane, 343 cm separation

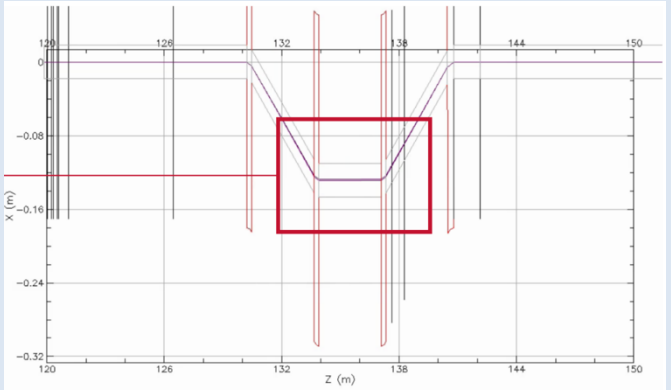
Center magnets offset by 13.1 cm

6.9 T in first three magnets for 5T at target

0.01 mrad deviation for 10^{-4} field error

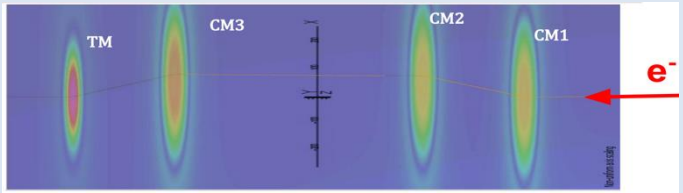


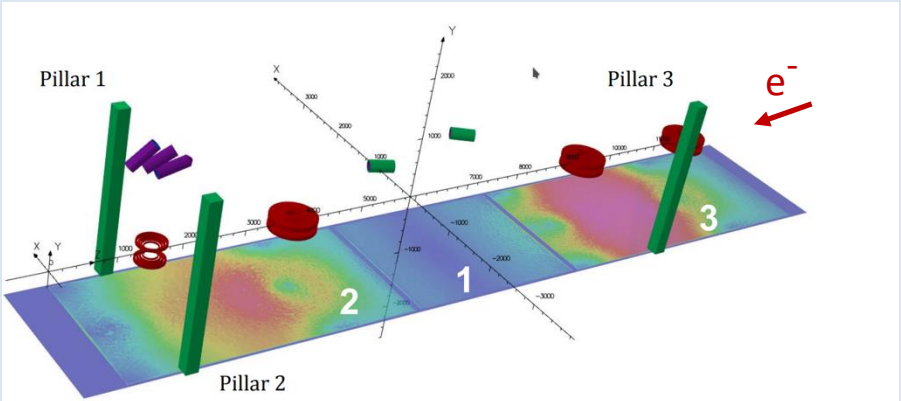
1 mm shift for 100 MeV beam energy change



Magnetic Forces

A complete analysis exist awaiting review from JLab experts



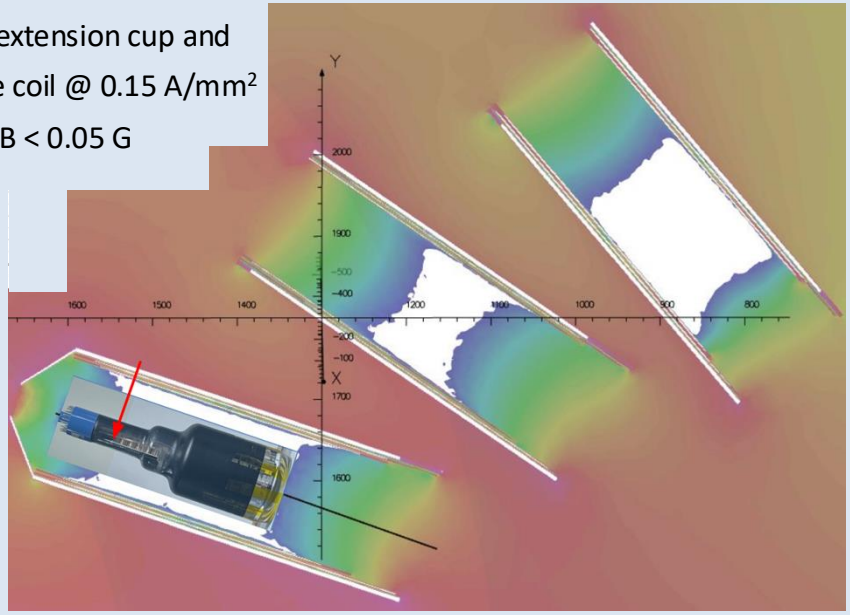


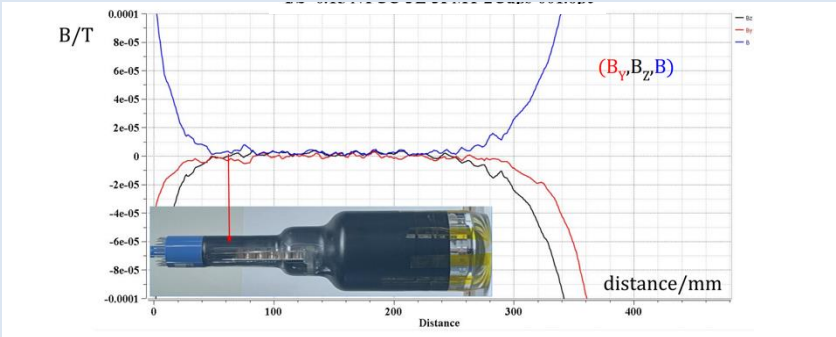
- Steel components of CTOF shields under < 3 N load;
- HTCC shields - under < 15 N load.
- A steel platform element (strut) inder load of < 90 N.
- Floor 2 (50 mm thick) and beamline magnets mutually attract with F_y = ~6,000 N
- Floor 3 and beamline magnets - with F_y =~10,000 N.

4 cm extension cup and

Active coil @ 0.15 A/mm^2

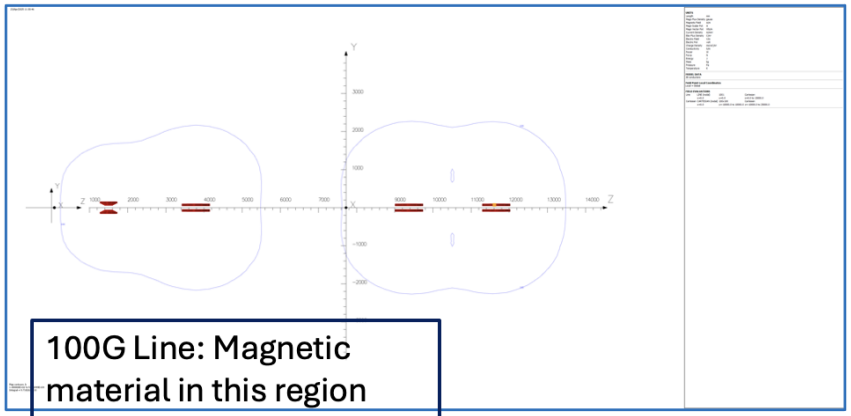
Inner B < 0.05 G



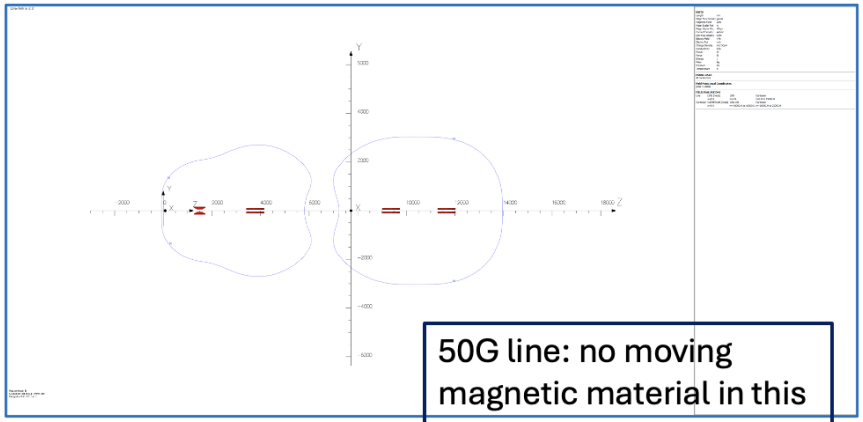


Magnetic Limits

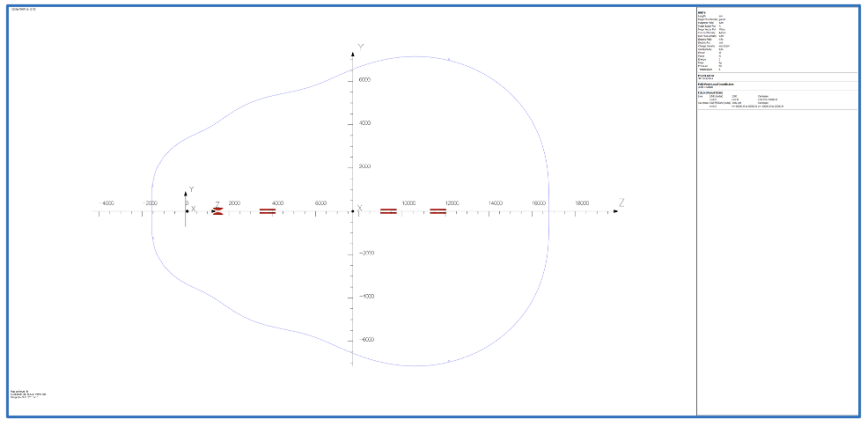
Preliminary test: No significant force on the target magnet coils due to (simplified HTCC)



100G Line: Magnetic material in this region might have impact on these magnets



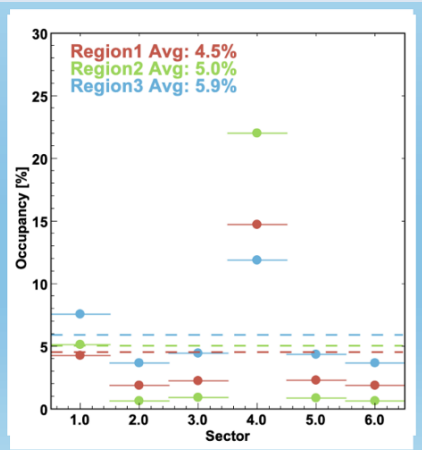
50G line: no moving magnetic material in this region

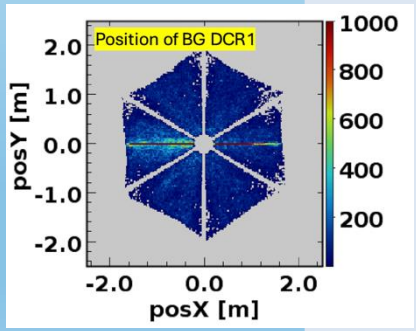


5G Line: this should be identified and have limited access for safety reasons

There is small z force (1275 N) on target magnet due to all the three chicane magnets.

DC Occupancy

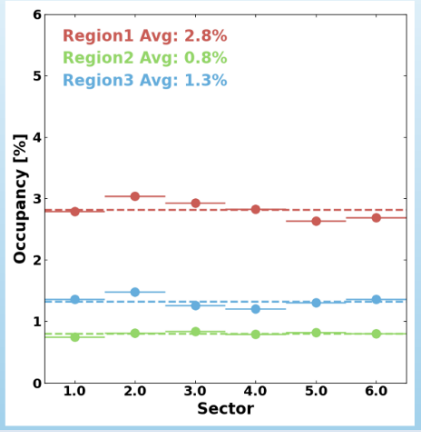


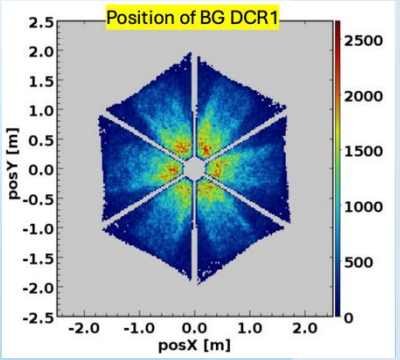


RGH

With sector 4

DC Regions Occupancies %

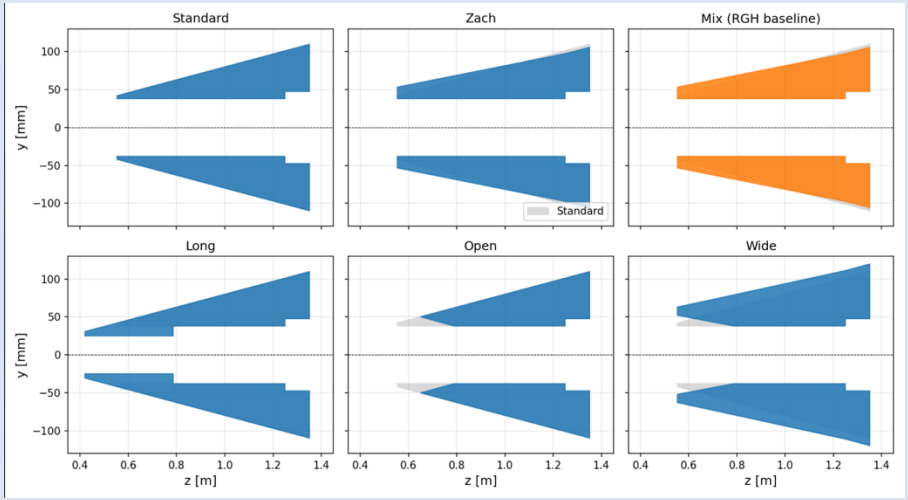




RGA

Fall 2018 sim

Detailed background simulations are ongoing



ELMO shaping study within the HTCC bore envelope

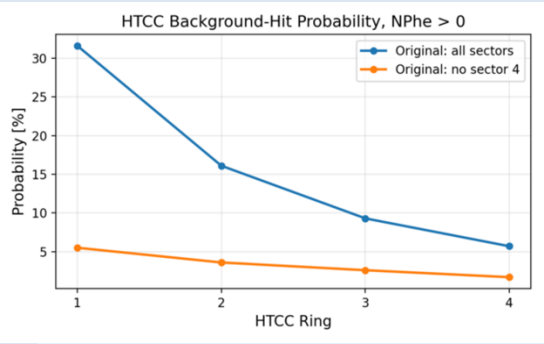
Region-averaged DC wire occupancy (%, no sector 4) for various ELMO configurations.

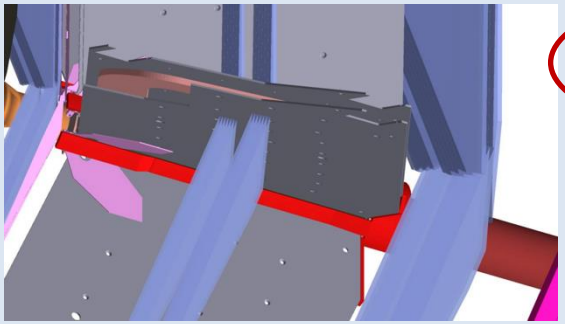
DC region	Standard	Zach	Mix	Long	Open	Wide
1	6.8	3.3	2.7	7.9	6.0	2.0
2	2.2	1.6	1.6	2.6	2.0	1.4
3	5.0	4.1	4.1	5.7	4.8	3.7

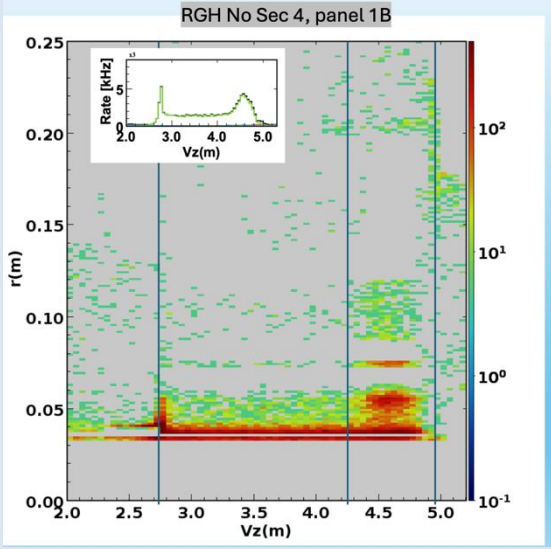
Although Wide variation performs better, due to its overlaps with HTCC Moller cone, Mix is used.

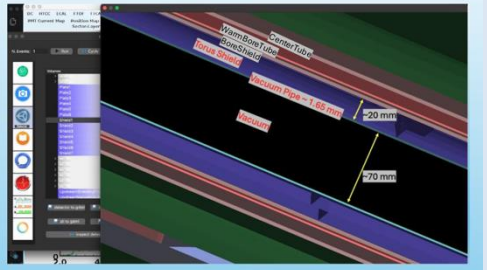
Torus Region

Refinement of GEMC model & shield under progress







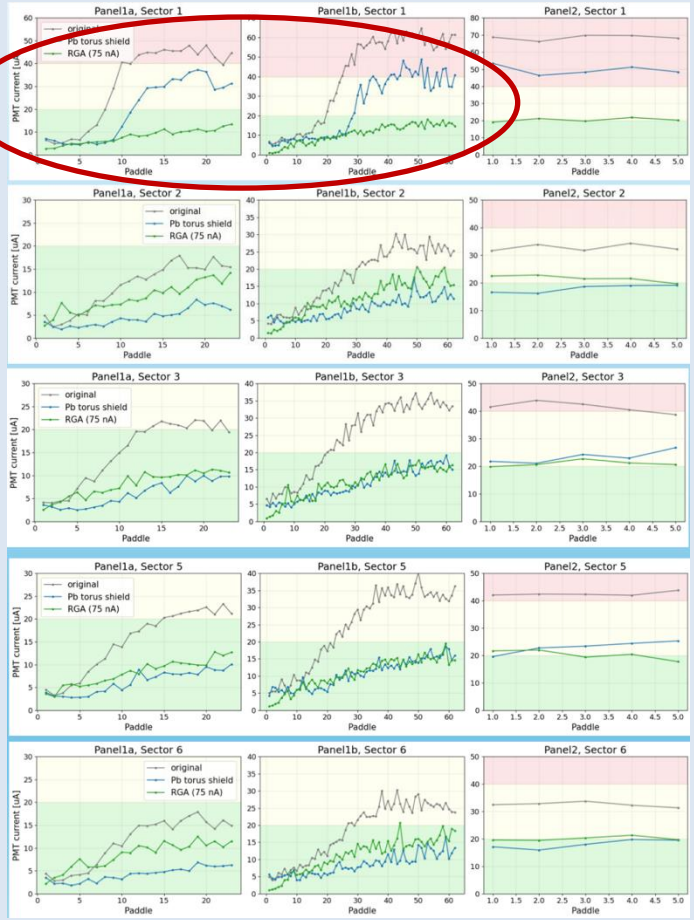


Layer	Material	r_inner (mm)	r_outer (mm)	Thickness
Beam vacuum	G4_Galactic	0	33.274	–
Vacuum pipe wall	G4_SS	33.274	34.925	1.65 mm
Air gap	fc air	34.925	36.8	1.875 mm
Shield1–7	beamline_W (tungsten)	36.8	56.8	20 mm = 2 cm
Tiny gap	fc air	56.8	57.1	0.3 mm
BoreShield	G4_SS	57.1	60.3	3.2 mm
Gap	fc air	60.3	61.9	1.6 mm
WarmBoreTube	G4_Al	61.9	63.5	1.6 mm

WarmBoreIR = 123.8/2.0 ~ 62.0 mm

14

FTOF

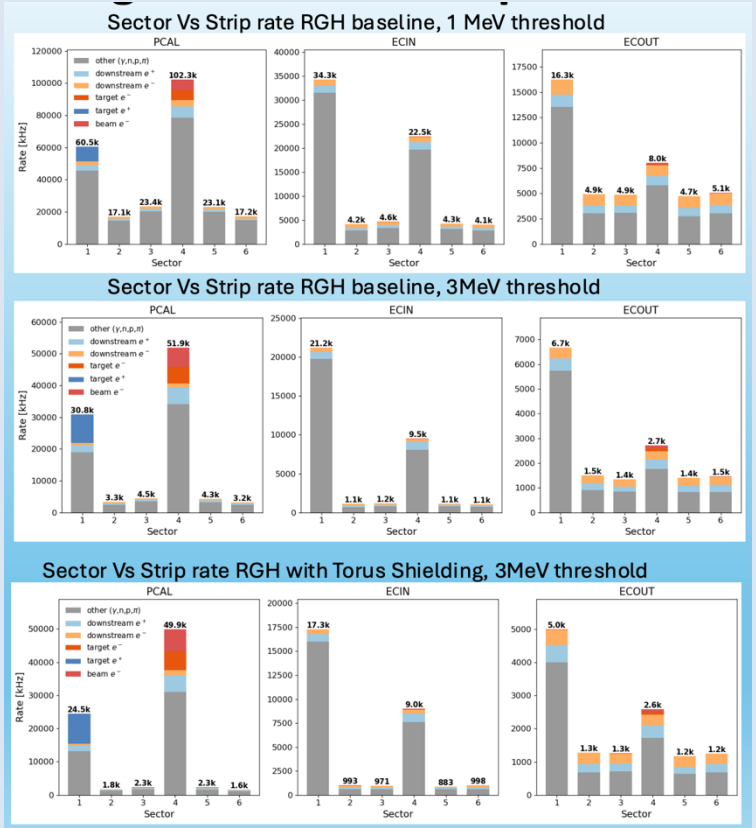


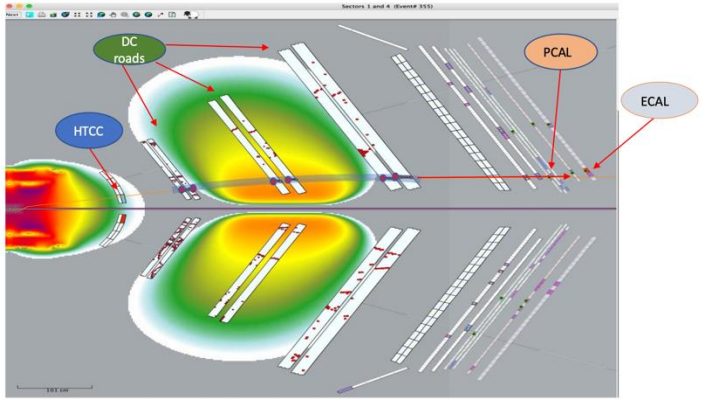
ECAL Occupancy & Trigger

No significant impact expected on trigger rate from sheet-of-flame

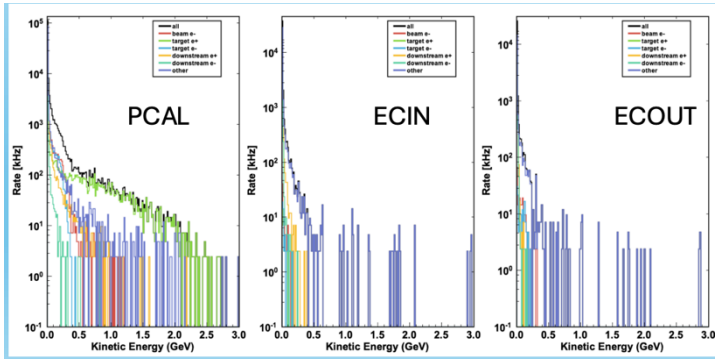
HTCC × PCAL × E(total) = PCAL+EC × DC (OR over sectors 1-6)

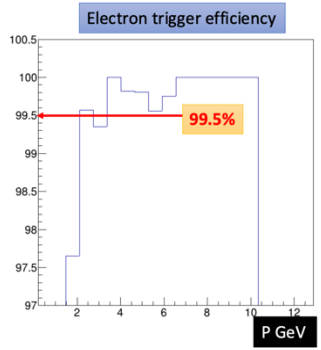
Nphe> 2 p.e. | PCAL E>60 MeV | E(total) > 150/300 MeV | ≥3/6 layers, ≥5/6 superlayers, road matched to ECAL cluster; source: CLAS12 Trigger NIM A 960 (2020)





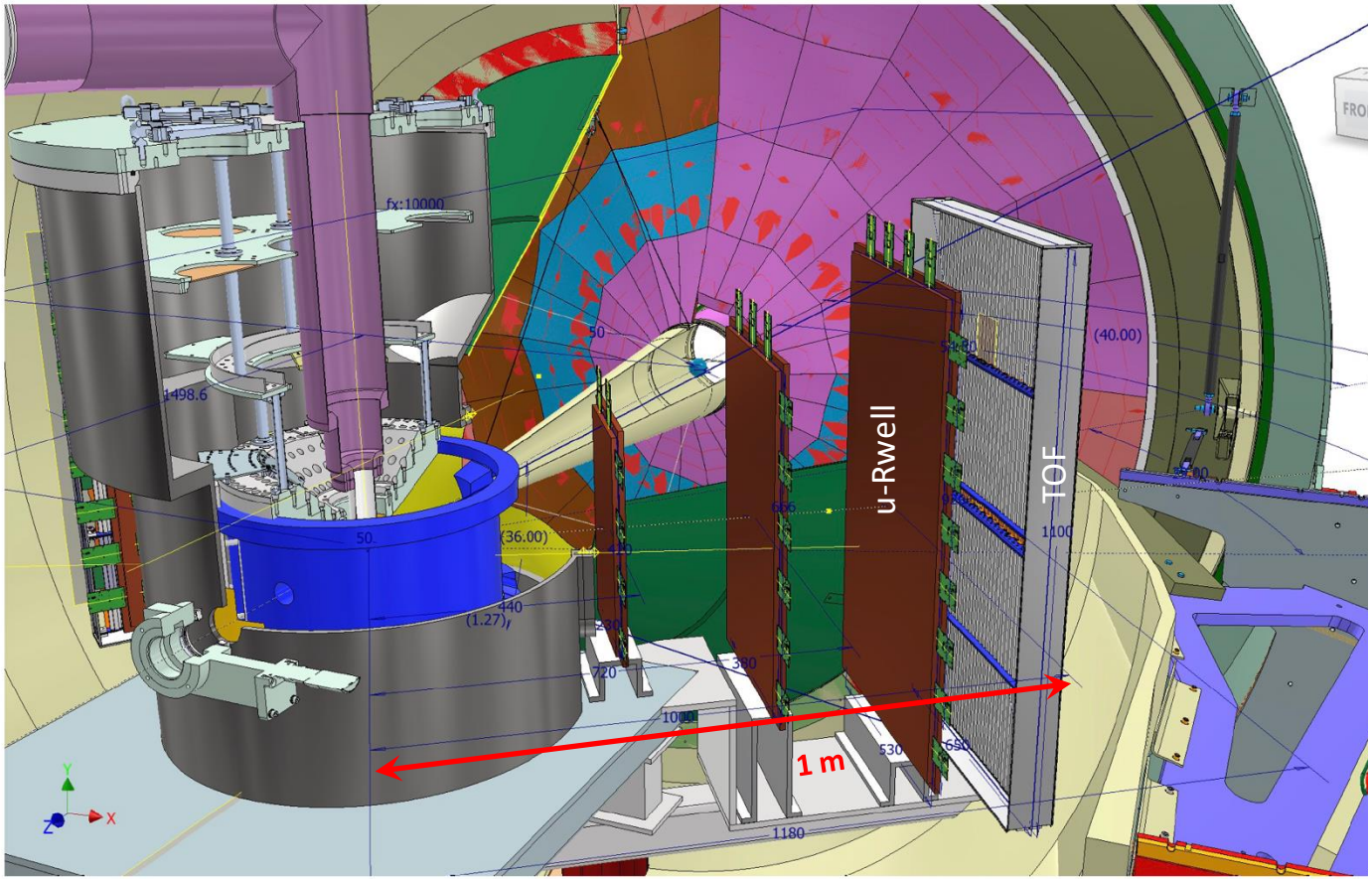
- HTCC > 2 phe
- PCAL+ECAL > 300 MeV
- DC segments: 5 out 6
- DC roads
- PCALU and track match



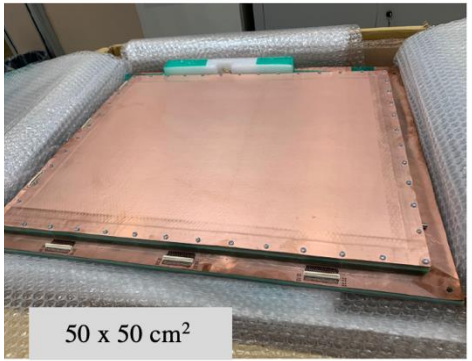


New recoil detector to cover the optimized target magnet acceptance.

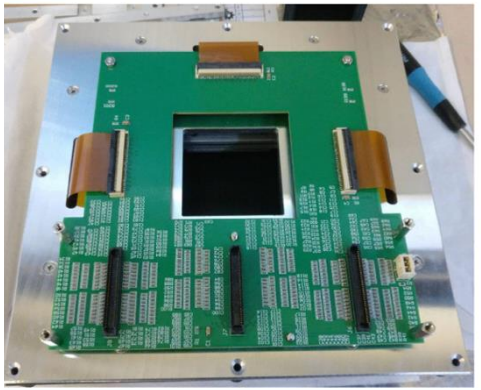
Completion of R&D activity expected in 2027



μ-Rwell tracking



Scintillator + SiPM TOF



Recoil Simulation

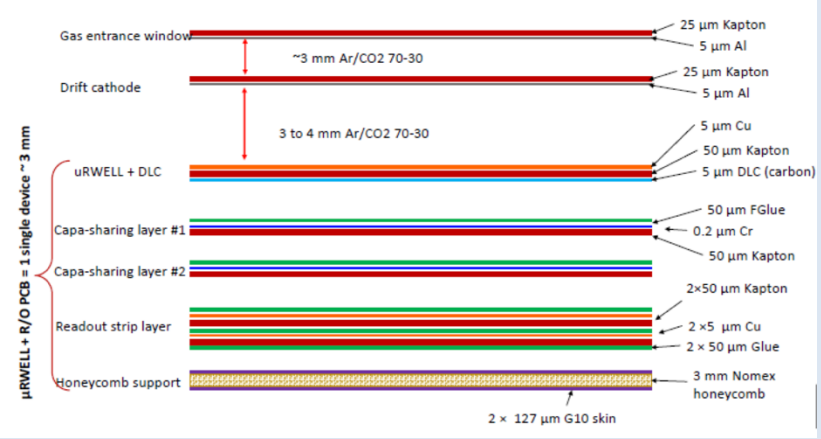
A complete simulation and reconstruction package is under development

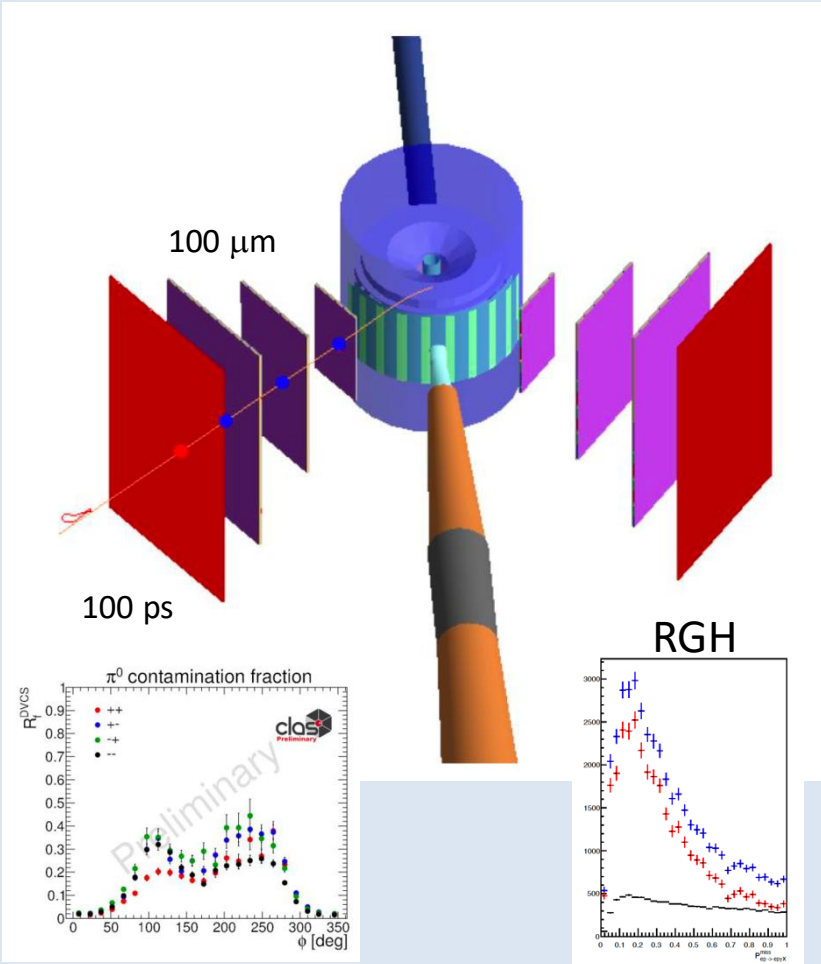
Specs defined by two “toy” reconstructions implemented for the proposal (INFN, Orsay)

uRwell implemented following the High-lumi model (Orsay)

TOF implemented following FTOF model (DUKE)

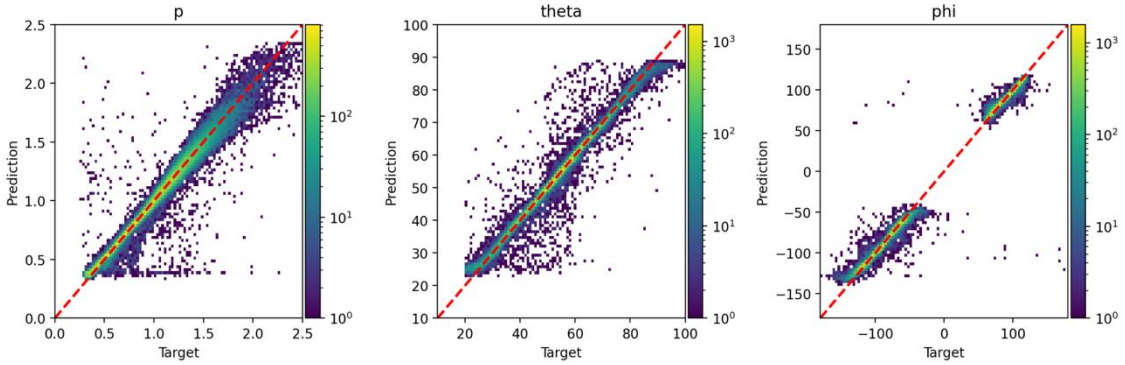
Now: working with software group
to implement an AI assisted tracking

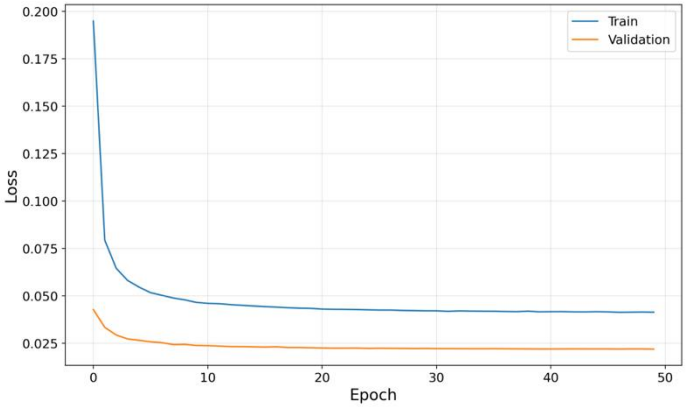


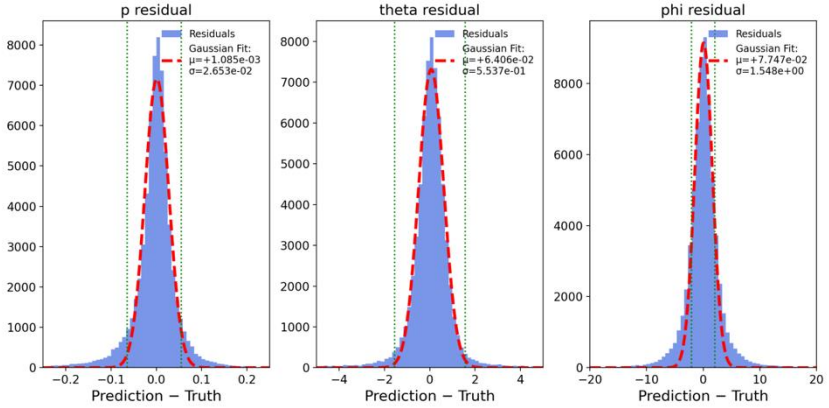


Recoil Reconstruction

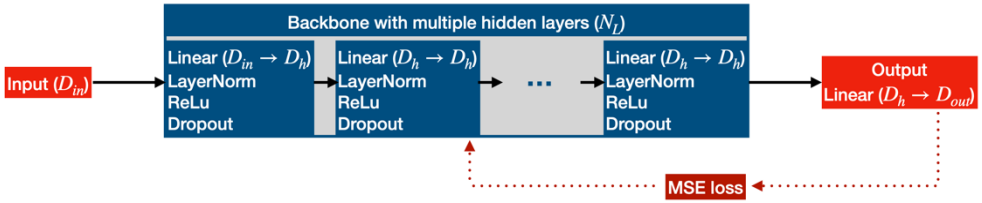
ML based reconstruction reproduces expected resolutions







MLP – based architecture



From 3 crosses and TOF predict values at vertex

- Δp: 0.0011 GeV $\pm$ 0.0265 GeV
- $\Delta\theta$: 0.0064° $\pm$ 0.5537°
- $\Delta\phi$: 0.0775° $\pm$ 1.5480°

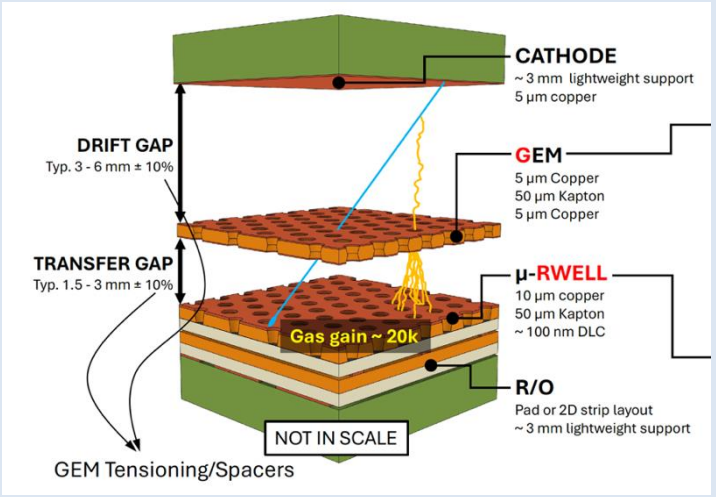
Recoil Tracking

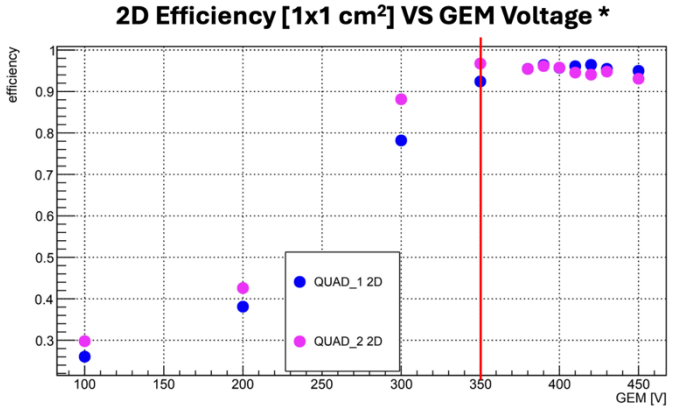
μRwell as spin off of the high-lumi project
(various prototypes from 10 x 10 cm² up to 40 x 46 cm² exist)

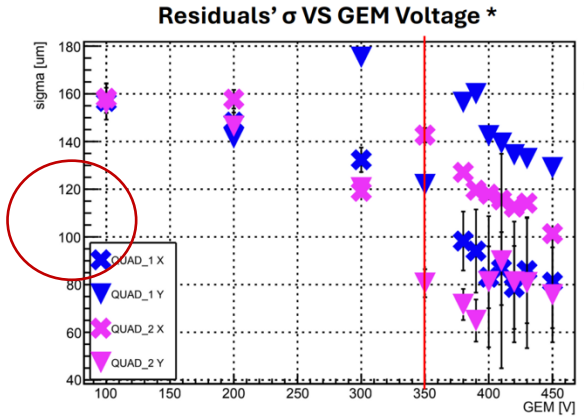
GEM-μRwell to provide 2D information with 100 μm resolution

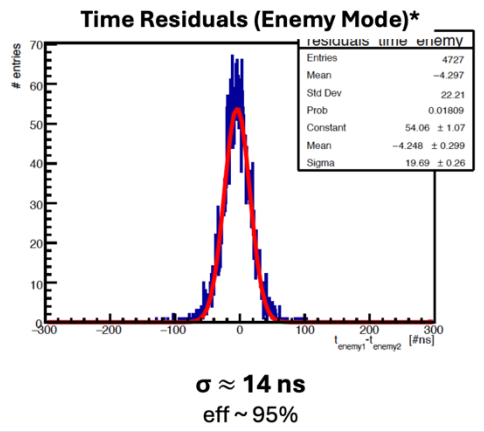
- ✓ Wanted gain/efficiency is preserved below 600 V safe bias
- ✓ < 10 ns time resolution can be achieved from signal shape fit
- ✓ TPC-like readout to correct the impinging angle has been proven

Test-beam at CERN in Oct '24 and new test-beam in July '26





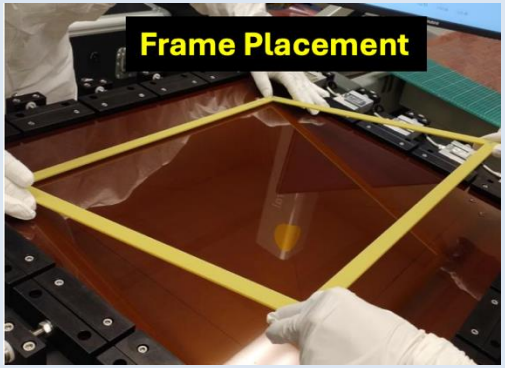


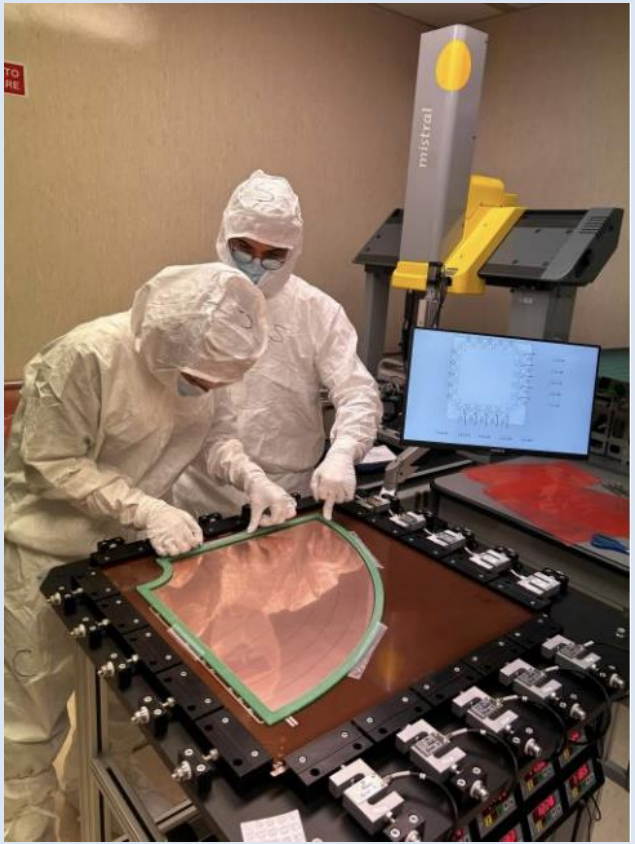


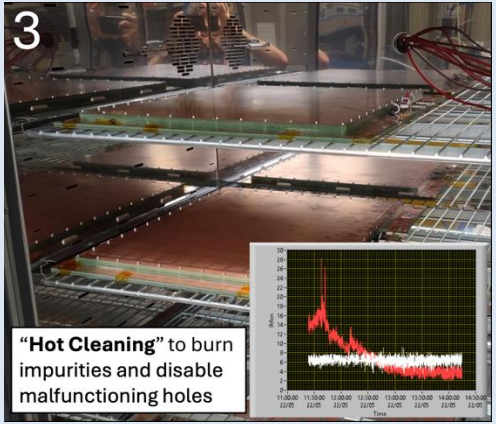
uRwell Lab in Rome

In house layer assembling, detector conditioning & test capability

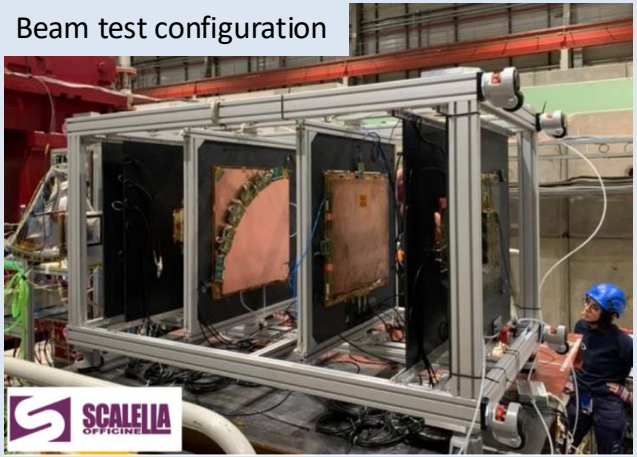
(working on global detector assembly and gas mixer unit)



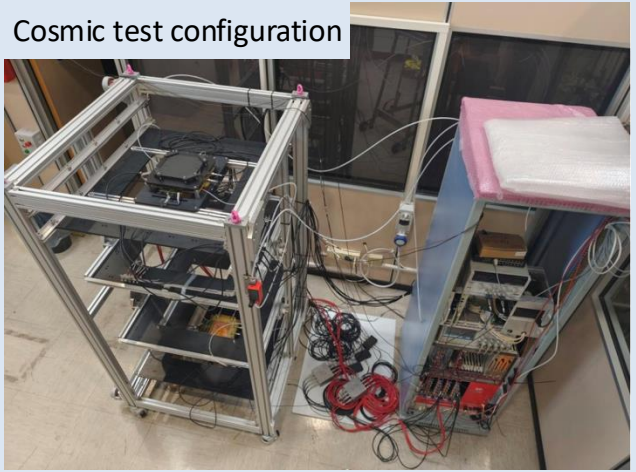




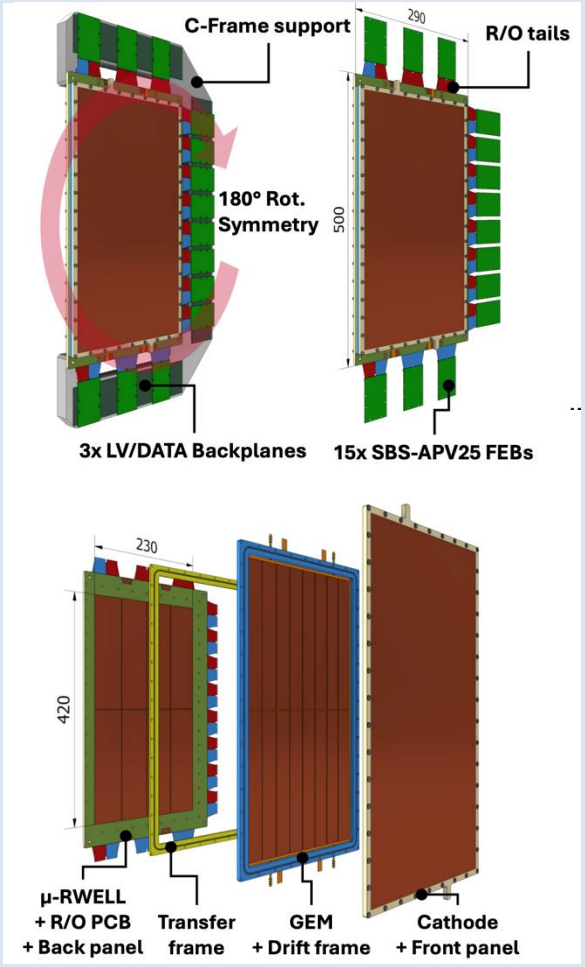
Beam test configuration



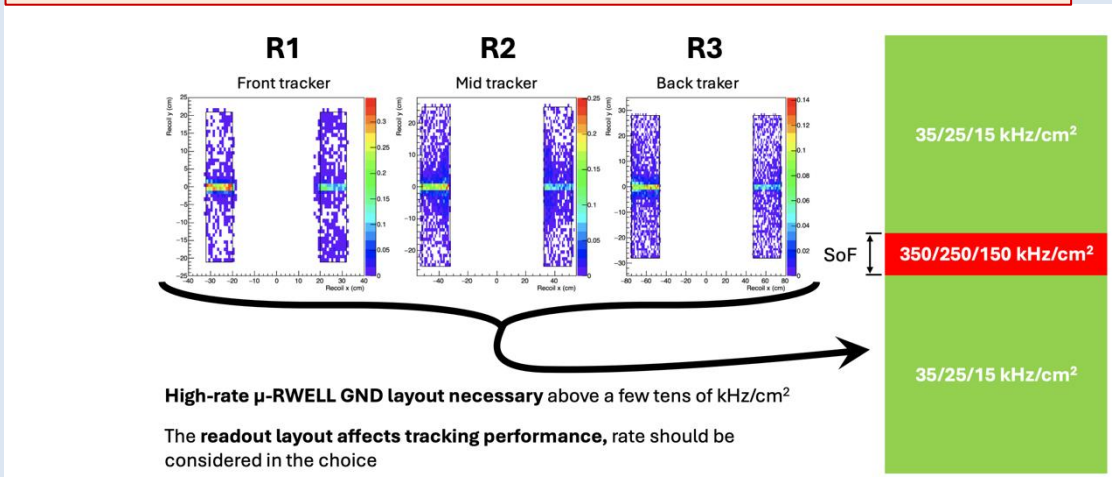
Cosmic test configuration



uRwell Tentative Design



A tracking design accounting for the asymmetric rate is possible

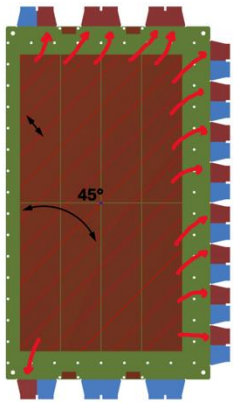


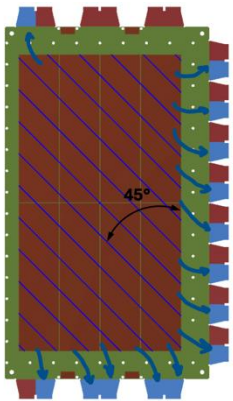
High-rate μ-RWELL GND layout necessary above a few tens of kHz/cm²

The **readout layout affects tracking performance,** rate should be considered in the choice

U View

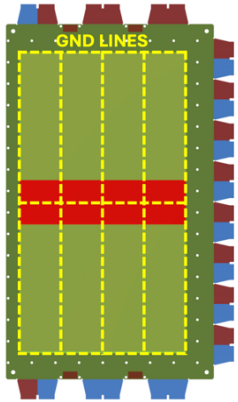
64 Channels
× 0.5 mm (pitch)
= 32 mm wide bands





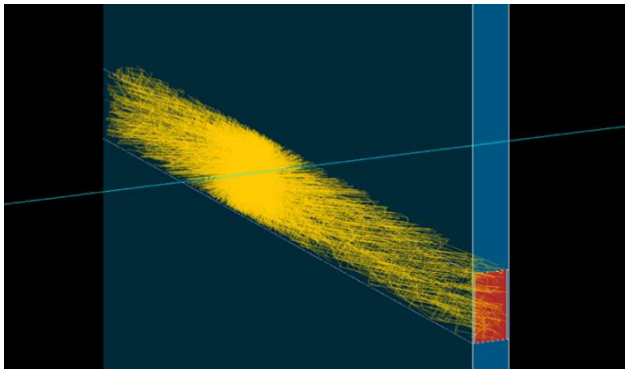
V View

Routing compatible with **common mode correction at MPD level**



Thin scintillating bars + SiPM can provide time resolution O(100 ps)

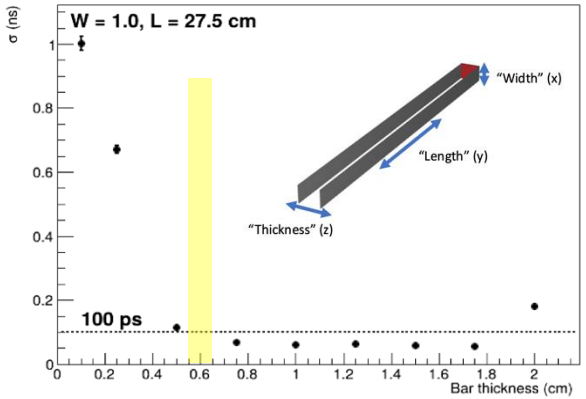
Technology choice already proven at PANDA and MUSE



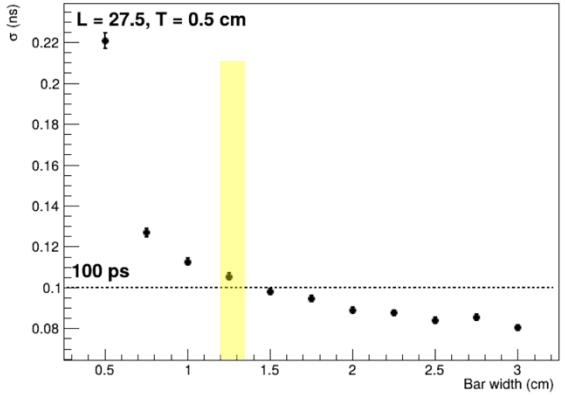
Timing resolution results – 0.5 GeV/c

Bar dimensions (mm) L x W x T	Time Resolution (ps) - without electronics	Time Resolution (ps)	Scale factor	New time resolution (ps)	PANDA resolution BC408 (ps)	PANDA resolution BC420 (ps)
170 x 5 x 5	90	87	0.6	145	97 +- 19	
120 x 5 x 5	72	70	0.6	117	81 +- 12	68 +- 10
50 x 5 x 5	43	43	0.6	72	83 +- 6	62 +- 5

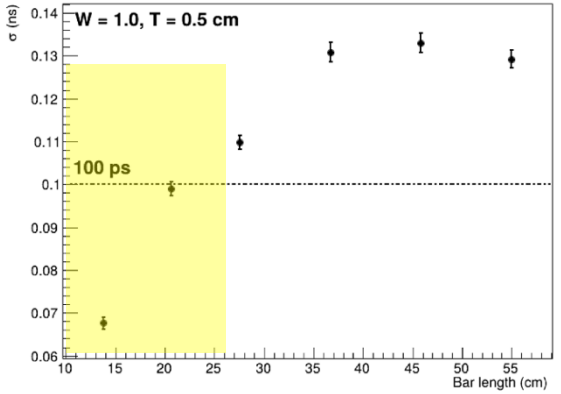
Reconstructed Time Resolution vs Bar thickness



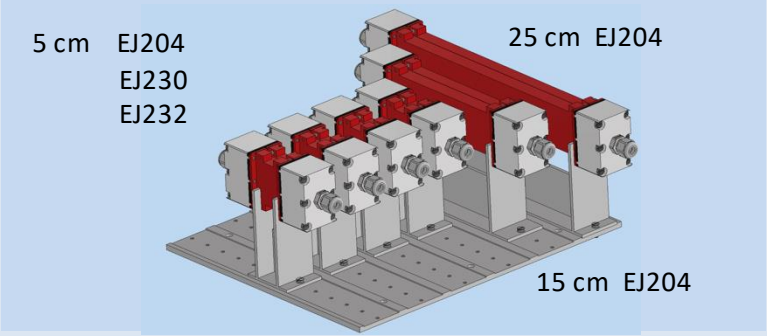
Reconstructed Time Resolution vs Bar width



Reconstructed Time Resolution vs Bar length



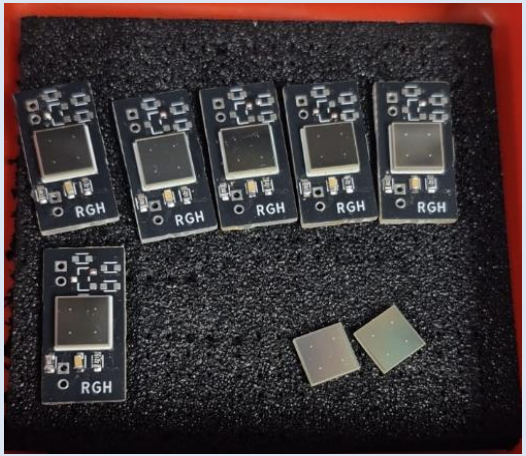
TOF Demonstrator



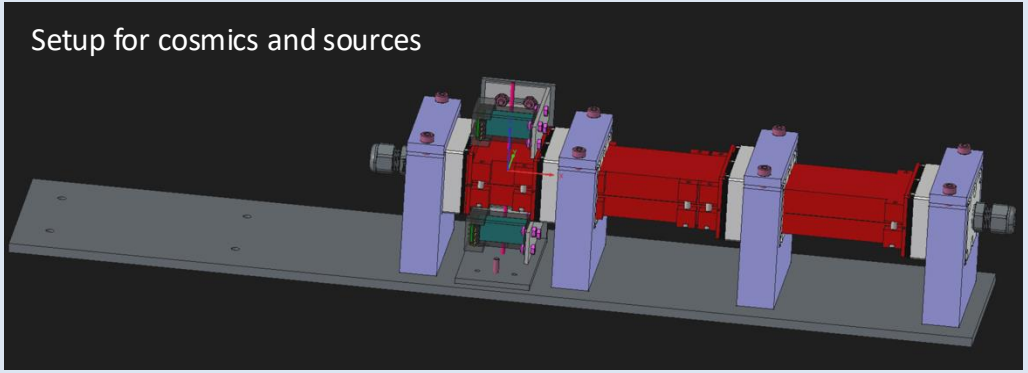
A TOF demonstrator has been realized with various scintillators



Hamamatsu 13360 6x6 mm^2

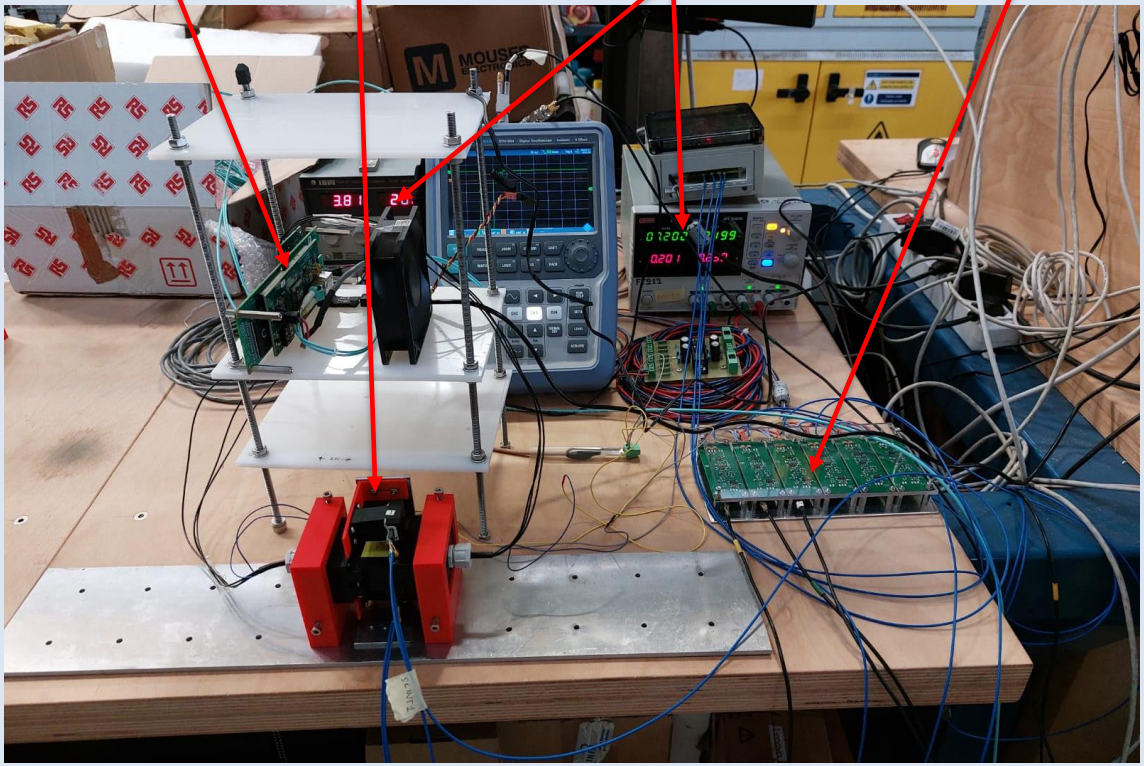






TOF Test Station

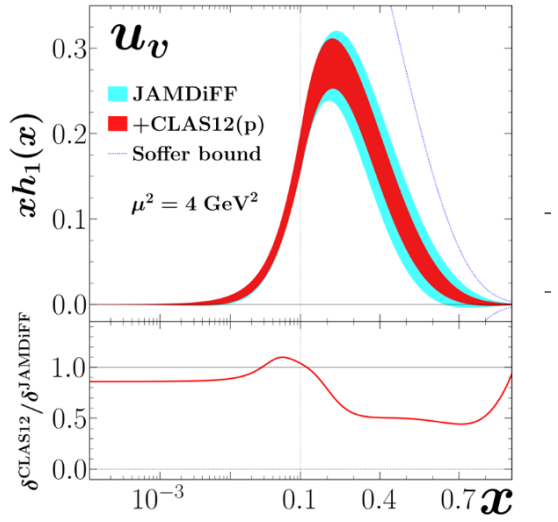
A test bench in Ferrara is ready with MAROC readout and upgraded TDC



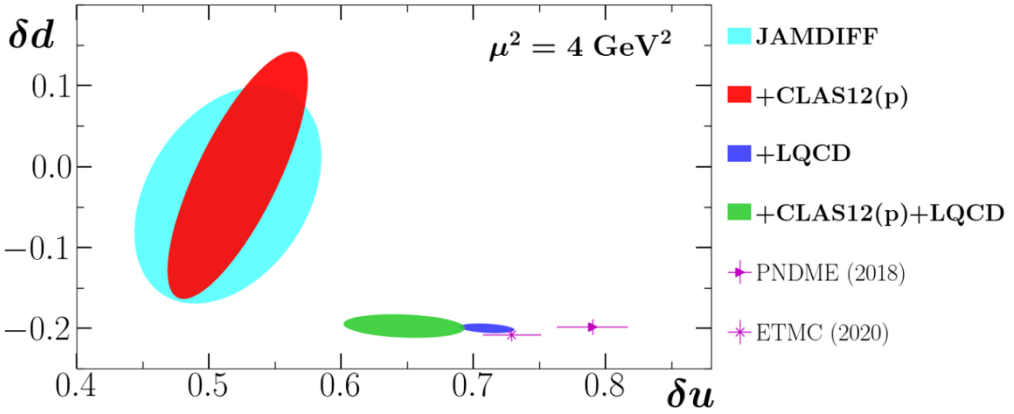


RGH is part of the phenomenology projections

- Recent projections from the JAM group show **RG-H** will be *competitive* with lattice efforts to constrain the tensor charge
- Note: pretty conservative assumptions for R-GH and only di-hadron channel



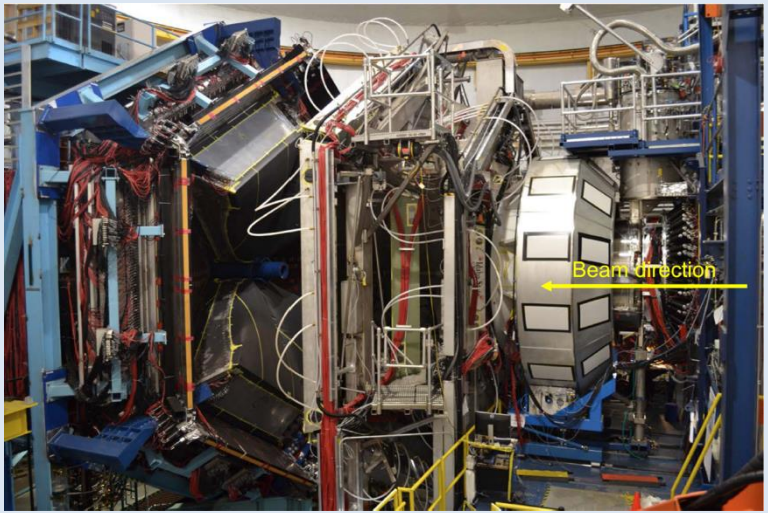
JAM group: Sawaya et al. *Phys.Rev.D* 114 (2026) 7, 074009

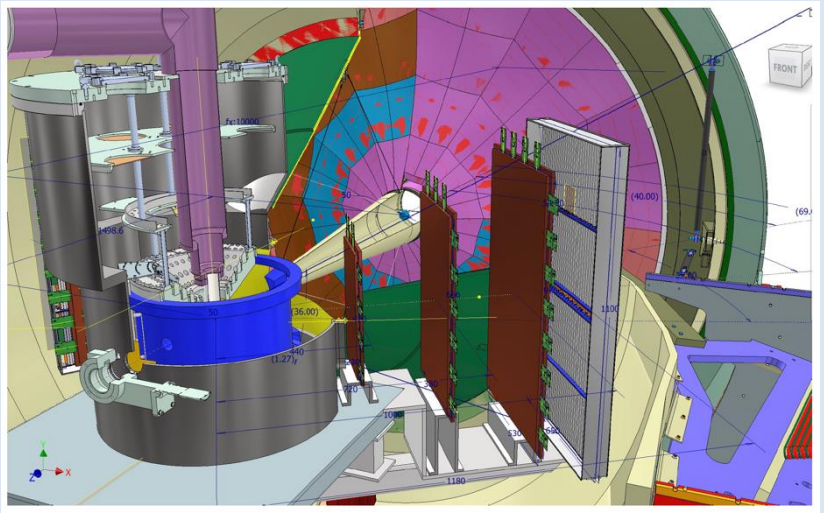


Conclusions

RGH implements the target configuration which is most sensitive to the 3D nucleon structure study and capitalizes on CLAS12 with a complete set of target polarizations

RGH: achieve unprecedent precision in the valence region to significantly improve our understanding of tensor charge, spin-orbit correlations, and quark angular momentum, complementing past and ongoing CLAS12 studies.





Goal of the workshop: Bring everybody on the same page and boost progresses. Identify priorities and timeline:

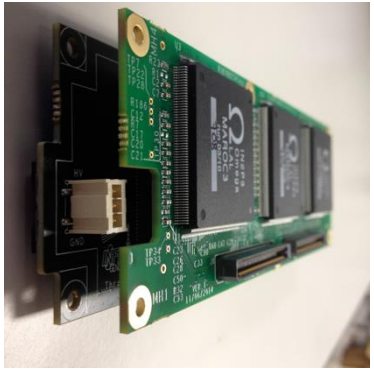
RGH has targeted 2030-31 as potential data-taking slot

Target magnet procurement and Beam chicane baseline expected in Spring ’27

Enough (> 1 k) spare channels from RICH readout now updated to ALERT firmware to meet 100 ps readout jitter

RICH readout

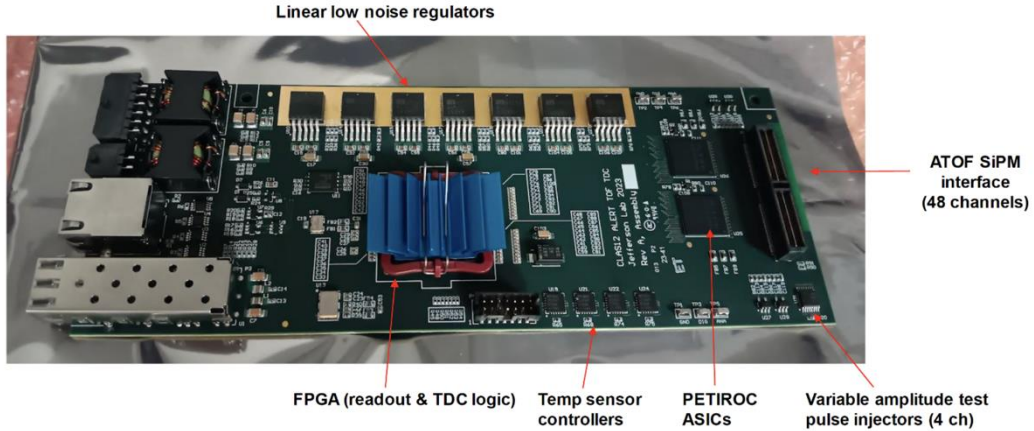
- ✓ MAROC dynamic range can cope with multi-photon signals
- ✓ Clock distribution supports 100 ps readout precision





Option to adopt CLAS12-ALERT readout

- ✓ PETIROC has a better dynamic range (multi-photons)
- ✓ Clock distribution supports 50 ps readout precision



Enough (> 10 k) spare channels exist from INFN GEM project for SBS in Hall-A

Based on the well-known APV25 chip + SSP DAQ (upgraded version of MPD/backplane under discussion)

E. Cisbani

- ✓ Able to cope with 250 kHz/cm^2 and 60% occupancy
- ✓ Same system used with the μRwell prototypes (adapter boards are required)





