Hall A Collaboration Meeting ’25
Status of SoLID and Pre-R&D Activities

January-16-2025

SOLENOIDAL LARGE INTENSITY DEVICE

Klaus Dehmelt – TJNAF

On behalf of the SoLID Collaboration

Solenoidal Large Intensity Device – SoLID Hall-A

- SoLID will explore QCD landscape ⇨ Complementary to research at other facilities, e.g., EIC
- SoLID will exploit CEBAF-12-GeV upgrade

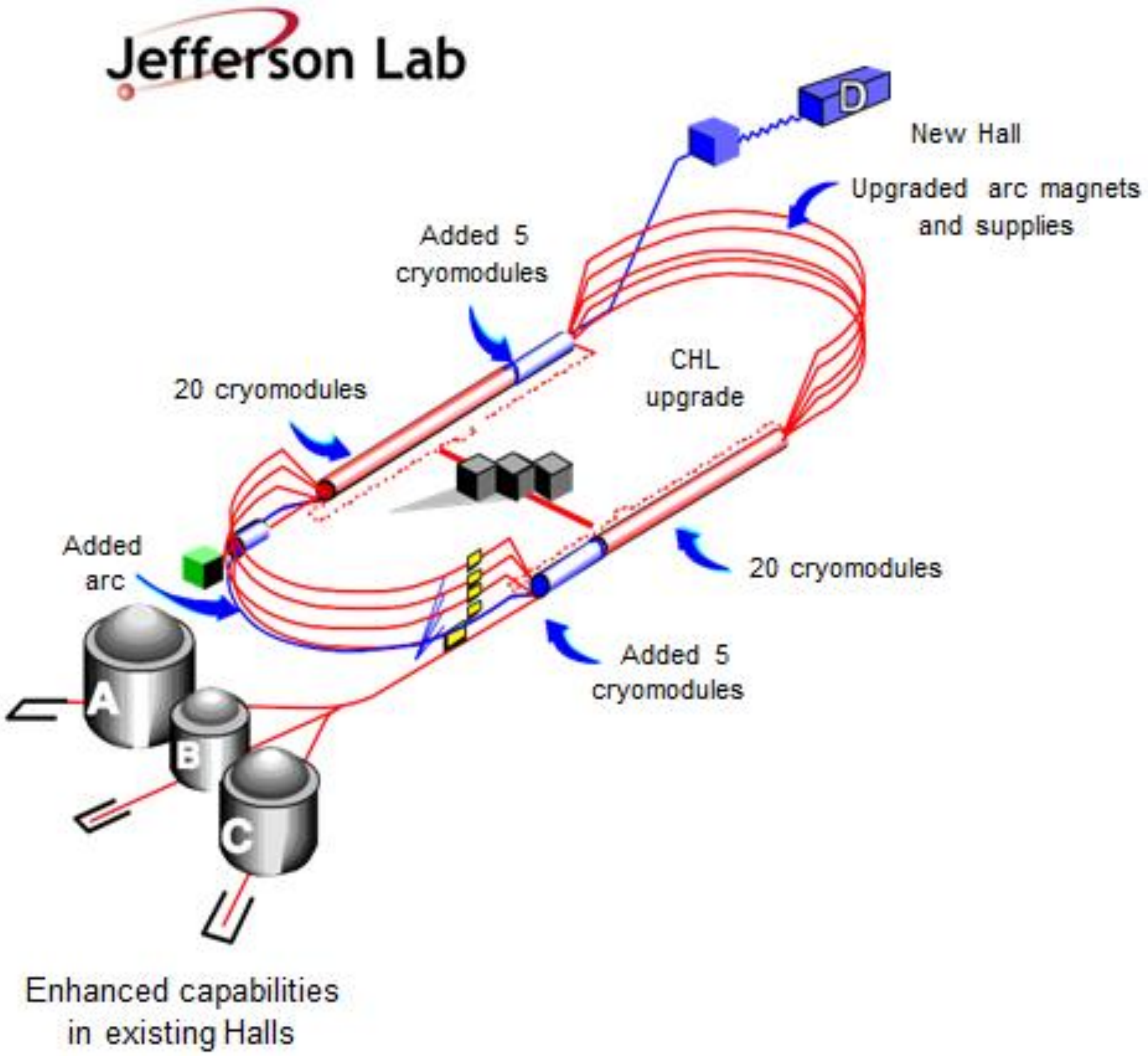
High Luminosity
$10^{37\text{-}39}$ /cm^2/s
[>100x CLAS12][>1000x EIC]

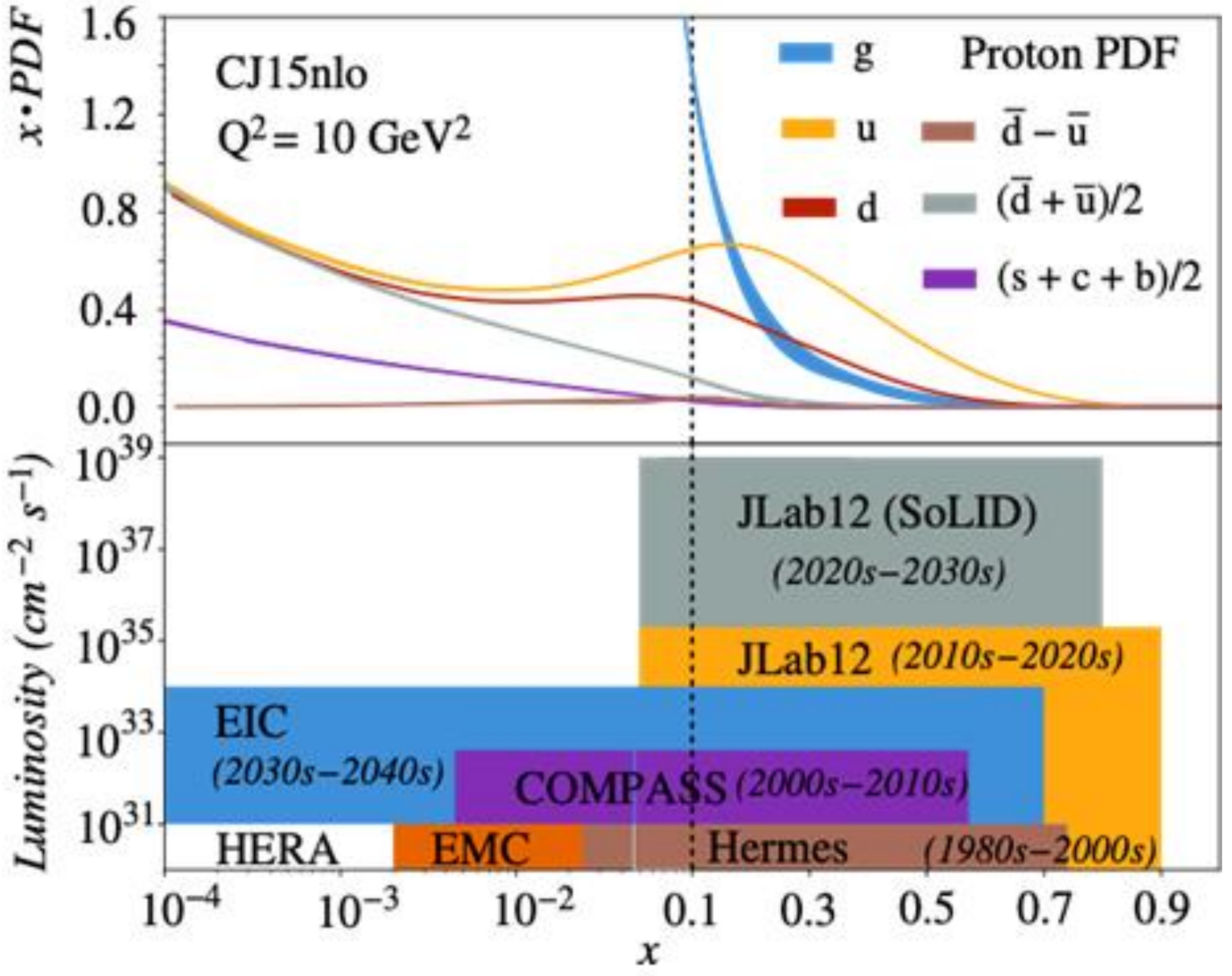
- SoLID will maximize science return

Large Acceptance
Full azimuthal ϕ coverage

- SoLID ⇨ core part of JLab 12-GeV program + future upgrades

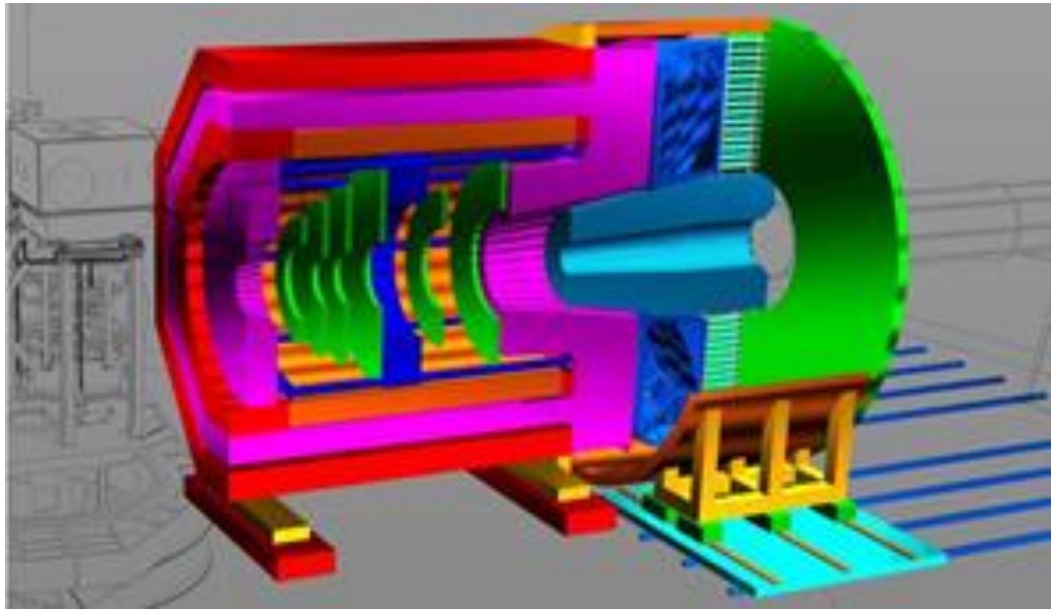
Solenoidal Large Intensity Device – SoLID Hall-A

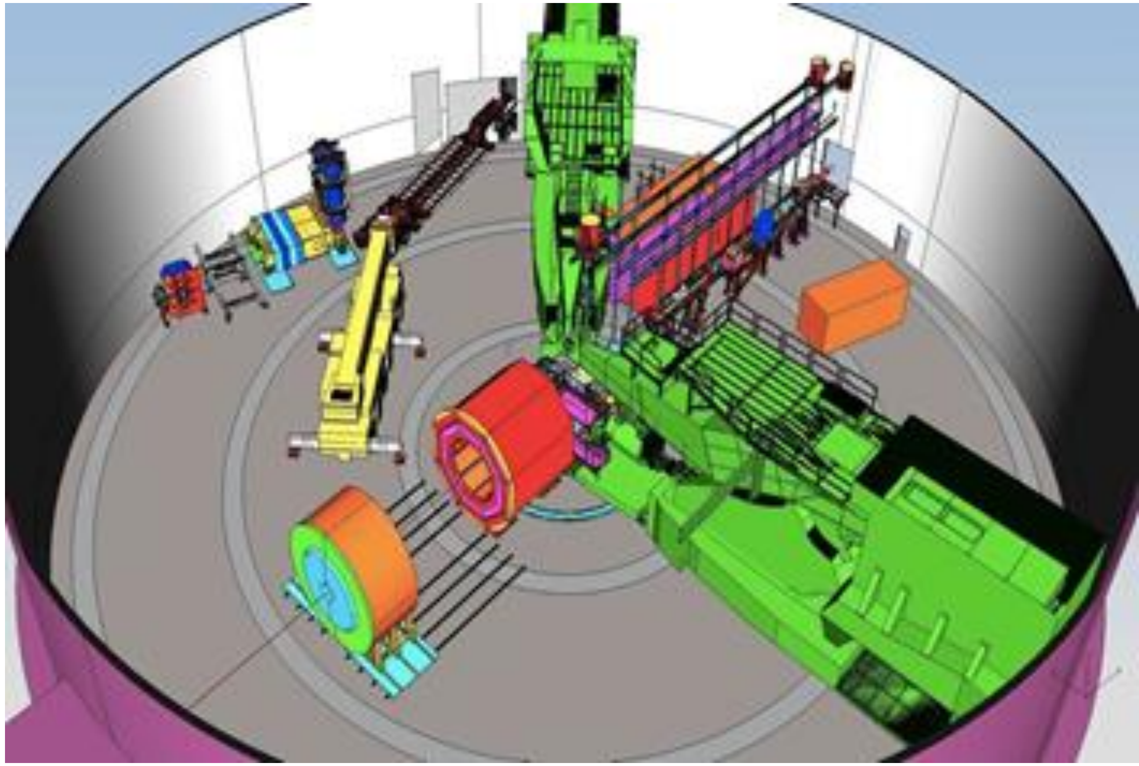




SoLID – The Apparatus

- Proposed apparatus in Hall-A





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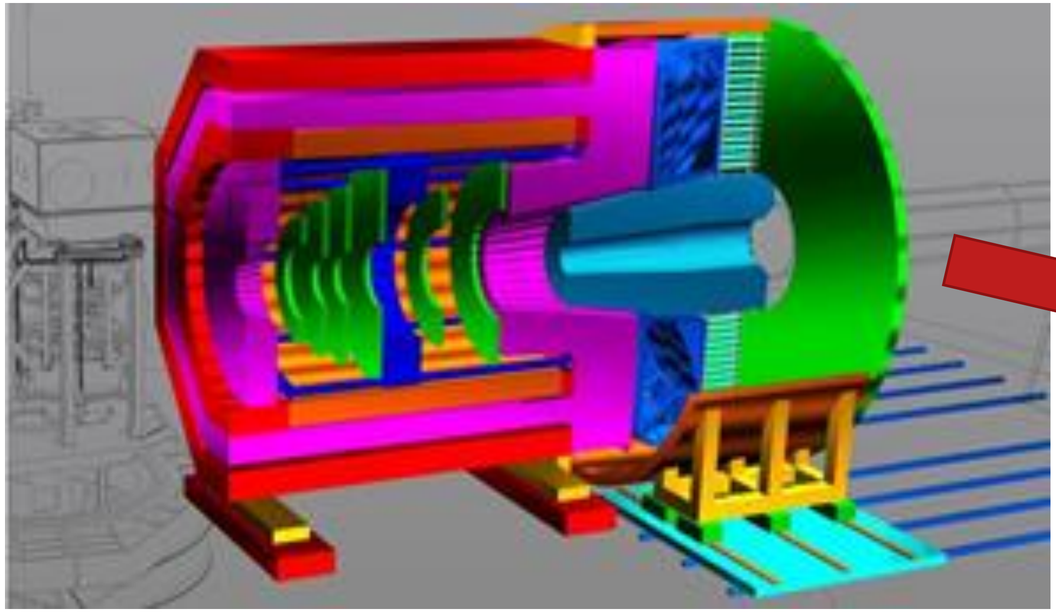

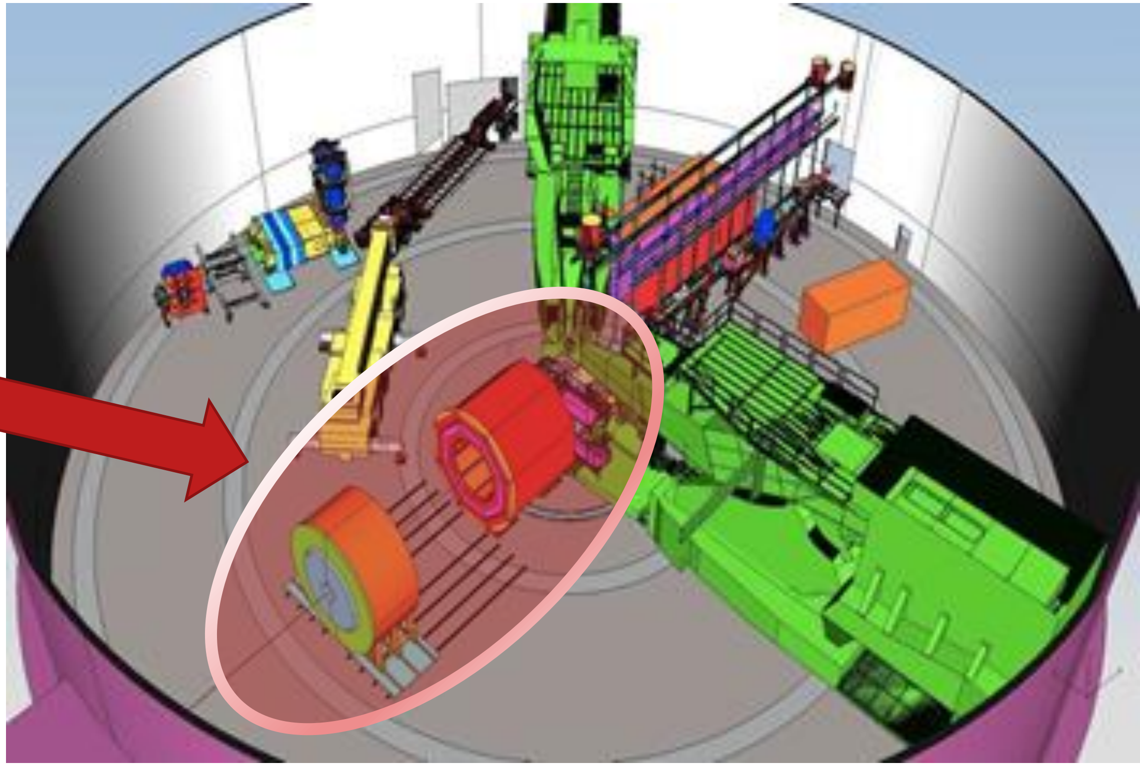

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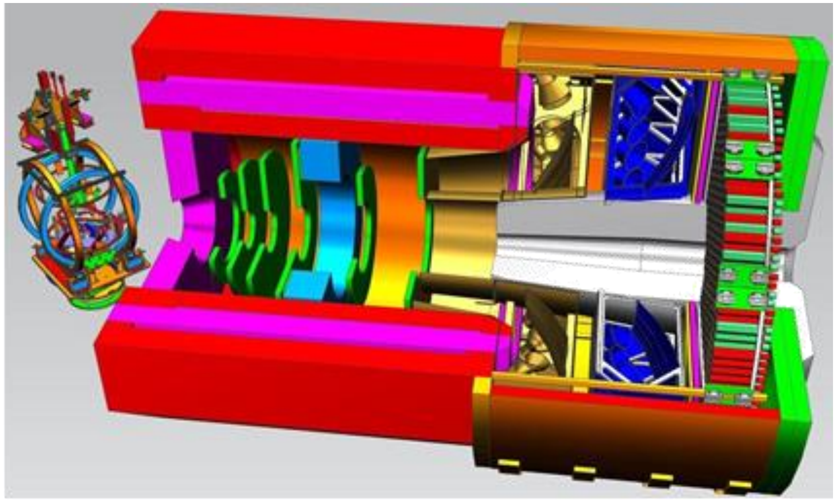
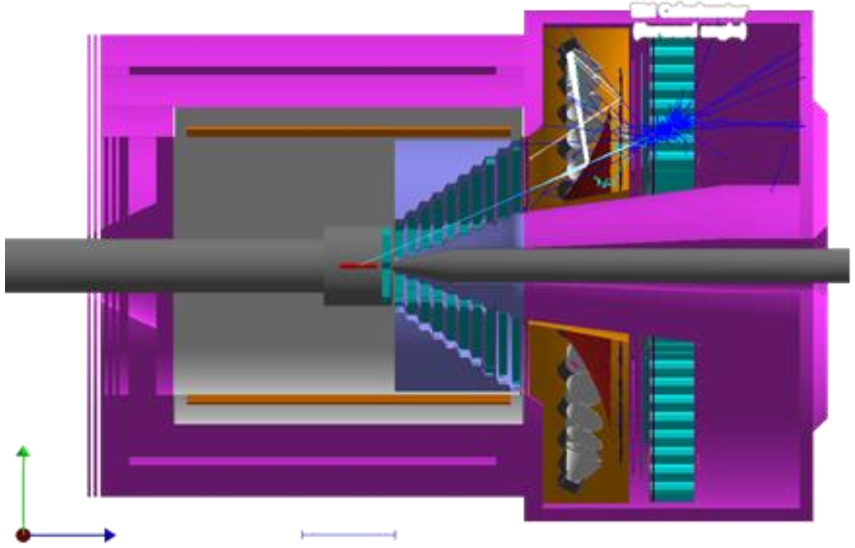
SoLID – The Apparatus

- Two configurations
  - Precision tomography in 3-D momentum space
  - Proton mass, mass radius, gravitational form factors



Polarized ^{3}He, NH_3, J/ψ setup

  - Standard model test, BSM, QCD via parity violating Deep Inelastic Scattering



PVDIS setup

SoLID – The Apparatus

- State of the Art Detectors
  - MPGD – GEM, μRWell/μRGroove tracker
  - Shashlik EMCal
  - HP Cherenkov detectors
  - Pipelined DAQ, streaming readout
  - Rapidly advancing computational facilities
  - First implementation of self-driving detector
  - Design considers large scale deployment of ML/AI
- Solenoid (CLEO magnet)

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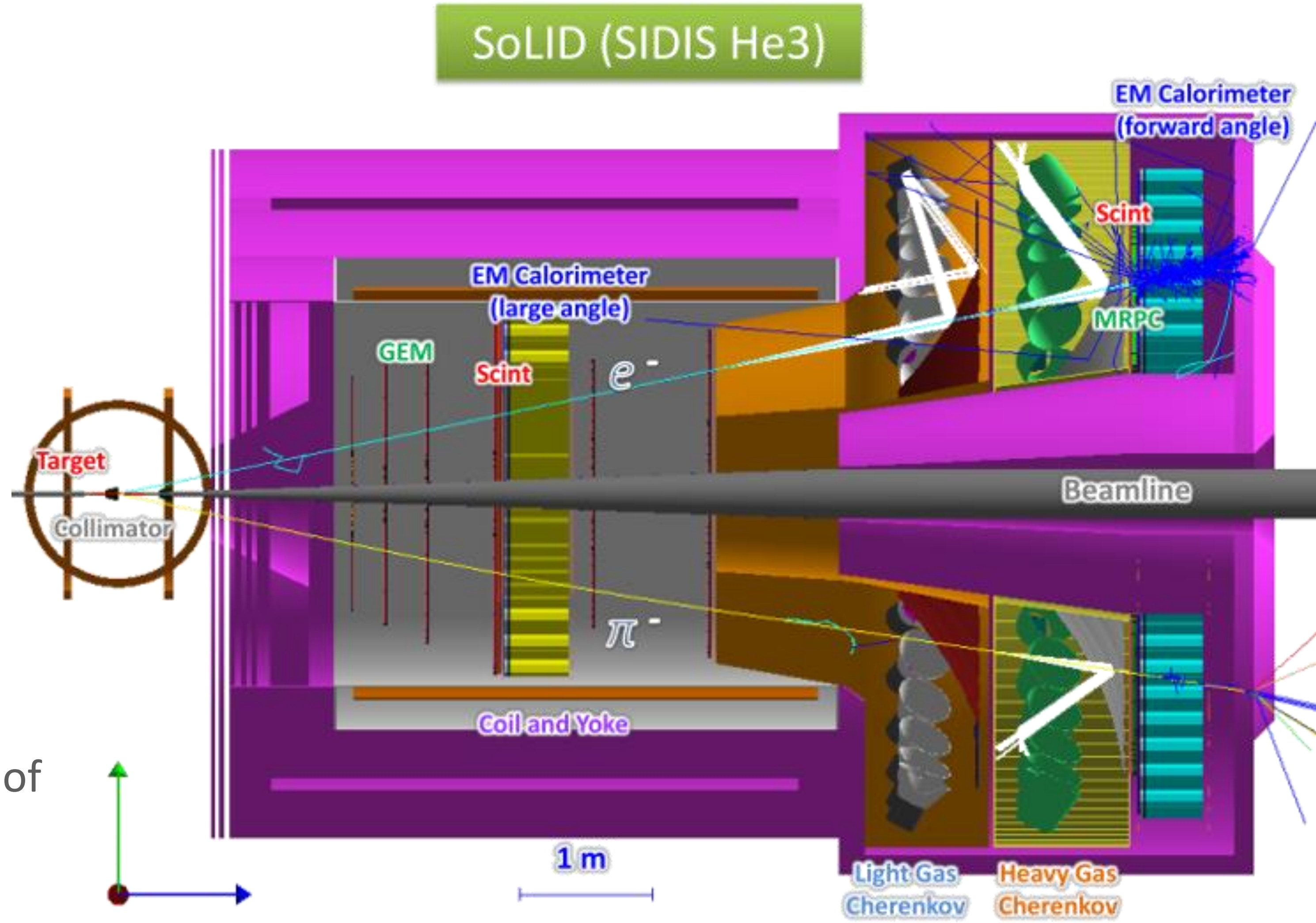

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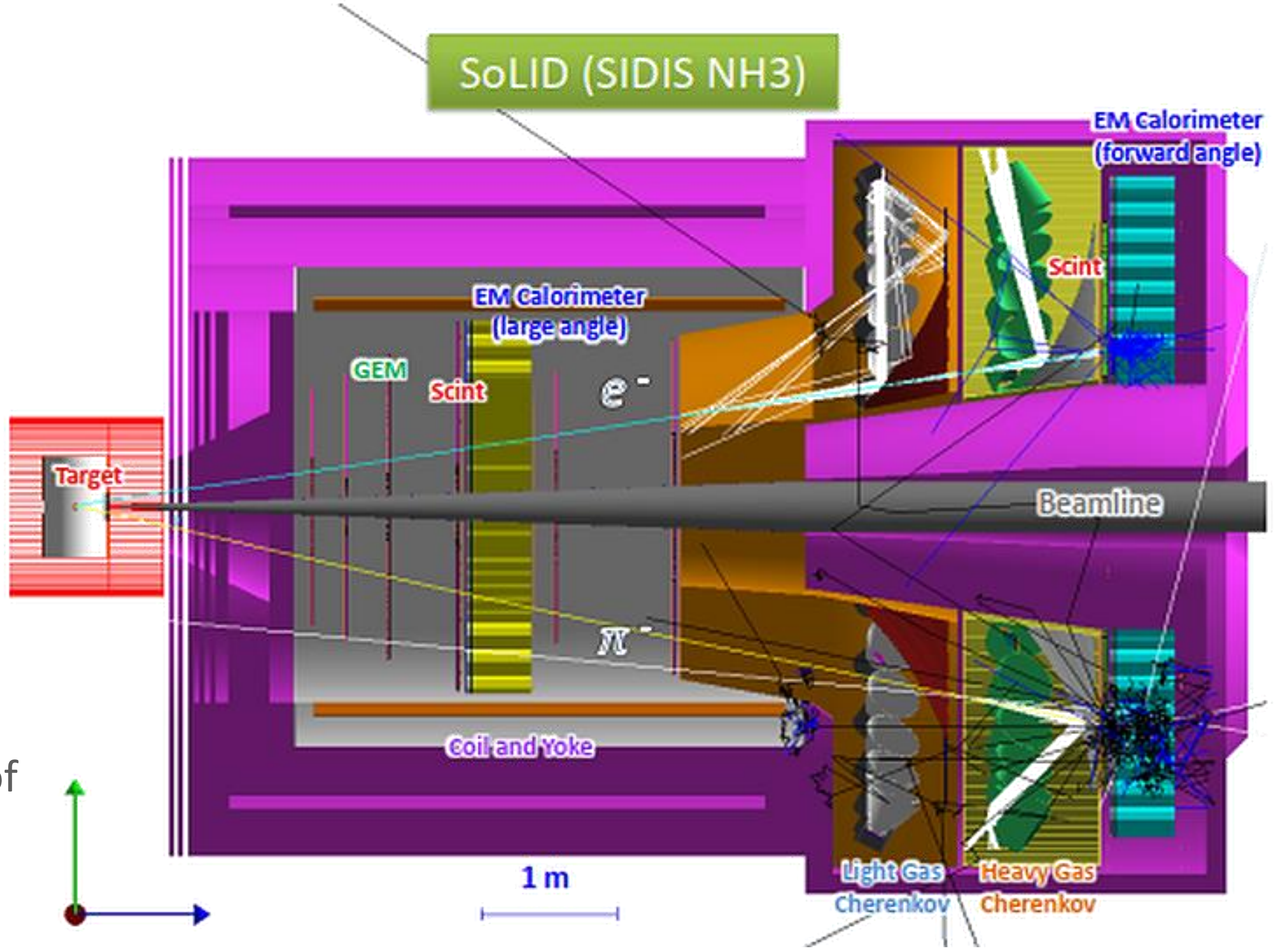

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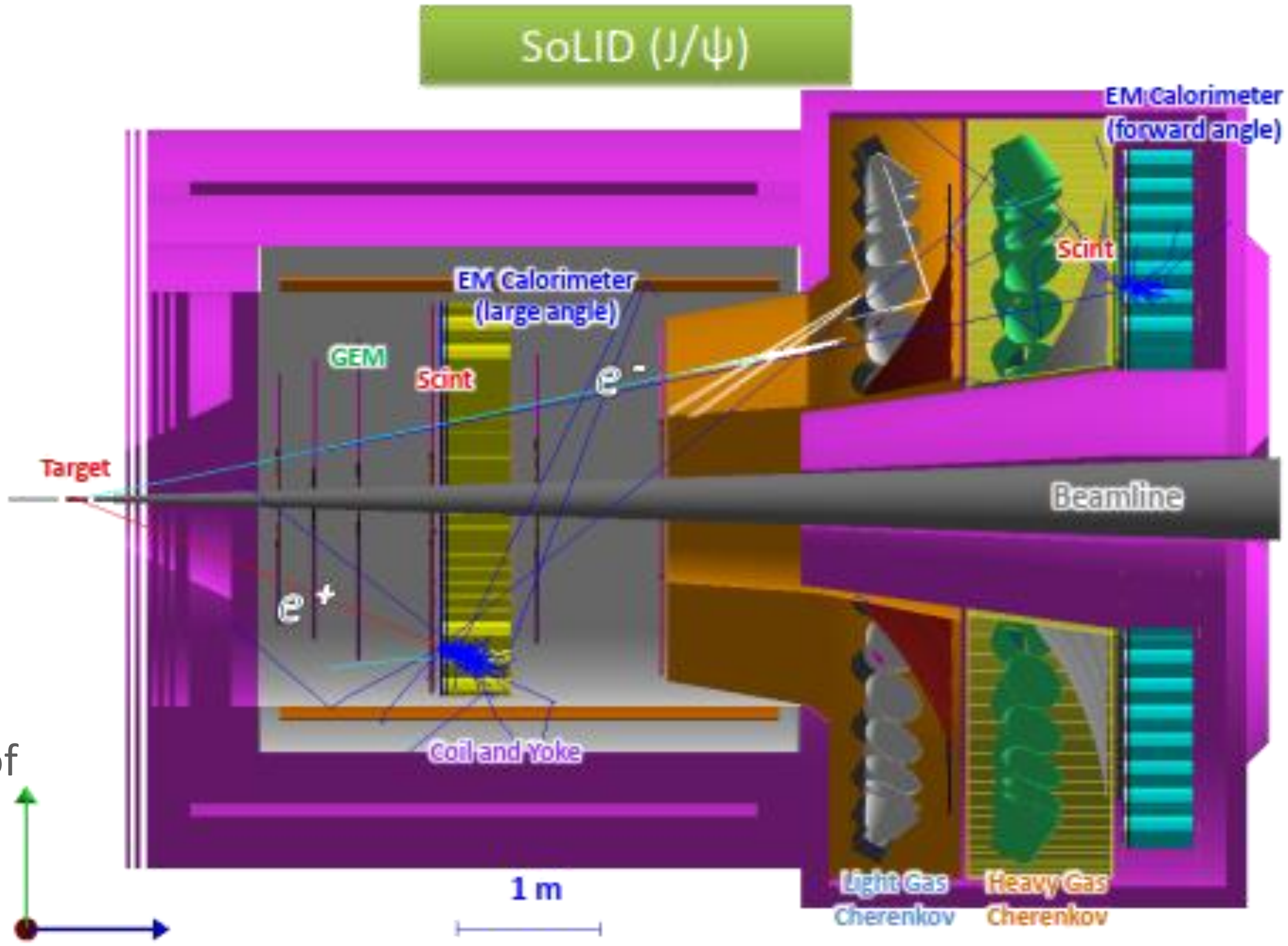

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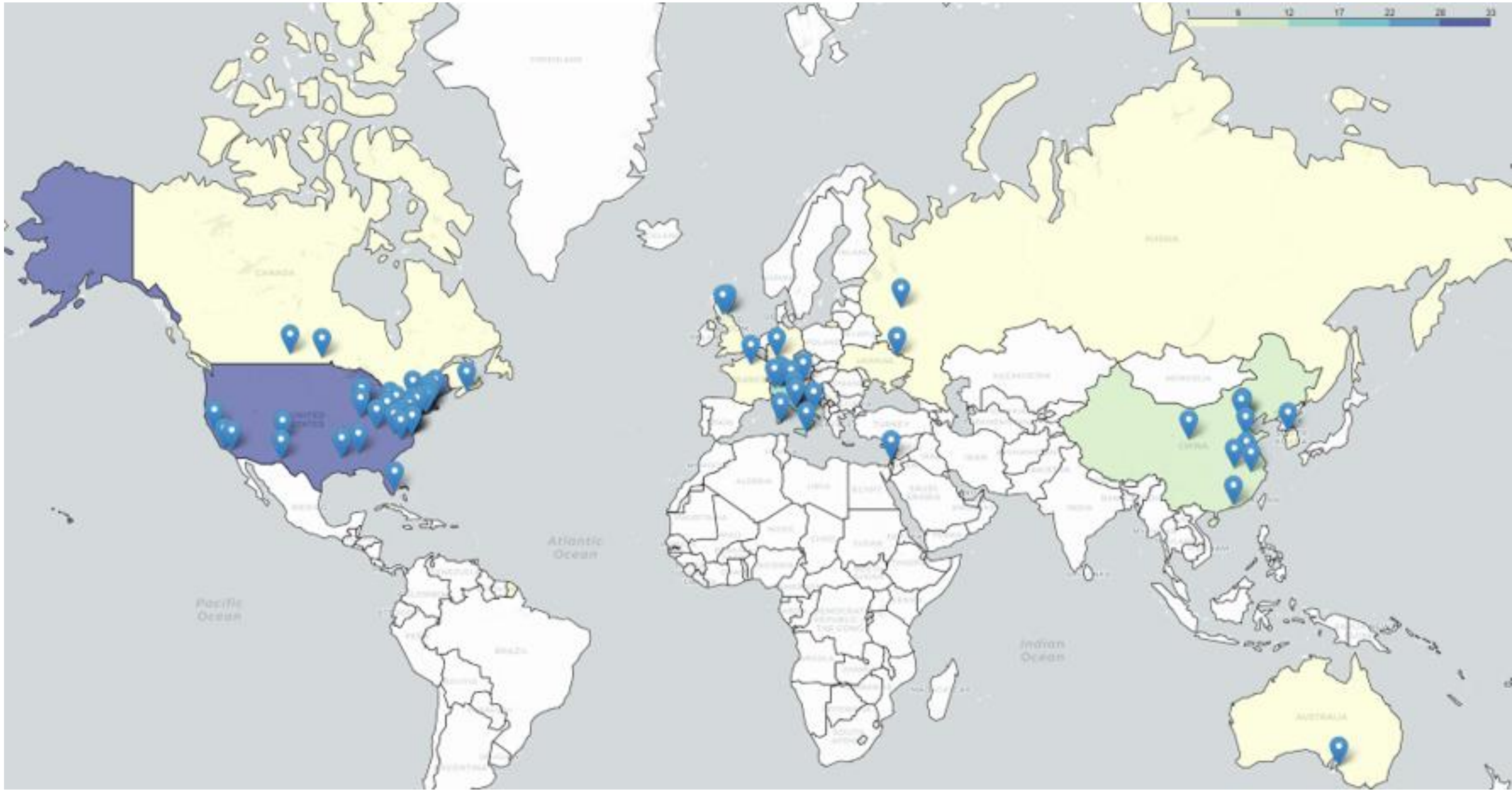
SoLID – The Apparatus

Equipment	dimension/description	description	performance, eff	performance, rej	conditions
Magnet	OD 3m, ID 1m, L> 3m	B> 1.35 T, BDL> 5 T-m	2π, 8 to 24° (22 to 35°)	P: 1-7 GeV, Res 2–3%	Fringe field < 5 G
GEMs	6 planes (5 planes)	Total 37 m^2, Chan 165K	Track Eff > 90%	Posi res 100μm	high rate
SPD	240 modules (forward); 60 modules (large angle)	5mm (FA); 20mm (LA)	150 ps (LA)	5:1 γ (FA); 10:1 γ (LA),	readout in magnet (LA)
EM Calorimeter	1800×100 cm^2	18 RL + 2 RL	E res 10%, eff> 90%	50:1 π	rad hard
Light Cherenkov	2m CO2 (1m CO2)	60 mirr, 270 PMTs	$N_{p.e.} > 10$, Eff> 90%	π 500:1 < 4.5 GeV	130 G field
Heavy Cherenkov	1m 1.7 atm C4F8	30 mirr, 480 PMTs	$N_{p.e.} > 10$, Eff> 90%	K 10:1 2.5-7.5 GeV	100 G field
DAQ	282 FADC @ 250 MHz	32 pipeline VXS, 30 SRS	Trig 100 KHz $\times$ 2.6 KB	Trig 30×20 KHz $\times$ 48 KB	high noise
Baffle	11×30 blocks,9 cm	5 cm, r 110-200 cm	area open $\phi > 4°$ out of 12°	reduce background	

SoLID – The Collaboration

- 270+ collaborators
- 70+ institutions
- 13 countries
- 4 continents



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SoLID – The Development

- Rich and diverse physics program ⇨ started in 2010
  - Total of 6 PAC approved SoLID experiments
  - High Rating
    - 5 A
    - 1 A-
  - 3 SIDIS (3-D structure)
  - 1 PVDIS (BSM)
  - 1 Threshold J/ψ (gluon force)
  - 1 A-n (new phenomena)
  - Plus 1 conditional approval Plus 6 run-group experiments (3-D and spin structure)

SoLID – The Development

Experiments	PVDIS	SIDIS-^{3}He	SIDIS-Proton	J/ψ
Reaction channel	$p(\vec{e},e')X$	$(e,e'\pi^{\pm})$	$(e,e'\pi^{\pm})$	$e+p\to e'+J/\Psi(e^-,e^+)+p$
Approved number of days	169	125	120	60
Target	LH_2/LD_2	^{3}He	NH_3	LH_2
Unpolarized luminosity ($cm^{-2}s^{-1}$)	$0.5\times10^{39}/1.3\times10^{39}$	$\sim 10^{37}$	$\sim 10^{36}$	$\sim 10^{37}$
Momentum coverage (GeV/c)	2.3-5.0	1.0-7.0	1.0-7.0	0.6-7.0
Momentum resolution	~2%	~2%	~3%	~2%
Polar angular coverage (degrees)	22-35	8-24	8-24	8-24
Polar angular resolution	1 mr	2 mr	3 mr	2 mr
Azimuthal angular resolution	-	6 mr	6 mr	6 mr
PID (e^-)	detection eff. $\geq 90\%$ pion contam. < 0.001	detection eff. $\geq 90\%$ pion contam. $< 1\%$	detection eff. $\geq 90\%$ pion contam. $< 1\%$	detection eff. $\geq 90\%$ pion contam. $< 1\%$
PID ($\pi^{\pm}$)		detection eff. $\geq 90\%$ kaon contam. $< 1\%$	detection eff. $\geq 90\%$ kaon contam. $< 1\%$	
Trigger type	Single e^-	Coincidence $e^- + \pi^{\pm}$	Coincidence $e^- + \pi^{\pm}$	Triple coincidence $e^-e^-e^+$
Expected DAQ rates	<20 kHz $\times$ 30	<100 kHz	<100 kHz	<30 kHz
Backgrounds	Negative pions, photons	(e,$\pi^-\pi^{\pm}$) (e,e'$K^{\pm}$)	(e,$\pi^-\pi^{\pm}$) (e,e'$K^{\pm}$)	BH process Random coincidence
Major requirements	Radiation hardness 0.4% Polarimetry π^- contamination Q^2 calibration	Radiation hardness Detector resolution Kaon contamination DAQ	Shielding of *sheet-of-flame* Target spin flip Kaon contamination	Radiation hardness Detector resolution

SoLID – The Development

- Pre-conceptual design, Pre-R&D, reviews, and current status

  2014: pCDR submitted to JLab with cost estimation, updated in 2017, 2019

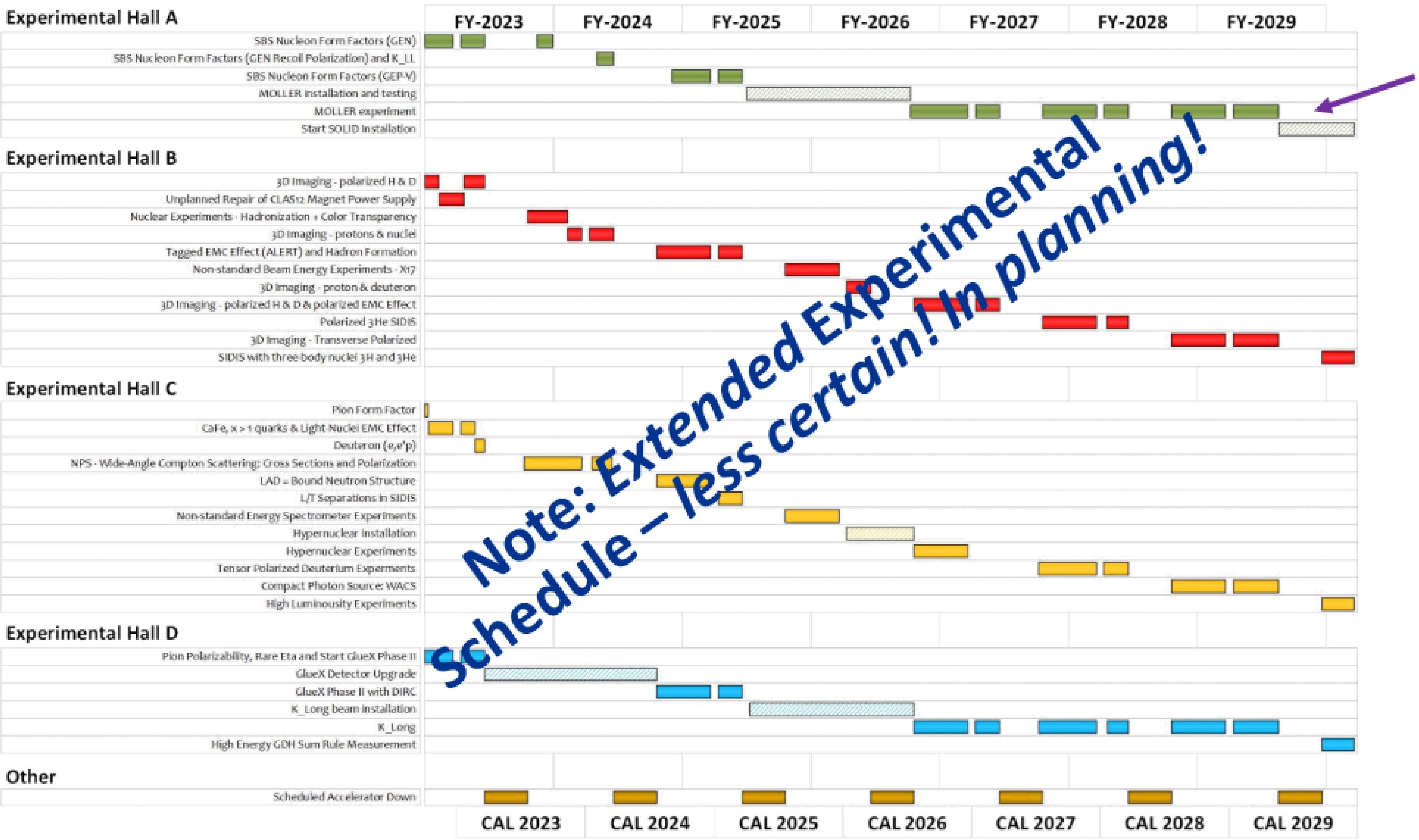
  Director's Reviews in 2015, 2019 and 2021
  2020: SoLID MIE (with updated pCDR/estimated cost) submitted to DOE 2020-now: DOE funded pre-R&D activities

  2021: DOE **Science Review for SoLID, positive feedback**

  2023: Long Range Plan, SoLID highlighted, one of the recommendations

  2024: Facility Review: Ready to Launch

SoLID – The Development



- SoLID installation could start ~mid-FY29
- 86% complete in FY29 without SoLID, 70% complete with SoLID (assuming optimal running operation)

…not including new proposals

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Long Range Plan 2023

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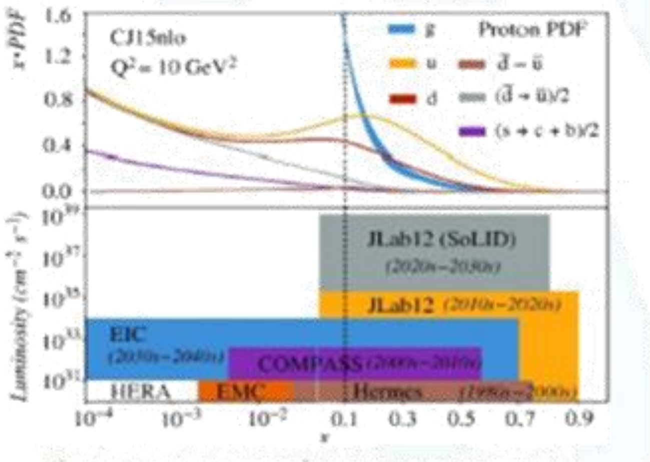
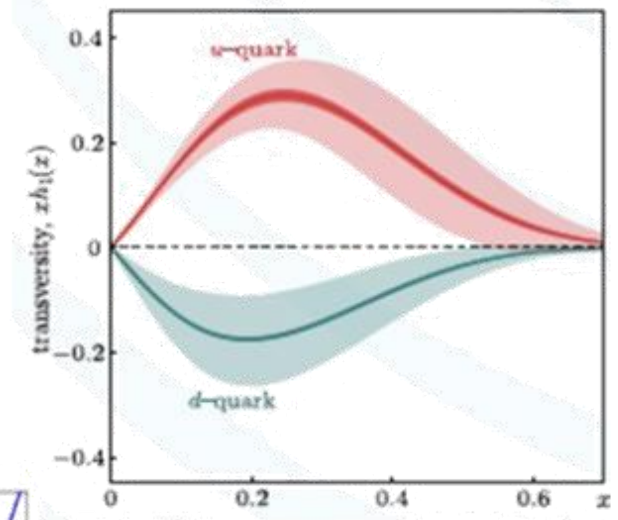
Long Range Plan 2023

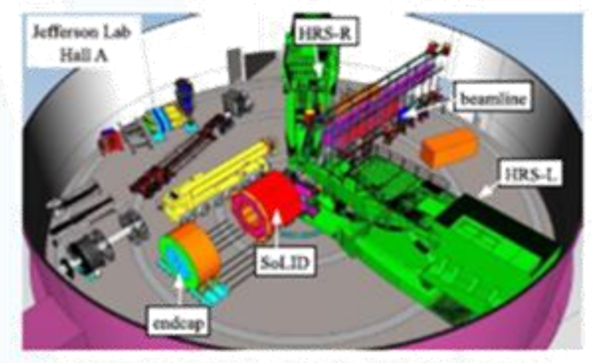
SoLID in Recommendation #4:

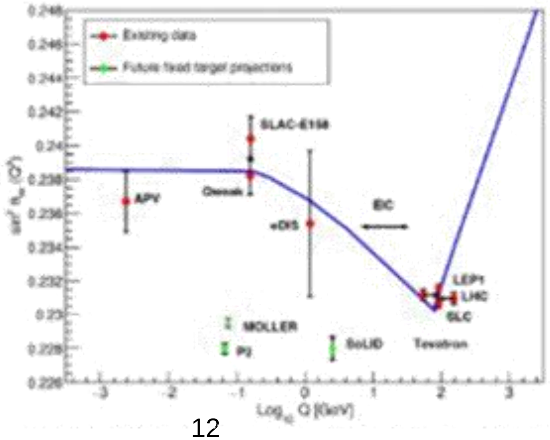
“*We recommend capitalizing on the unique ways in which nuclear physics can advance discovery science and applications for society by investing in additional projects and new strategic opportunities*”… which include “*the Solenoidal Large Intensity Device (SoLID) at Jefferson Lab*”.

SoLID prominently featured in the report:





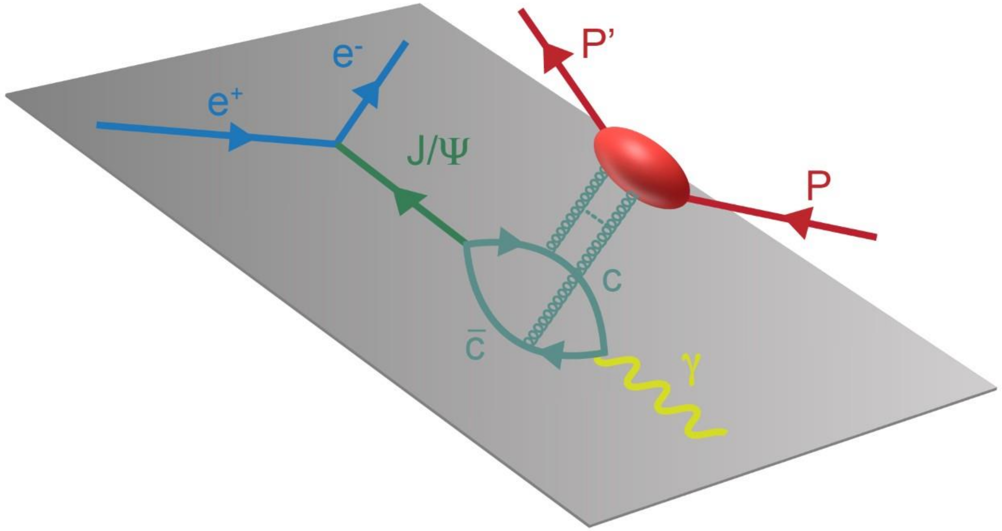


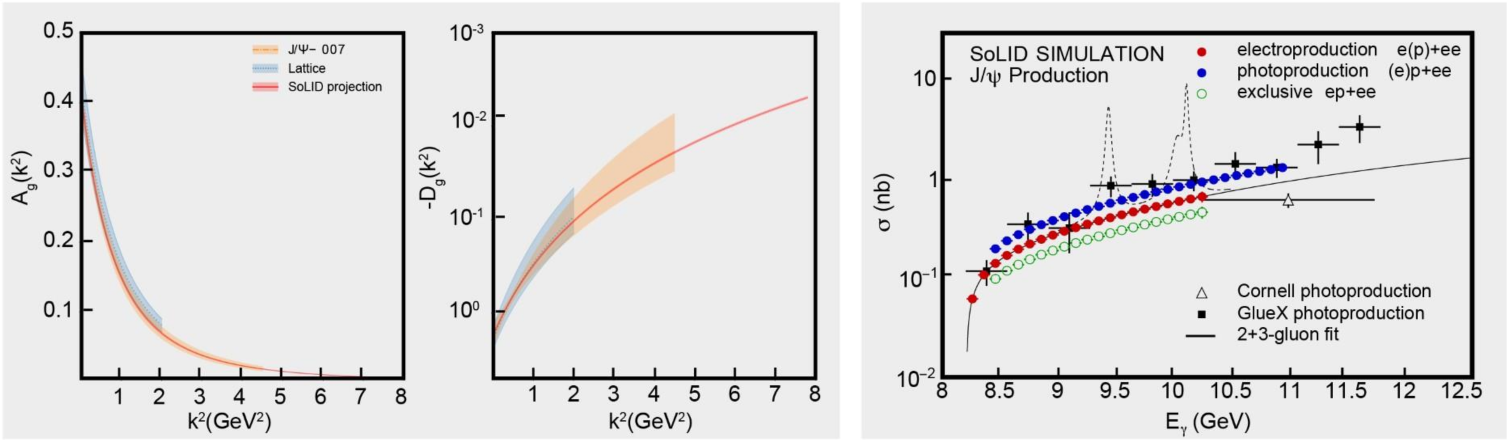


Proton Mass, Gravitational Form Factors, and Mass and Scalar Radii

INNOVATION NEWS NETWORK

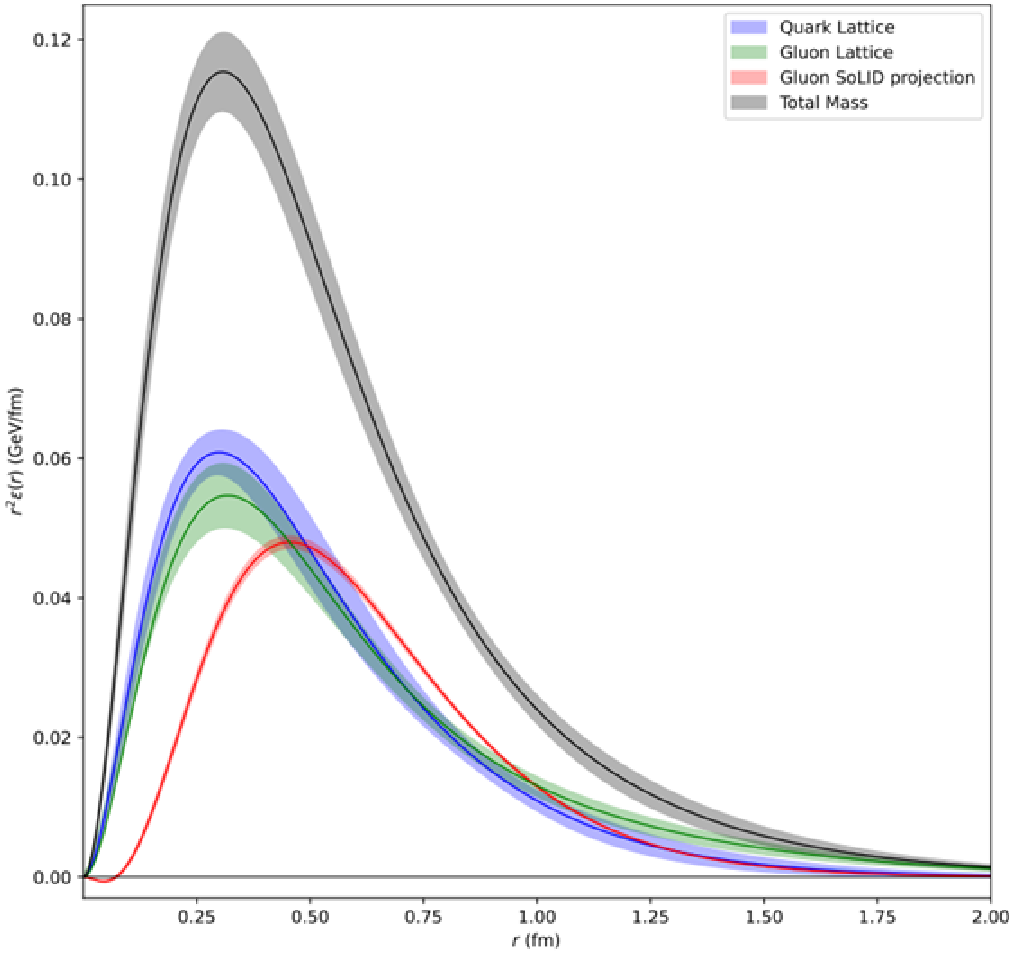
H. Gao and Z.-E. Meziani





The simulated total electro- (red) and photo- (blue) production of J/ψ on a proton (far right panel).
Each data point represents the integral of the measured differential cross section as a function of the Mandelstam variable 't',
from which the A and D gluonic gravitational form factors would be extracted with the precision shown by the red band.
Also plotted is our present knowledge of these form factors from experiment J/ψ-007 (orange), together with the lattice QCD calculations (blue).

Proton Mass, Gravitational Form Factors, and Mass and Scalar Radii



Mass density profile of the proton in the Breit frame.
The plot includes the latest lattice calculation of dipole-tripole A & D GFF form factors and a projection using a Holographic QCD extracted form factors parameters with the uncertainty impact.

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Realization of SoLID – Ongoing Activities at JLab Now

- Proposed ~$30M “redirect” to support SoLID project (JLab Operations to take on more dependencies – magnet, some infrastructure,…)
  - Planning to put forward at March/April LMBB
  - Requires some strategy (MOLLER project issues now cause concern)
- Two Capital Equipment projects already in place
  - Magnet refurbishment and testing
  - Data acquisition
- Working with DOE research to identify preR&D opportunities
  - Supporting electronics testing and trigger development
- Physics AD meets with DOE research (Gulshan Rai) monthly
  - Pre-R&D plan white paper to be submitted by the end of Jan. ’25
  - Encouraged to consider another white paper for MPGD ASIC development
- Staff continuing to assist in development

Pre-R&D Activities – Past Activities

- Recent past activities were summarized in reports

SoLID pre-R&D
Quarterly Progress Report

August 2021 to January 2022
SoLID Collaboration

April 12, 2022

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Pre-R&D Activities – Past Activities

- Recent past activities were summarized in reports

SoLID Detector Performance from the 2022-2023 Beam Test

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N. Liyanage,[1] Z.-E. Meziani,[6] B. Moffit,[2] M. Nycz,[1] S. Opatrny,[1] C. Peng,[6] M. Paolone,[7] B. Raydo,[2]
P. A. Souder,[3] Y. Tian,[3] Z. Ye,[8] D.W. Upton,[1] J. Zhang,[1] Z.-W. Zhao,[4] and X. Zheng[1]

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[3]*Syracuse University, Syracuse, NY, USA*
[4]*Duke University and Triangle Universities Nuclear Laboratory, Durham, NC, USA*
[5]*Longwood University, Farmville, VA, USA*
[6]*Argonne National Laboratory, Argonne, IL, USA*
[7]*New Mexico State University, Las Cruces, NM, USA*
[8]*Tsinghua University, Beijing, China*

(Dated: January 10, 2025)

abstract

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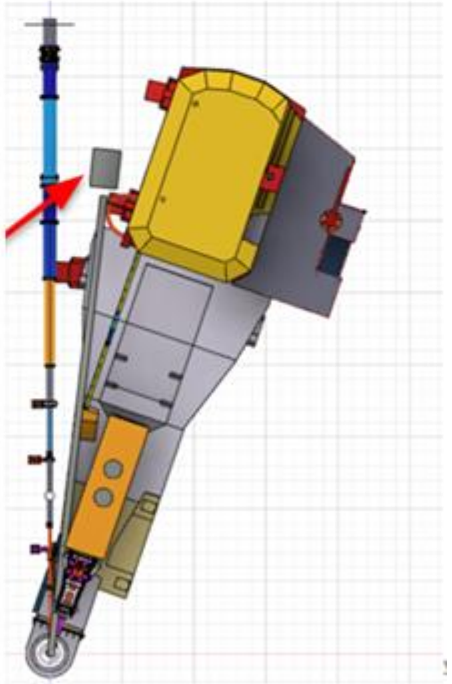
Pre-R&D Activities – Past Activities

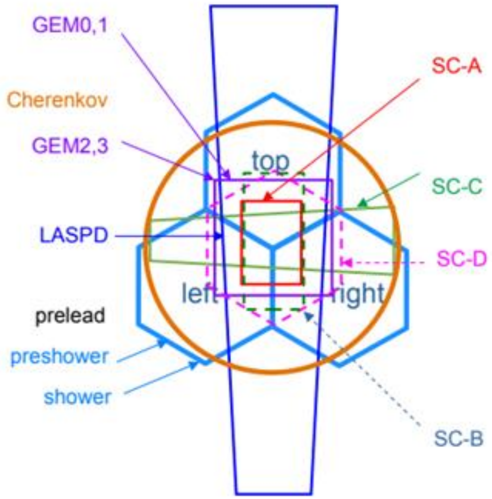
FY22 Hall C Beam Test Overview

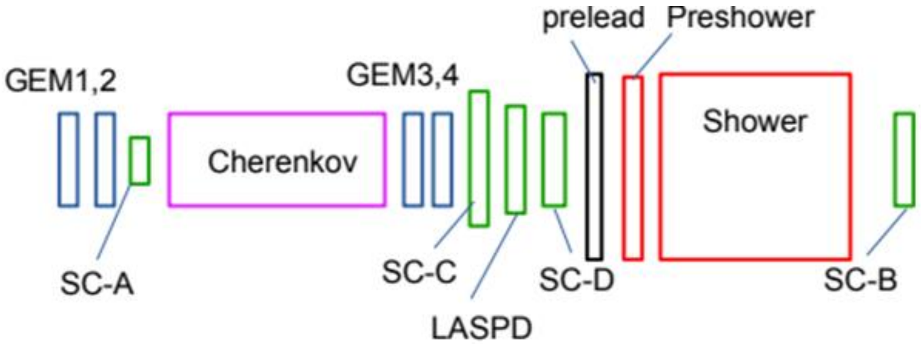
1. Goal was to study ECal and SPD performance under high rate, high radiation
2. Installed in Hall C in summer – fall 2022
3. Three stages:
   - 80 deg beam-left in Fall 2022, low rate "commissioning"
   - 7 deg beam-right in Jan 2023, high rate part 1
   - 18 deg beam-right in Feb-March 2023, high rate part 2
   - de-install in March 2023
4. Analysis was focused on:
   - Comparison of data with simulation
   - detector performance and stability from low to high rate
   - ECal and SPD PID performance
5. Report now ready for review by collaboration, is part of it publishable?

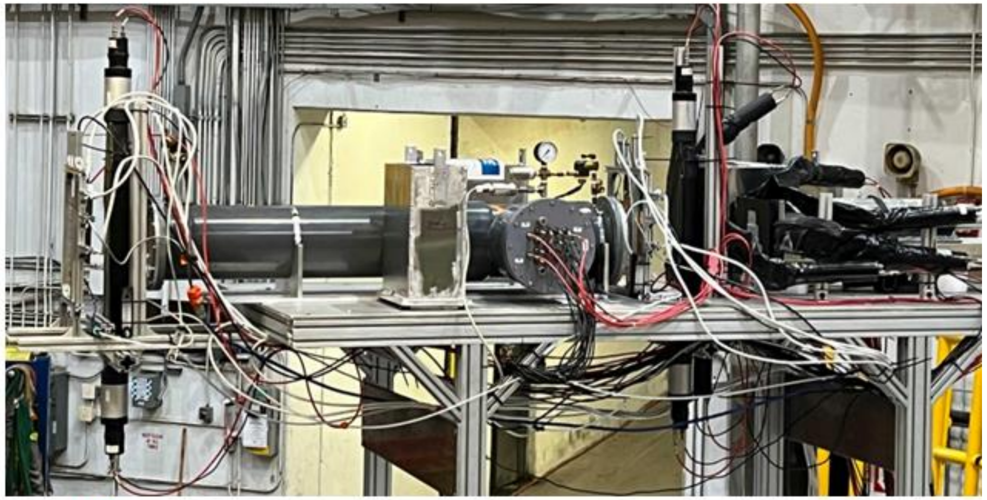


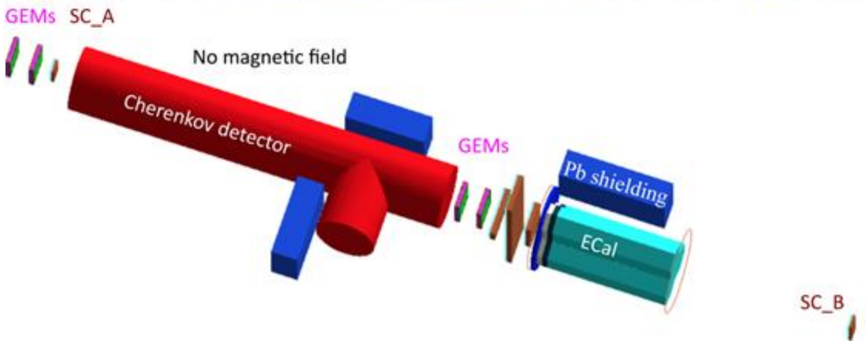
Pre-R&D Activities – Past Activities

Setup Overview









Pre-R&D Activities – MPGD Readout

- GEM readout → more general MPGD readout

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Pre-R&D Activities – MPGD Readout

- GEM readout → more general MPGD readout

  - Highest priority : GEM chip
    - Evaluate SALSA chip in high background environment
    - Continue testing VMM board signal to noise
    - Develop dedicated ASIC chip for GEM
    - Test with uRWell

Pre-R&D Activities – MPGD Readout

- GEM readout → more general MPGD readout

Salsa

- Collaboration of Irfu CEA Saclay and U. of Sao Paulo.
- SALSA

- 64-Ch, updated design from SAMPA V5, migrating to 65 nm CMOS.
- Peaking time: 50 – 500 ns
- Inputs: Cin optimized for 200 pF; Rates: 25 kHz/Ch; Dual polarity.
- ADC: 12 bits, 10 – 50 MSPS.
- Extensive data processing capabilities.
- Triggerless and triggered operation.
- Power: 15 mW/Ch
- Gbps links.
- I2C configuration.

- Evaluation board available this year - Might want a dedicated SoLID version to match tracker low gain operation and handle high rates at input
- Can bypass analog part but need to develop analog front end
- Data links somewhat limited

- Might want a dedicated version of SALSA

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Pre-R&D Activities – MPGD Readout

- GEM readout → more general MPGD readout

VMM test

- Ordered two test board
- Build 6 SoLID prototype boards
- Evaluation board : can look at data with detector small subset of channels
  - Issue with external trigger but waiting for new firmware
  - Can check pedestal width
  - Signal to noise with detector with source and cosmics
  - Look at direct readout signals for 12 channels of detector
- Prototype development for data performance, test direct output with detector and X-ray source

Pre-R&D Activities – MPGD Readout

- GEM readout → more general MPGD readout

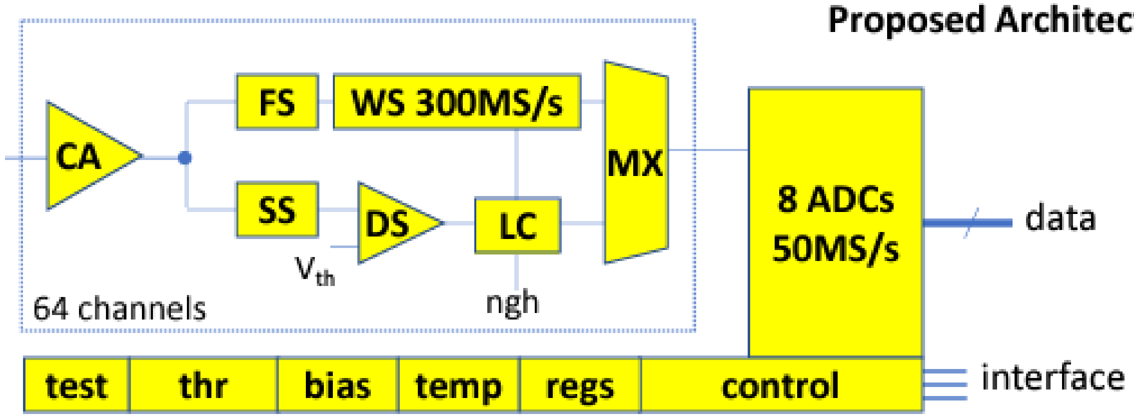
New potential dedicated ASIC

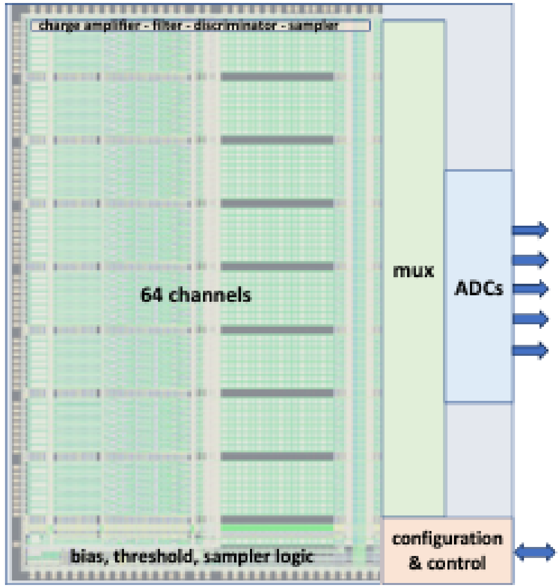
- High luminosity running
- Pile-up and deadtime can be significant

- Dedicated chip
  - Optmized gain and dynamic range
  - Optimize shaping time for high rate operation : from 50 ns to 25 ns or better
  - Zero dead time
  - High speed links to allow streaming

Pre-R&D Activities – MPGD Readout

Proposed Architecture





CA: charge amplifier
- optimized for 50-200pF
- programmable gain 25fC to 250fC

FS: fast shaper
- programmable 5-20ns

SS: slow shaper
- for discrimination (zero suppression)
- programmable 20-100ns

DS: discriminator
- trimmable per channel
- external trigger option

WS: waveform sampler
- 128 sampling cells (127 effective)
- continuous sampling until trigger
- 300MS/s → ~ 400ns waveform
- programmable pre-post trigger samples

LC: local control logic
- internal or external trigger
- neighbor (sub-threshold) logic

ADCs
- 8 operating at 10-bit 100MS/s
- waveform conversion time ~ 2.5µs

Data
- channel, trigger, 127 samples = 1,280 bits per waveform
- up to 8 waveforms with sub-threshold neighbors = 10,240 bits
- up to 8 SLVS outputs operating in DDR at ~ 500MS/s
- conversion/readout time (dead time) ~ 2.5µs per event
- maximum event rate ~ 330kHz
- maximum data rate ~ 4Gb/s

Architecture
- event-driven analog/digital with acquisition/readout
- SEU tolerant register and logic
- DSP-ready

Power, Size, Technology, Schedule
- power consumption below 3mW/channel
- anticipated die size ~ 6x8 mm²
- technology TSMC 65nm 1.2V
- development time ~ 24 months (1st proto in 12 months)

Design
- charge amplifier, shapers and samplers based on verified architectures
- ADCs from collaborative effort
- first prototype design time
  - ~ 12-13 months plus ADCs
  - ADC can be parallel effort
- second prototype design time
  - ~ 4-5 months

Key Features
- power-efficient analog zero-suppression
- efficient data generation and transfer
- highly flexible, highly programmable

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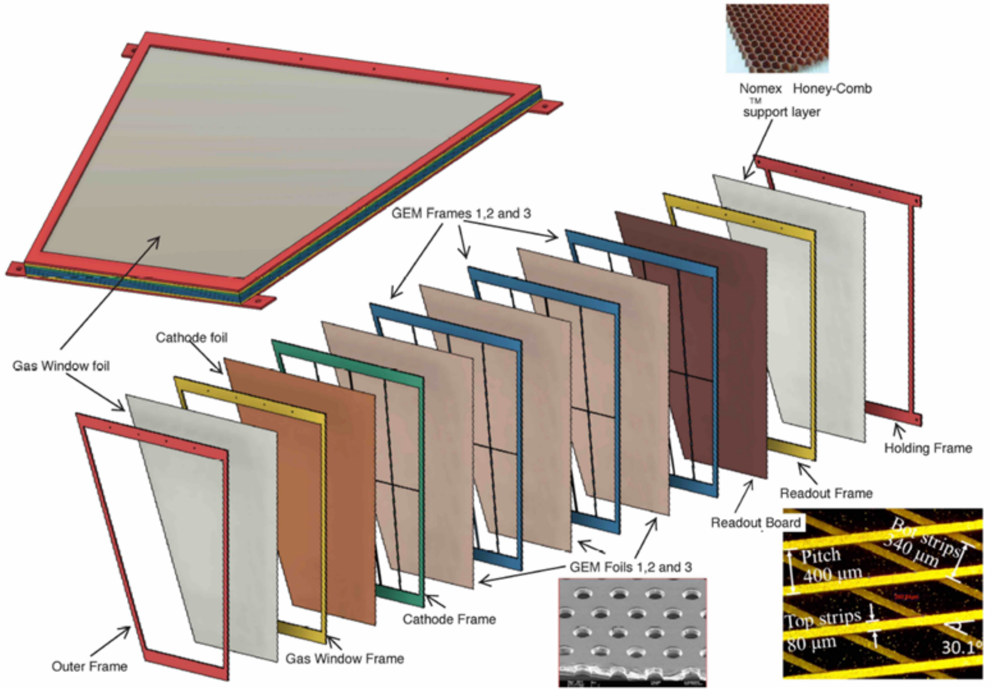
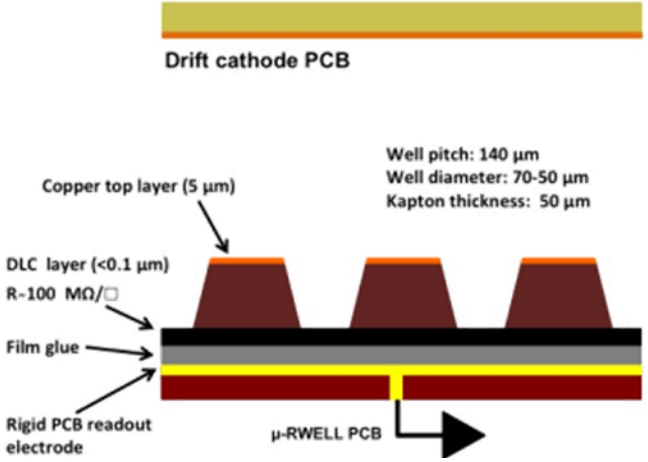
Pre-R&D Activities – Tracking Options

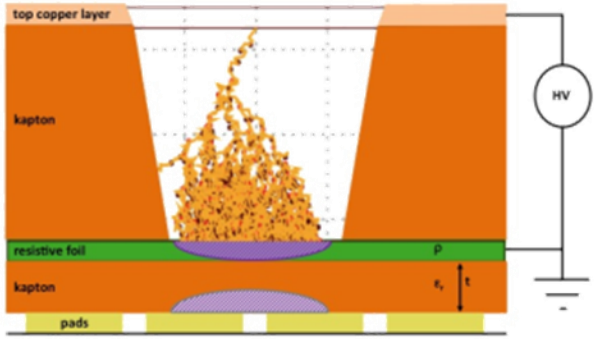
- Tracking options

Pre-R&D Activities – Tracking Options

- Default configuration: Triple-GEM
- Alternative configuration: μRWell and derivatives







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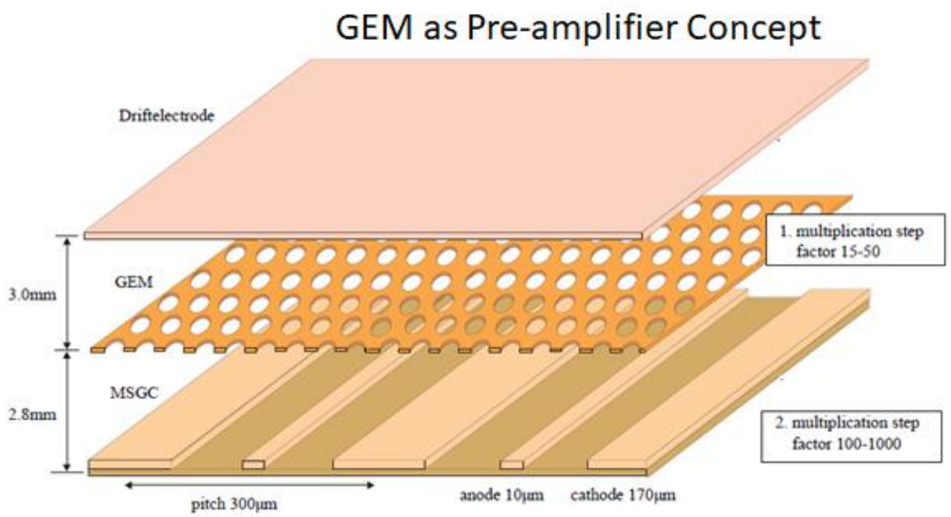
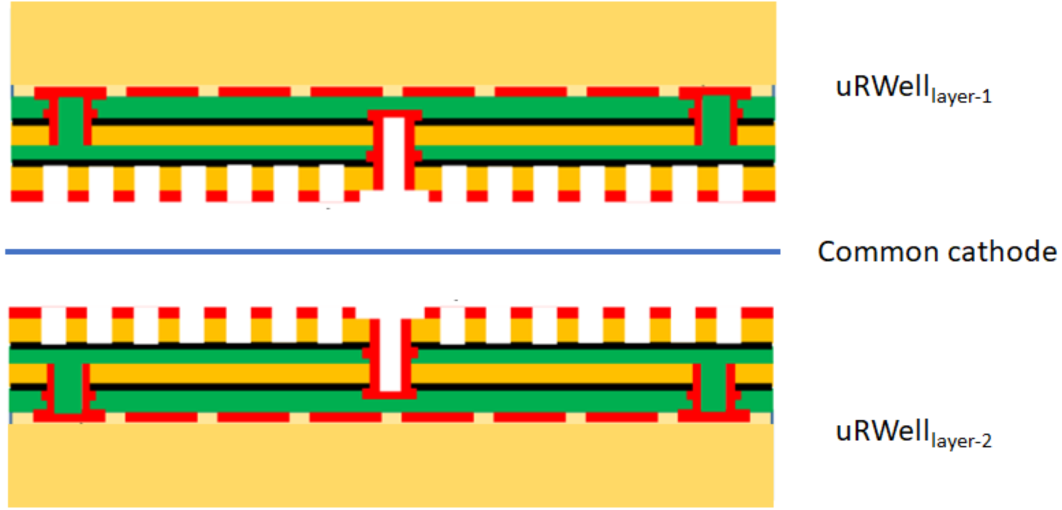
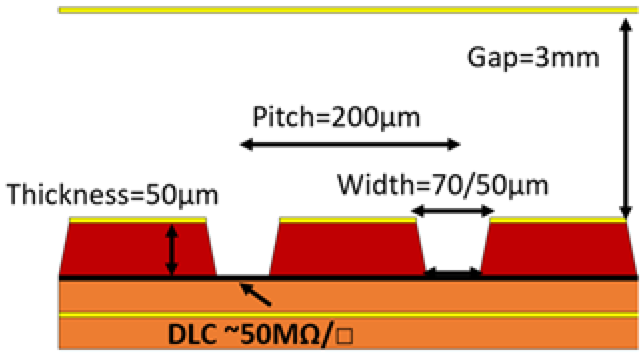
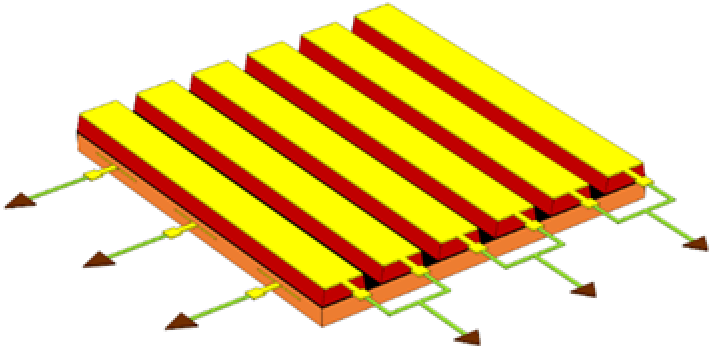
- Alternative configuration: μRWell and **derivatives**







μRGroove



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Pre-R&D Activities – MCP-PMT

- MCP-PMT

  - ❑ Argonne early MCP-PMT development for EIC-PID
  - ❑ LAPPD/HRPPD magnetic field test results
  - ❑ LAPPD validation in high-rate environment at JLab Hall C
  - ❑ Recent status of new 10x10 cm MCP-PMT fabrication facility
  - ❑ Planned Hamamatsu MCP-PMT test for SoLID SPD

Future test:

- ❑ Prototype test of Argonne 10x10 cm MCP-PMT
- ❑ Full test of Hamamatsu MCP-PMT for SoLID SPD

Pre-R&D Activities

- GEM readout → more general MPGD readout
- Tracking options
- MCP-PMT

SoLID_preRD_Fall2024 → Proposed Milestones and Budget

Pre-R&D Activities And Test Beam Plans – Hall C

- Perform a sector test with SoLID sub-detectors

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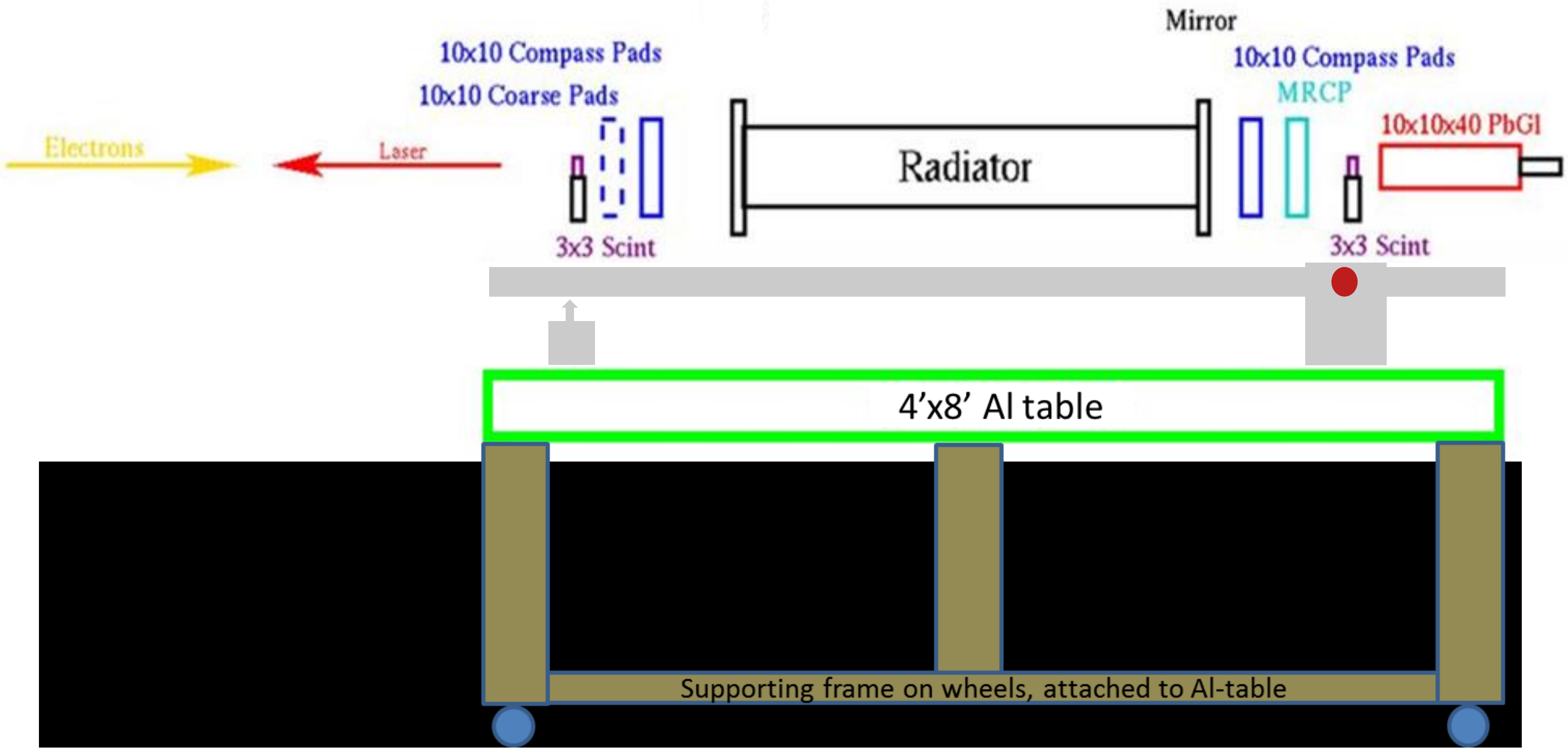
Pre-R&D Activities And Test Beam Plans – Hall C

Experiments	PVDIS	SIDIS-^{3}He	SIDIS-Proton	J/ψ
Reaction channel	$p(\vec{e}, e')X$	$(e, e'\pi^{\pm})$	$(e, e'\pi^{\pm})$	$e + p \to e' + J/\Psi(e^-, e^+) + p$
Approved number of days	169	125	120	60
Target	LH_2/LD_2	^{3}He	NH_3	LH_2
Unpolarized luminosity ($cm^{-2}s^{-1}$)	$0.5\times10^{39}/1.3\times10^{39}$	$\sim 10^{37}$	$\sim 10^{36}$	$\sim 10^{37}$
Momentum coverage (GeV/c)	2.3-5.0	1.0-7.0	1.0-7.0	0.6-7.0
Momentum resolution	~2%	~2%	~3%	~2%
Polar angular coverage (degrees)	22-35	8-24	8-24	8-24
Polar angular resolution	1 mr	2 mr	3 mr	2 mr
Azimuthal angular resolution	-	6 mr	6 mr	6 mr
PID (e^-)	detection eff. $\geq$ 90% pion contam. < 0.001	detection eff. $\geq$ 90% pion contam. < 1%	detection eff. $\geq$ 90% pion contam. < 1%	detection eff. $\geq$ 90% pion contam. < 1%
PID ($\pi^{\pm}$)		detection eff. $\geq$ 90% kaon contam. < 1%	detection eff. $\geq$ 90% kaon contam. < 1%	
Trigger type	Single e^-	Coincidence $e^- + \pi^{\pm}$	Coincidence $e^- + \pi^{\pm}$	Triple coincidence $e^- e^- e^+$
Expected DAQ rates	<20 kHz × 30	<100 kHz	<100 kHz	<30 kHz
Backgrounds	Negative pions, photons	(e,$\pi^-\pi^{\pm}$) (e,e'$K^{\pm}$)	(e,$\pi^-\pi^{\pm}$) (e,e'$K^{\pm}$)	BH process Random coincidence
Major requirements	Radiation hardness 0.4% Polarimetry π^- contamination Q^2 calibration	Radiation hardness Detector resolution Kaon contamination DAQ	Shielding of *sheet-of-flame* Target spin flip Kaon contamination	Radiation hardness Detector resolution

Pre-R&D Activities And Test Beam Plans – Hall C



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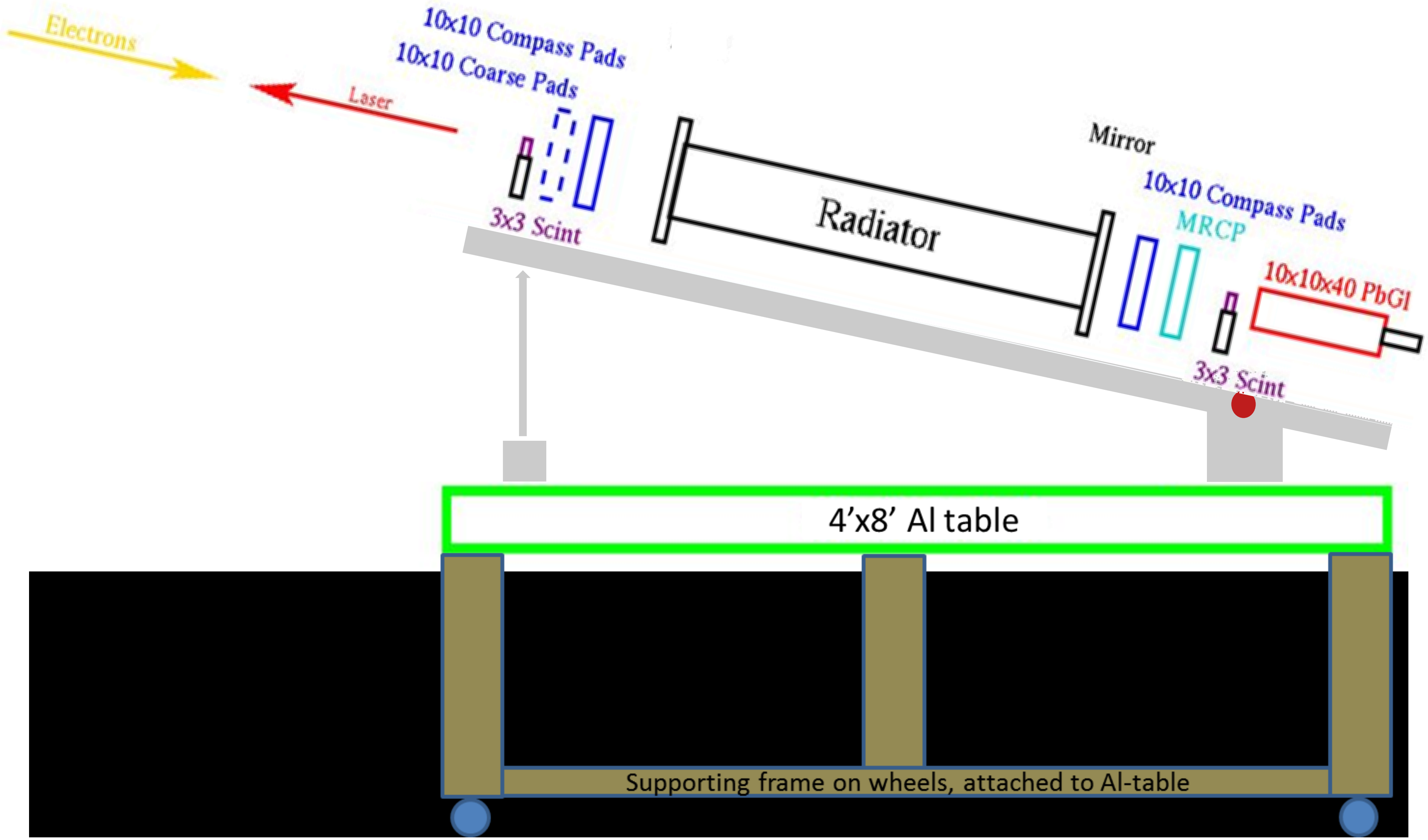
Pre-R&D Activities And Test Beam Plans – Hall C



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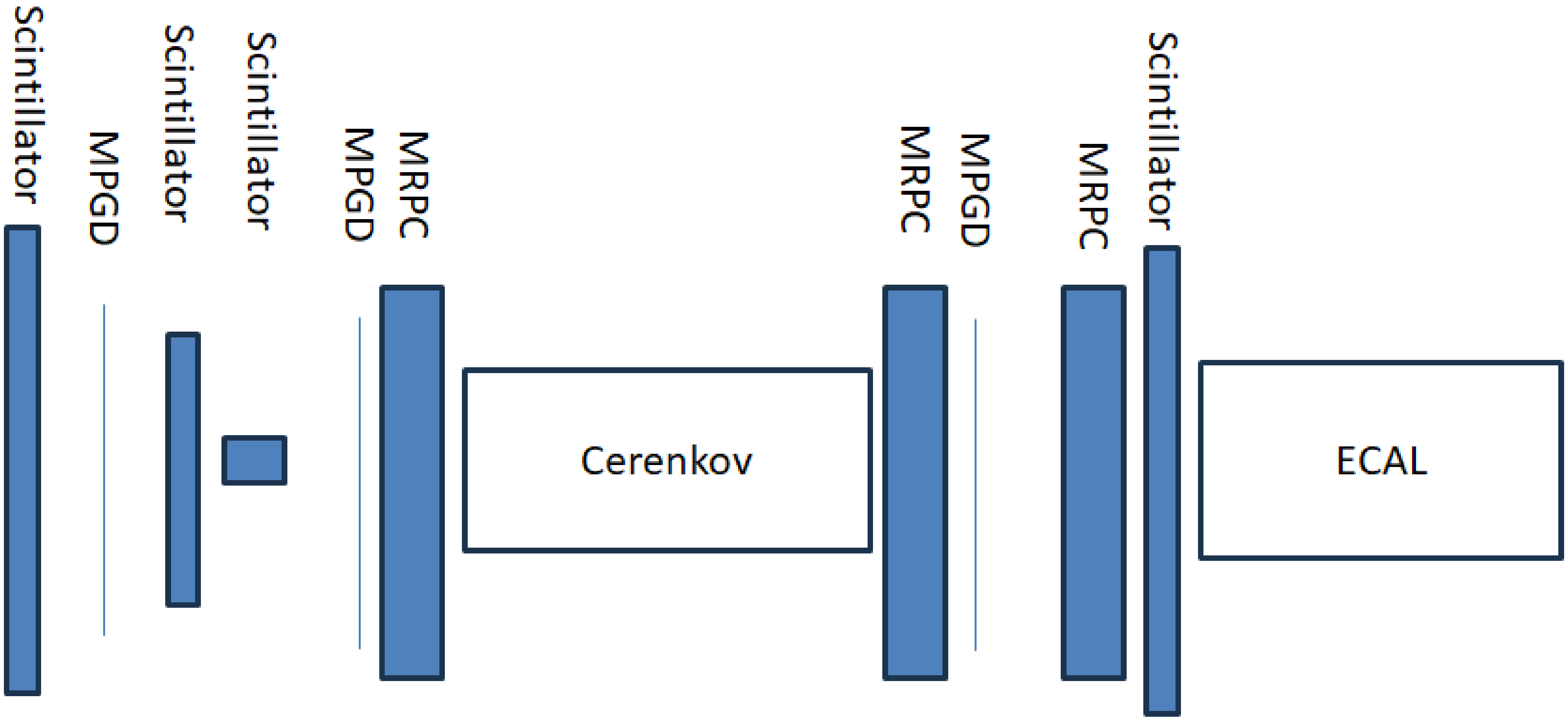
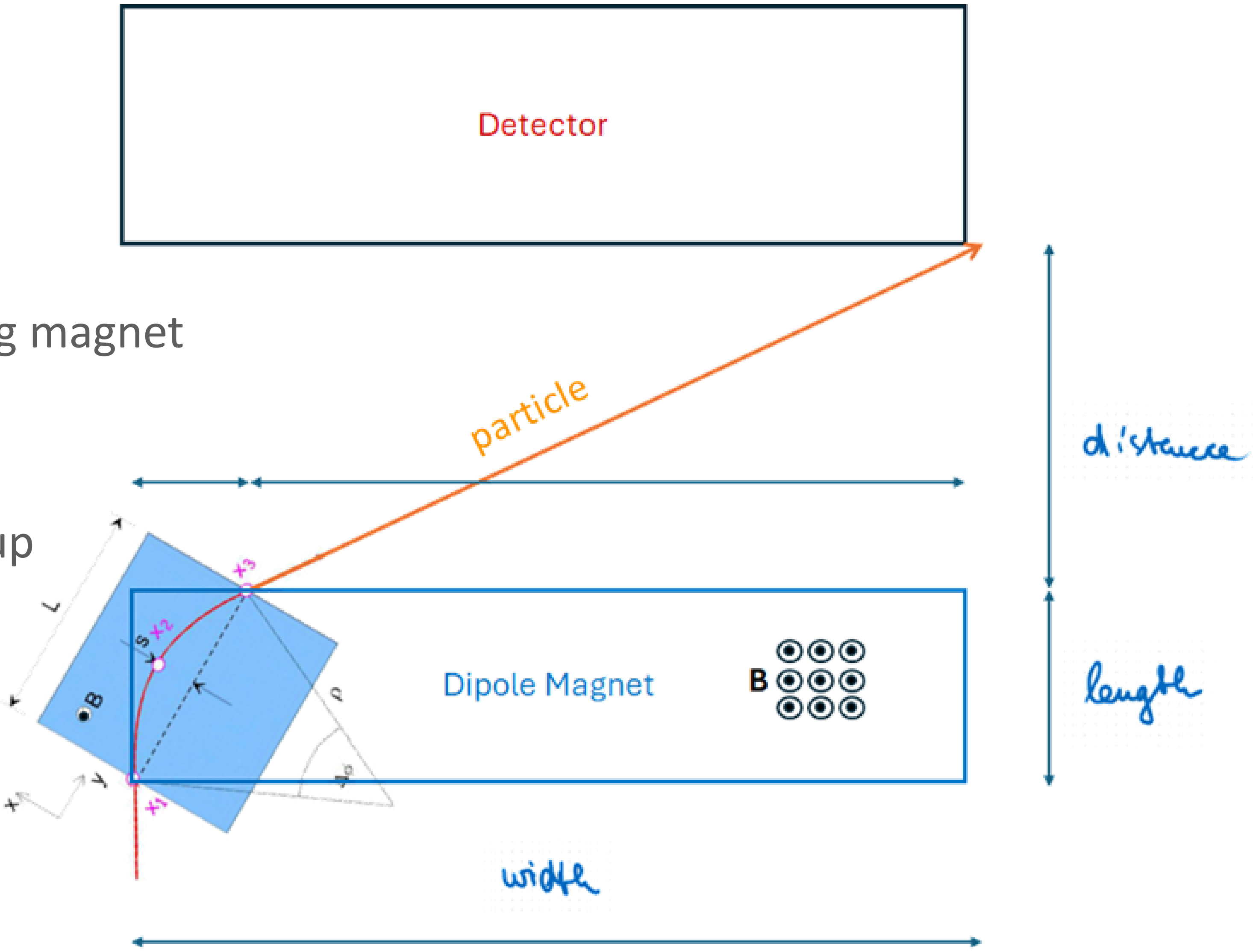
Pre-R&D Activities And Test Beam Plans – Hall C



Pre-R&D Activities And Test Beam Plans – Hall C

- Background reduction
  - Remove Møller electrons → sweeping magnet
  - Dipole magnet
    - Aperture, gap, field strength
  - Accommodated around detector setup



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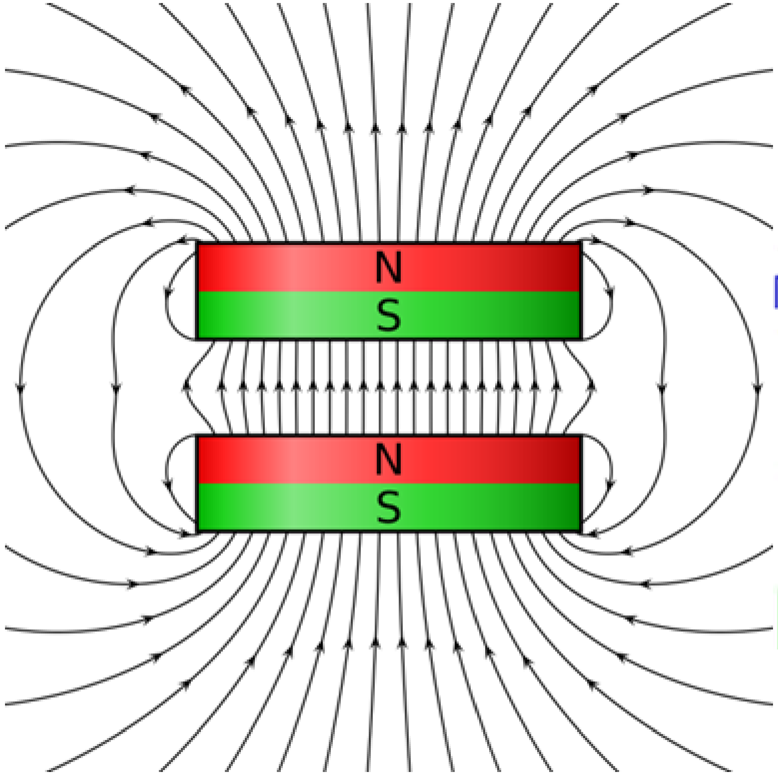
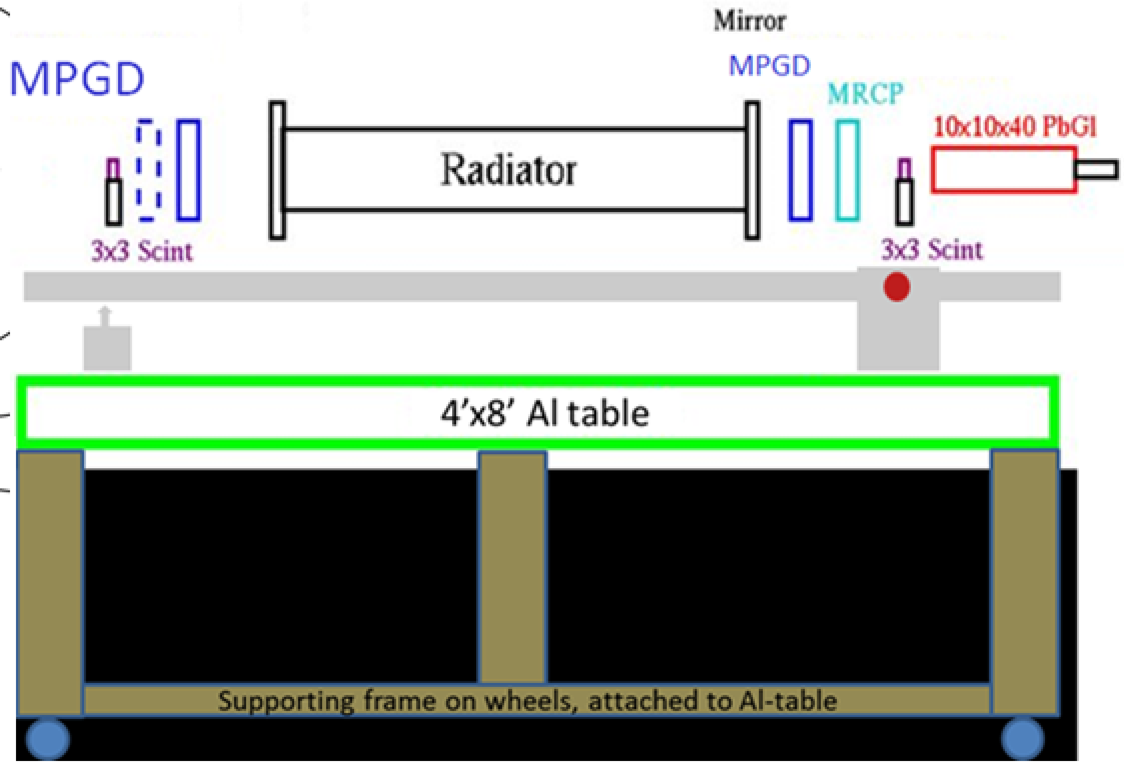
Pre-R&D Activities And Test Beam Plans – Hall C





Pre-R&D Activities And Test Beam Plans – Hall C

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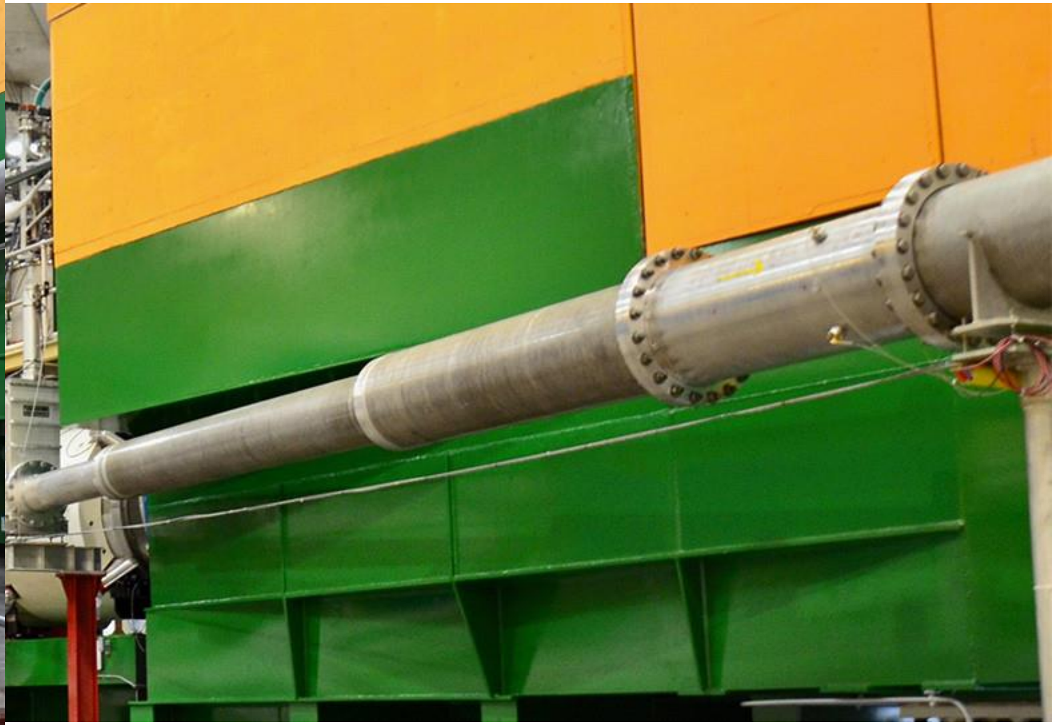
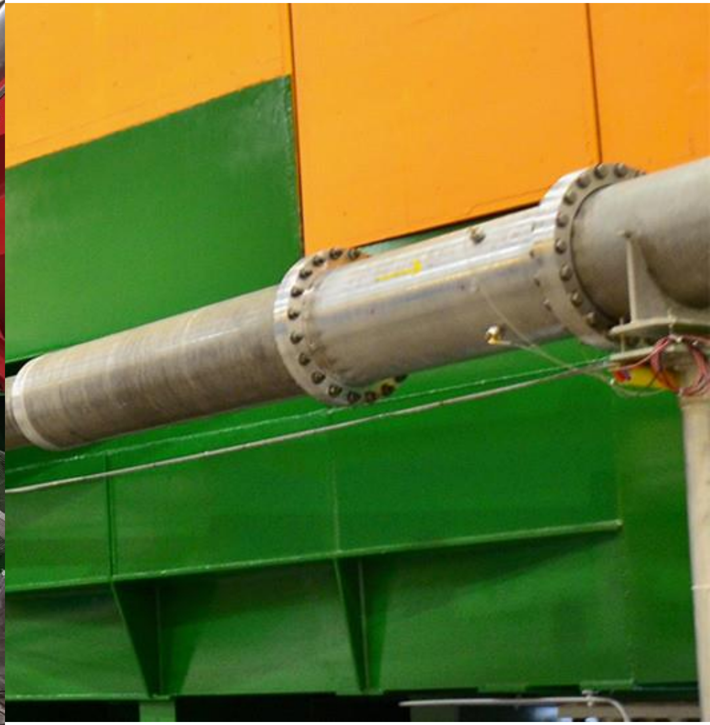
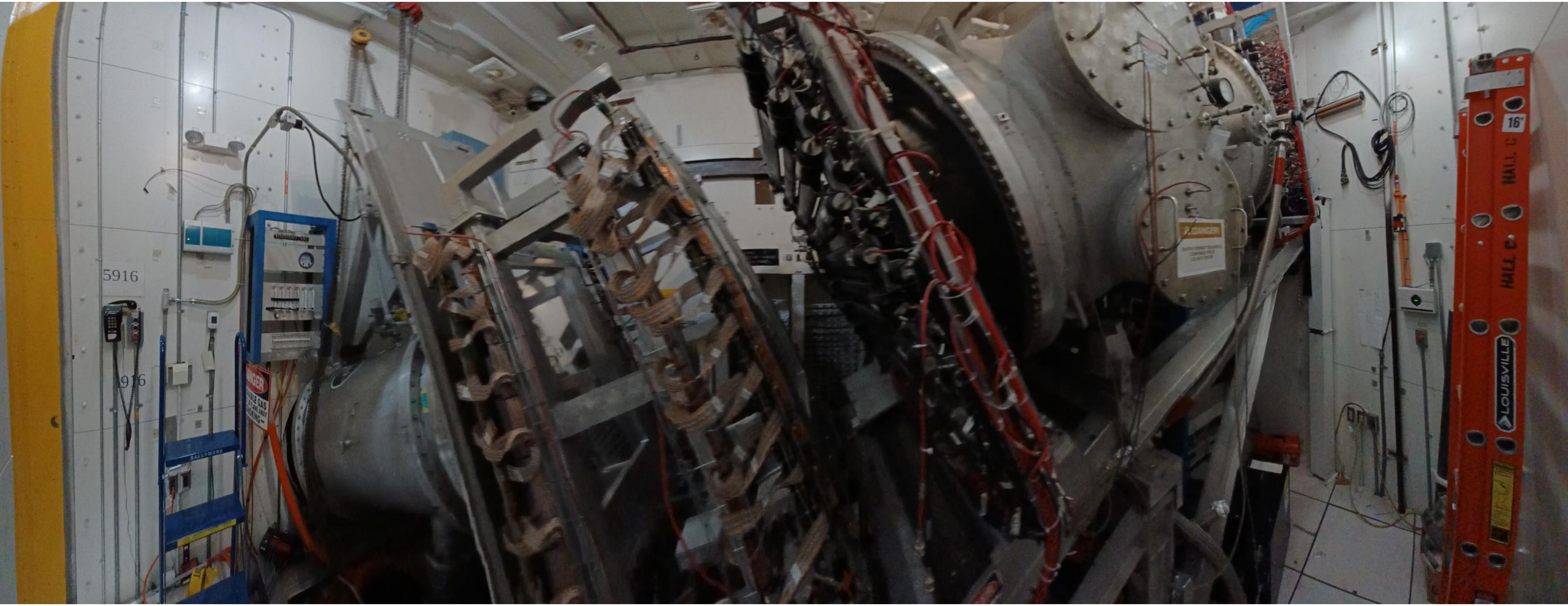


Pre-R&D Activities And Test Beam Plans – Hall C



Pre-R&D Activities And Test Beam Plans – Hall C



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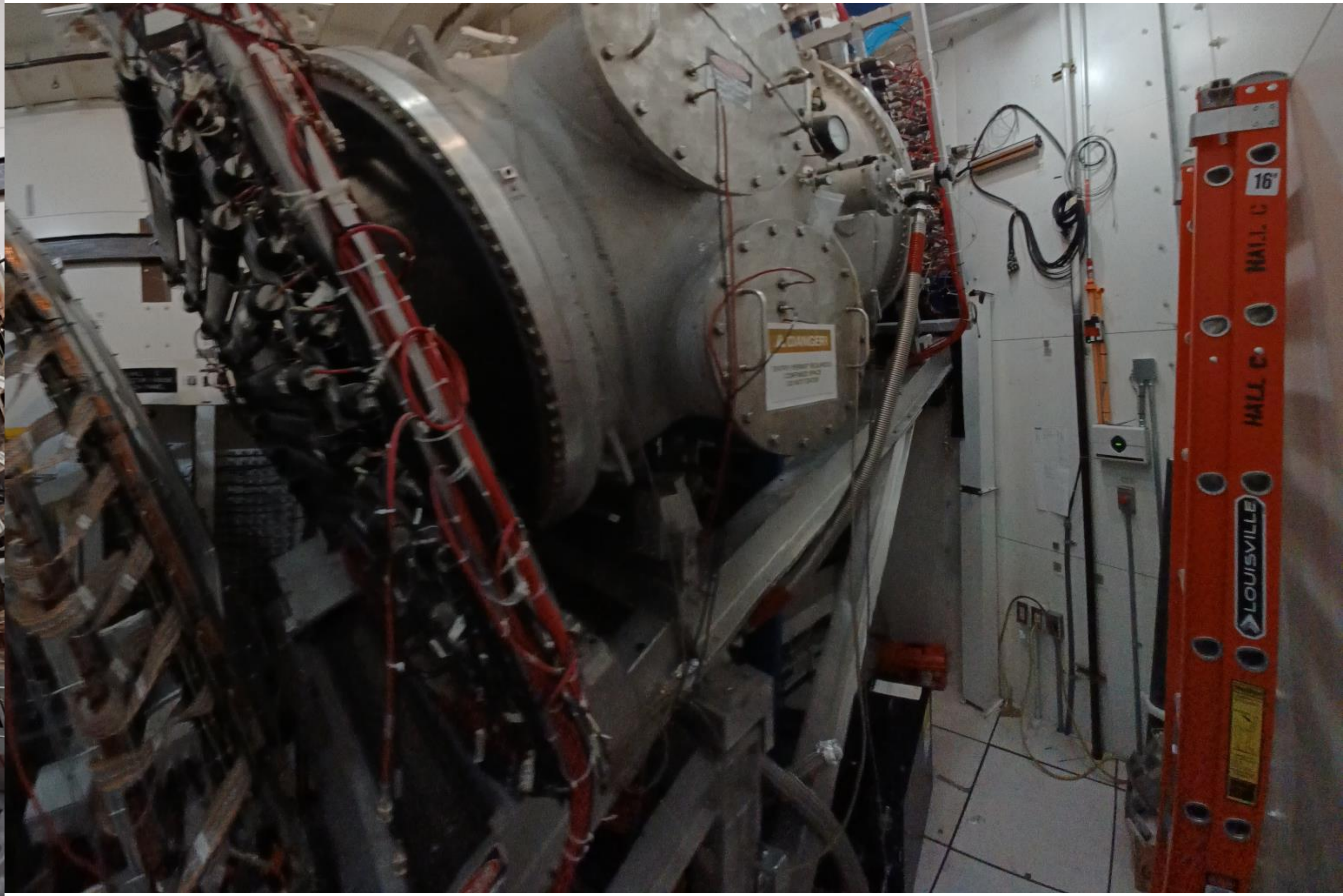
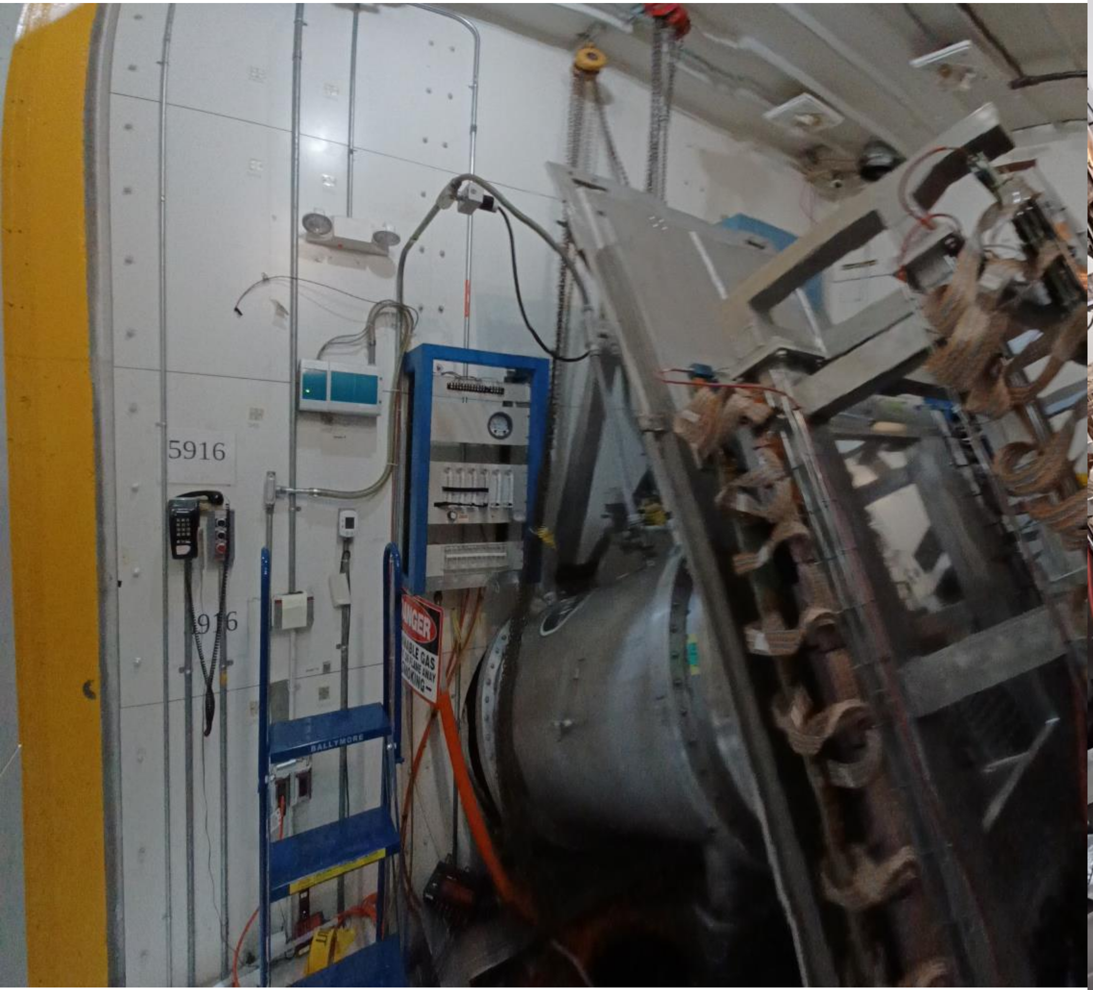
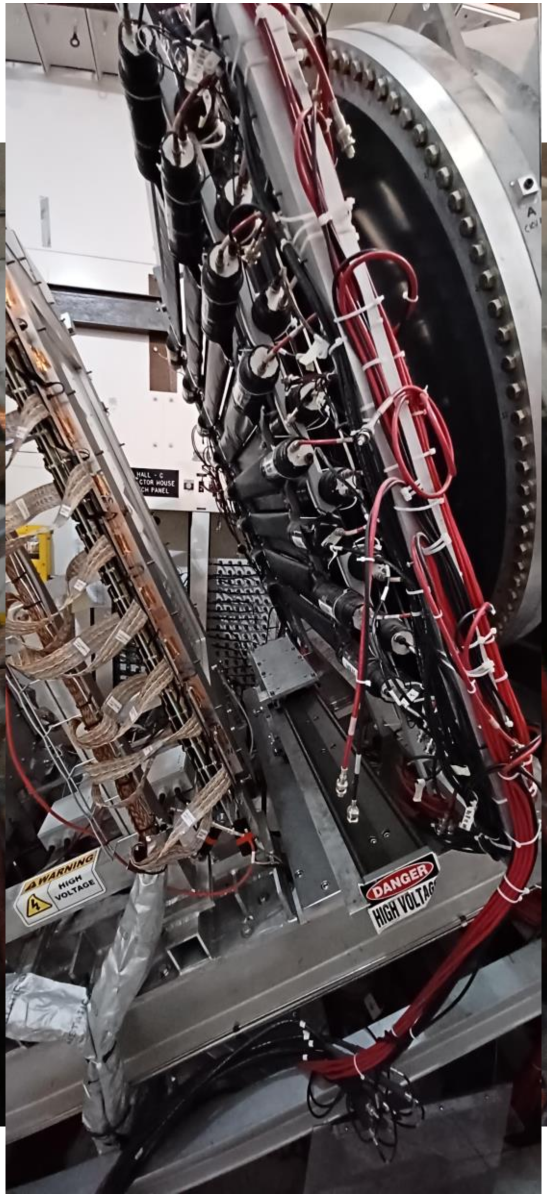
Pre-R&D Activities And Test Beam Plans – Hall C



Pre-R&D Activities And Test Beam Plans – Hall C





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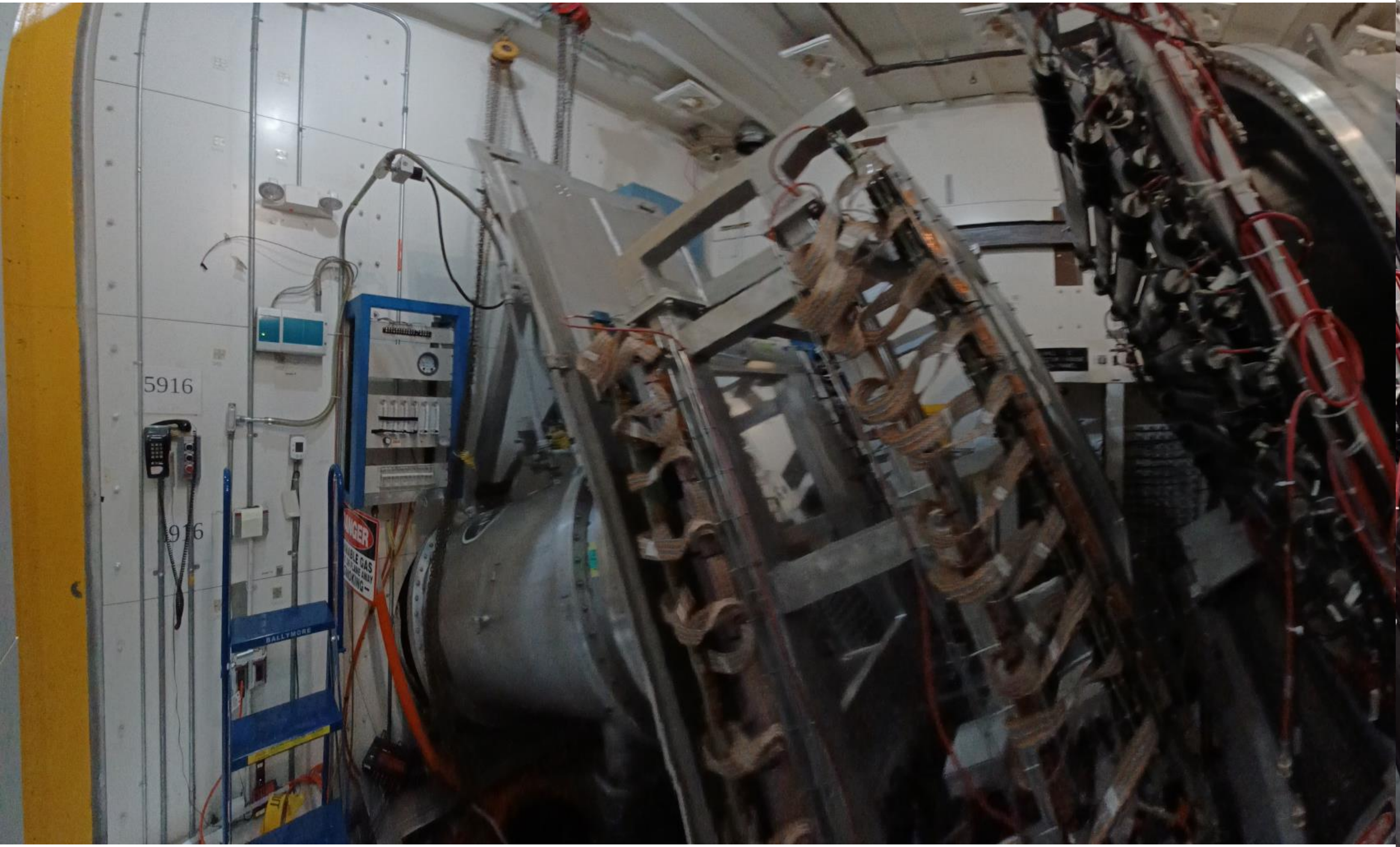
Pre-R&D Activities And Test Beam Plans – Hall C



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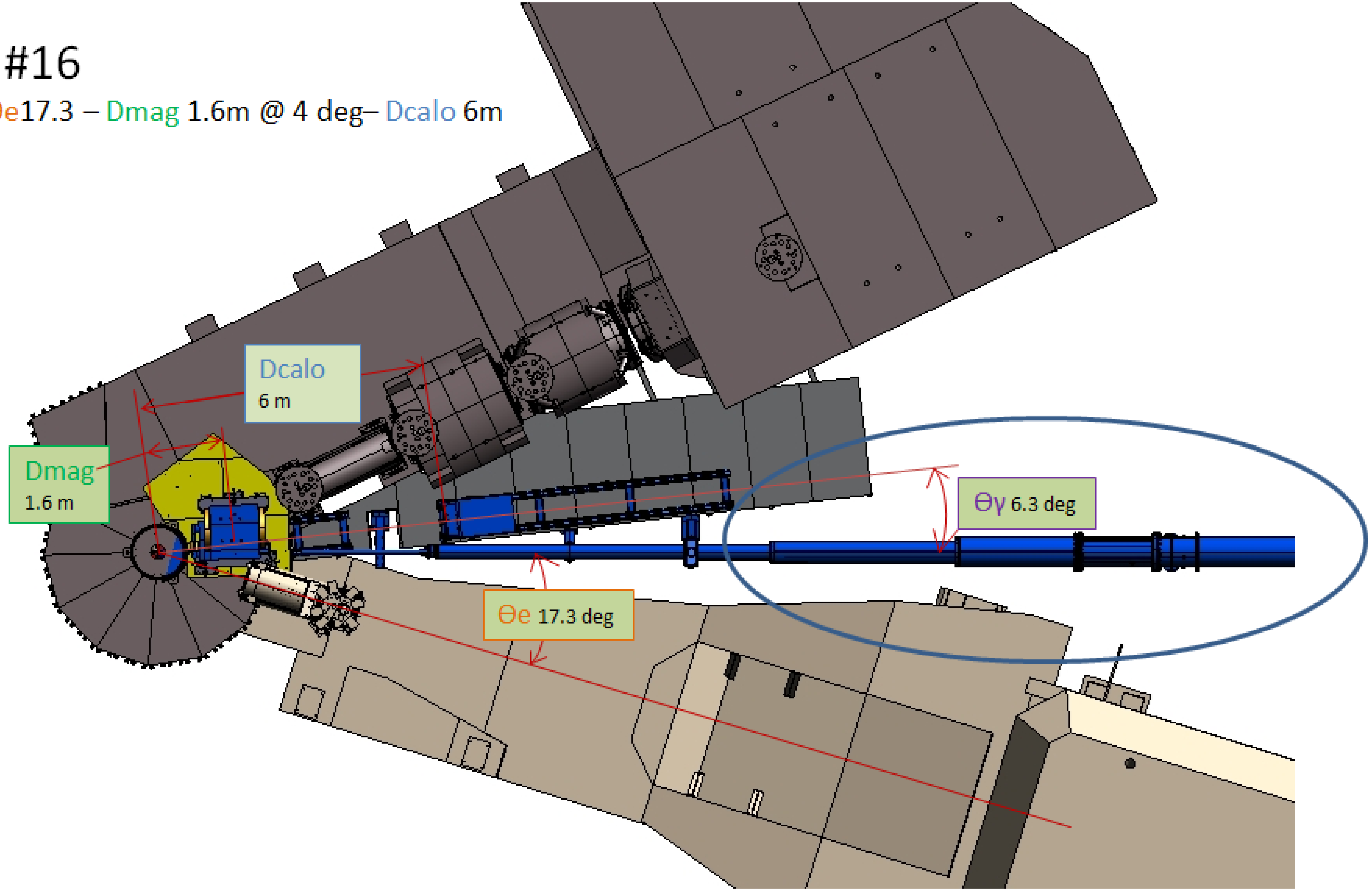
Pre-R&D Activities And Test Beam Plans – Hall C

- DVCS #16
  - ϴγ6.3 – ϴe17.3 – Dmag 1.6m @ 4 deg– Dcalo 6m



Summary and Conclusion

- **SoLID** collaboration looks back a decade of hard planning and executing activities
- **SoLID** collaboration developed a mature pre-conceptual design
- **SoLID** is a core part of JLab's 12-GeV program and beyond
- **SoLID** is prominently highlighted in the 2023 NSAC LRP
- **SoLID** has strong support from Jefferson Lab
- Pre-R&D topics
  - GEM readout → more general MPGD readout
  - Tracking options
  - MCP-PMT
  - Need to be finalized in document to be sent to G. Rai
- Test beam plan
  - Concept available
  - Detailed requirements and requests to be worked out
  - Resources to be identified and finalized


BACK UP

Long Range Plan 2023

- SoLID mentioned 24 time in the LRP 2023

1.3.1. Opportunities to Advance Discovery

Strategic opportunities exist to realize a range of projects that lay the foundation for the discovery science of tomorrow. These projects include the 400 MeV/u energy upgrade to FRIB (FRIB400), the Solenoidal Large Intensity Device (SoLID) at Jefferson Lab, targeted upgrades for the LHC heavy ion program, emerging technologies for measurements of neutrino mass and electric dipole moments, and other initiatives that are presented in the body of this report.

Future advances in nuclear physics rely upon a vibrant program of detector and accelerator R&D, pushing for instance the current limits on detector sensitivity and on accelerator beam transport technology. R&D for novel nuclear physics detector and accelerator ideas influence fields such as medicine and national security. Such developments must continue.

Whether the EMC effect involves any spin dependence has never been explored. The spin structure function EMC effect could provide complementary information; a first measurement of the polarized EMC ratio in lithium-7 is planned. Furthermore, by contrasting structure function measurements in calcium-40 and calcium-48, we can study the quark flavor dependence of the EMC effect. Another novel method is to measure the PVDIS asymmetry in calcium-48 with SoLID at Jefferson Lab, which effectively yields the ratio of weak to electromagnetic couplings and is thus sensitive to the ratio of quark flavors.

3.2.2. HOW ARE QUARKS DISTRIBUTED IN THE NUCLEON?

The momentum of quarks and gluons (which are both partons) inside the proton can be studied using the DIS process, introduced above. Parton distribution functions (PDF) describe the likelihood of finding a parton in the nucleon as a function of that parton's momentum fraction (x). At Jefferson Lab, DIS experiments primarily probe valence quarks; data in the valence regime can directly test fundamental theoretical predictions. The ratio of the distribution of down to up quarks in the proton $d(x)/u(x)$ is of particular interest and has been measured by three experiments (MARATHON, BONuS12, and Hall C). The MARATHON experiment measured the tritium/helium-3 DIS cross section ratio, thus comparing the proton (uud) with the neutron (udd). From there, the ratio of the neutron-to-proton structure function, which is related to the distribution of all the quarks in the nucleon, is extracted. That ratio is sensitive to d/u and is shown in Figure 3.2(left) as a function of x. The new results from MARATHON show the ratio leveling off between 0.4 and 0.5 as x increases to 1, consistent with the value predicted by QCD of 3/7. The BONuS12 experiment, which uses a novel technique to measure DIS from an effectively free neutron target, will soon publish results for the same ratio. A model-independent extraction of the ratio in Figure 3.2 can also be obtained in parity-violating DIS (PVDIS) with the proposed SoLID experiment at Jefferson Lab, where the strange-quark PDF in the valence regime can also be accessed.

Transverse momentum imaging and spin–momentum and spin–spin correlations. Transverse-momentum imaging techniques, in conjunction with spin-dependent measurements, probe various spin–momentum correlations in the nucleon. These correlations are analogous to spin–orbit coupling effects in atomic systems. In addition to providing multidimensional images of quark and gluon momentum distributions within the nucleon, measurement of spin-momentum correlations in the nucleon can test our understanding of subtle aspects of QCD as a quantum field theory. Transverse spin–spin correlations are also of interest: the transversity distribution describes the difference in probability of scattering off of a transversely polarized quark in a transversely polarized proton where the quark spin direction is parallel or antiparallel to the proton spin direction. As shown in Figure 3.4, combining measurements from multiple recent experiments has revealed that the transverse spin of up quarks is more likely to be in the same direction as the proton spin, whereas that of down quarks is more likely to be in the opposite direction. The origin of these large and opposing spin–spin correlations is not yet understood. Proposed measurements at the Jefferson Lab SoLID detector and the future EIC will significantly improve our knowledge of these correlations. Transverse spin–spin correlations are also related to a property of the nucleon called the tensor charge, which can be calculated in lattice QCD. The tensor charge is linked to nucleon and quark electric dipole moments, which are sensitive to physics beyond the Standard Model.

Searching for Physics Beyond the Standard Model

The recent Qweak experiment at Jefferson Lab measured the parity-violating asymmetry in elastic electron proton scattering and extracted for the first time the proton weak charge at the 6.3% level, leading to a determination of the weak mixing angle, a fundamental parameter of the Standard Model (Chapter 6). The future Jefferson Lab program will comprise two experiments that will advance our knowledge of physics beyond the Standard Model: MOLLER will measure the electron's weak charge and determine the weak mixing angle with a precision comparable to high-energy collider experiments, and SoLID PVDIS will uniquely access a precise electron-quark coupling that probes the parity-violating nature of quarks. The accuracy envisioned for SoLID PVDIS will also enable precision probes of the nucleon's partonic structure, including the down to up quark PDF ratio of the proton and the dynamic origin of the nuclear EMC effect of calcium-48.

The 12 GeV era at Jefferson Lab has included a suite of new experimental equipment. Hall A has transitioned into a multiple experiment installation hall, most notably facilitating the Super BigBite Spectrometer (SBS) experiments, MOLLER, and SoLID equipment and programs. The SBS program involves two open, single-bend, resistive spectrometers and two large standalone calorimeters for electromagnetic and hadron calorimetry. This apparatus will enable studies of the electromagnetic structure of the nucleon to an unprecedentedly small length scale. MOLLER will measure parity-violating asymmetries in electron scattering off atomic electrons in a high-power liquid hydrogen target by rapidly flipping the longitudinal polarization of the 11 GeV electron beam. This asymmetry is proportional to the weak charge of the electron, which in turn is a function of the electroweak mixing angle, a fundamental parameter of electroweak theory.

Long Range Plan 2023

- SoLID mentioned 24 time in the LRP 2023

With the study of nucleon structure evolving from single- to multidimensional measurements that employ exclusive processes and the quest for understanding the origin of the proton mass based on studies of near-threshold meson production, frontier QCD research requires, first and foremost, higher statistics. Similarly, parity-violating electron scattering requires increasing statistical precision to test the Standard Model at low to medium energies. Such emerging needs from both QCD and fundamental symmetries call for a truly large-acceptance, high-intensity device to fully capitalize on CEBAF's high-luminosity beam. SoLID, planned for Jefferson Lab as an integral part of the CEBAF 12 GeV program, was designed to meet such needs. SoLID will use the CLEO II 1.4 T solenoid magnet and a large-acceptance detector system to operate at luminosities among the highest at Jefferson Lab. The realization of SoLID in Jefferson Lab Hall A is shown in Figure 9.4.

Looking to the future, many opportunities for detector R&D in the near and intermediate term exist, and examples include superconducting nanowire particle detectors that are being developed for nuclear physics applications for the EIC and experiments at Jefferson Lab. Furthermore, excitingly, cross-cutting development efforts with advanced computing are conceived to facilitate self-driving detector systems: ePIC at EIC or SoLID at Jefferson Lab are candidates for initial large-scale deployment of such a concept. Here, a combination of heterogeneous computing, AI, ML, advanced computing, and streaming readout is anticipated to reduce the time from data collection to publication and improve efficiency of experimental operations.

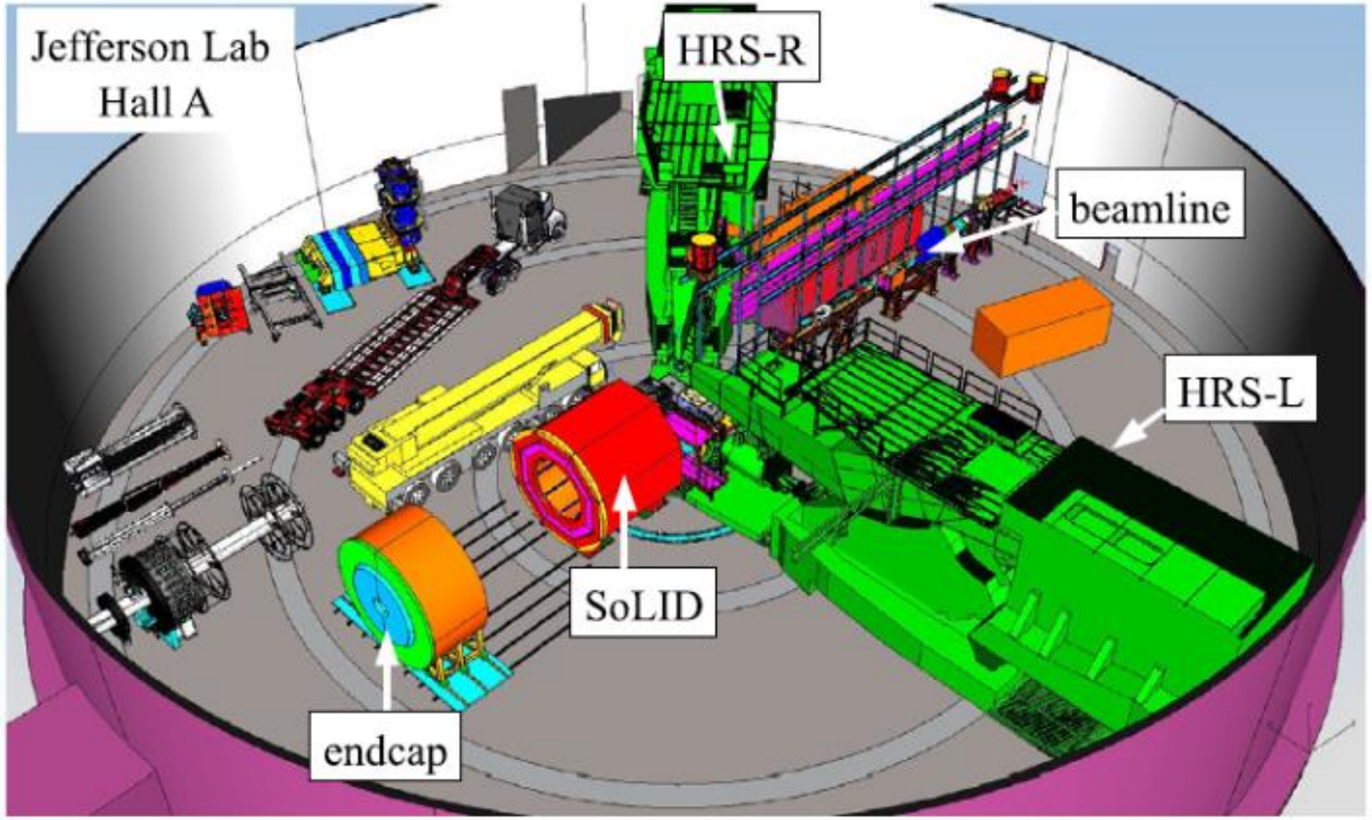


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Figure 9.4. Schematic layout of SoLID in Hall A of Jefferson Lab. *The endcap is pulled downstream to allow detector installation and reconfiguration. The two high-resolution spectrometers (HRS-L and HRS-R, not in use) are parked at backward angles [41].*