WG6 Group Summary at DIS2024

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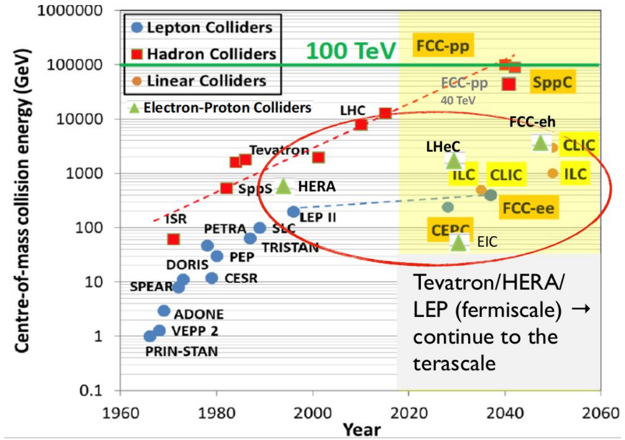
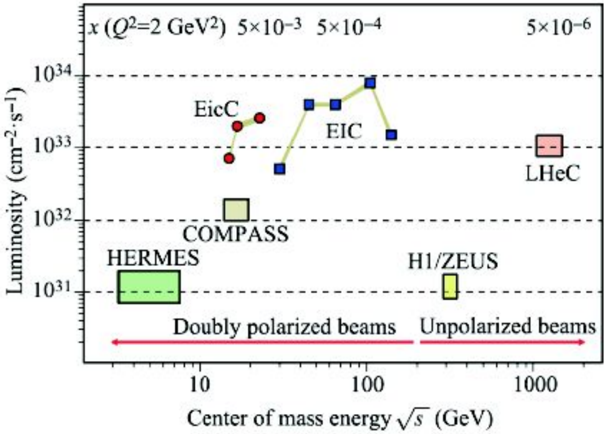
General Working Group Overview

- **# of Talks: 42**
  - **WG6 Session: 42**
  - **WG3 + WG6: 77**
  - **WG1 + WG6: 3. Not included in this update**

- **Talk length: 15 + 5 Minutes**

- **Topic:**
  - Strategic planning
  - Future experiment and facilities
  - New physics ideas





Future is bright

Now

2026

JLab Moller

2030

JLab SoLID

2032

Super Tau
Charm Factory

2033-2035

EIC
LHeC
JLab e^+
EIcC

2037

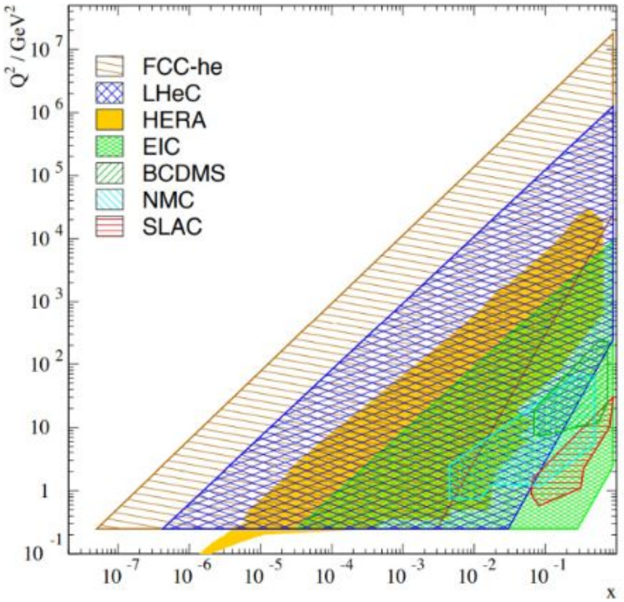
JLab 22 GeV

2038

EIC Detector 2

2040+

FCC
FCC-ee
FCC-he
ILD

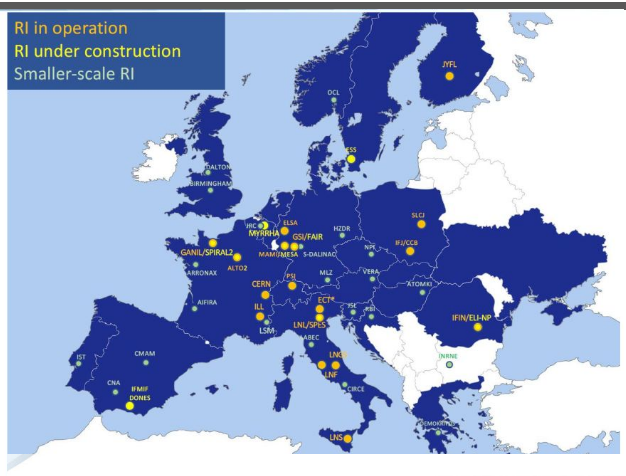


Long Range Plan (LRP) efforts:

- The European Committee for Future Accelerators (ECFA) LRP **(Invited, couldn't come)**
- 2023 P5 Report **(Invited, couldn't come)**
- The Nuclear Physics European Collaboration Committee (NuPECC) LRP **(here)**
- 2023 Nuclear Science Advisory Committee Long Range Plan for Nuclear Science **(talk cancelled)**

NuPECC Long Range Plan Process

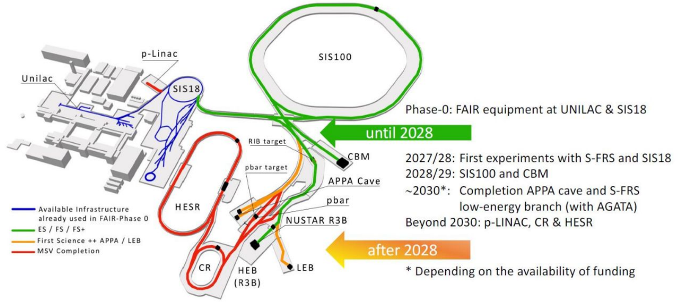
The NuPECC Long Range Plan 2024,
Carlos Muñoz Camacho



- May 30, 2022: Call for community input (5 pages) for the NuPECC Long Range Plan 2024 – Deadline: Oct 1st, 2022
- January 2023: Formation of Thematic Working Groups (TWG) to analyze contribution received (153)

1. Hadron Physics
2. Strongly Interacting Matter under Extreme Conditions
3. Nuclear Structure and Reaction Dynamics
4. Nuclear Astrophysics
5. Symmetries and Fundamental Interactions
6. Research Infrastructures
7. Applications and Societal Benefit
8. Nuclear Physics Tools
9. Open Science and Data
10. Nuclear Science – People and Society

- April 3, 2024: Draft document released to the community (370 pages)
- April 15-17, 2024: Town Meeting (Bucharest, Romania) - https://indico.ph.tum.de/event/7593/
- **Final document: Fall 2024**



Draft document released to the community (370 pages)
April 15-17, 2024: Town Meeting (Bucharest, Romania)
https://indico.ph.tum.de/event/7593/

Recommendations for Nuclear Physics Infrastructures

- The first phase of the international FAIR facility is expected to be operational by 2028… The completion of the full facility including the program of APPA, CBM, NUSTAR and PANDA should be vigorously pursued
- Timely completion and full exploitation of [] GANIL/SPIRAL2 projects should b
- Nuclear physics opportunities at CERN (ALICE 3, scientific exploitation of ISOL
- ELI-NP (Extreme Light Infrastructure) – nuclear photonics
- ISOL facilities in Europe (ALTO, IGISOL, ISOLDE, SPES, and SPIRAL) and future u TATTOOS@PSI, and RIB@IFIN)
- Explotaition of large-scale stable beam facilities (FAIR/GSI, GANIL/SPIRAL2, IF smaller ones…
- Exploitation and optimisation of the European lepton beam facilities, includin Completion of the MESA facility and the High-Intensity Muon Beams project a optimisation of the M2 Muon Beam Facility at CERN, are recommended.
- Neutron facilities like ILL, and n_ToF at CERN…
- Theory centres and groups should be strongly supported throughout Europe, Centre for Theoretical Studies (ECT*, Trento, Italy).
- Collaboration with non-European infrastructures should be fostered. In particular, European participation in the construction of the ePIC experiment at the future […] EIC is recommended.

Existing facilities: We recommend the continuing support of the successful hadron physics programs in Europe and the participation of European groups at global facilities. Particularly important hadron physics facilities are:

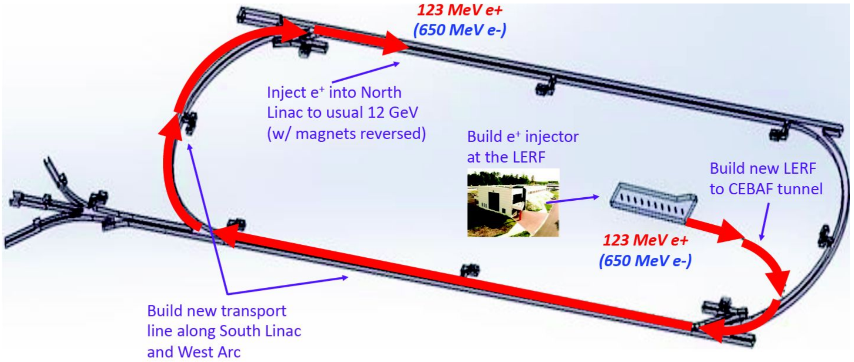
- AMBER at CERN
- ELSA in Bonn, HADES at GSI, MAMI and MESA in Mainz, all Germany
- Jefferson Laboratory in Newport News, USA

Furthermore, we recommend the support of ongoing hadron physics activities at the multipurpose facilities Belle II, BESIII and the LHC.

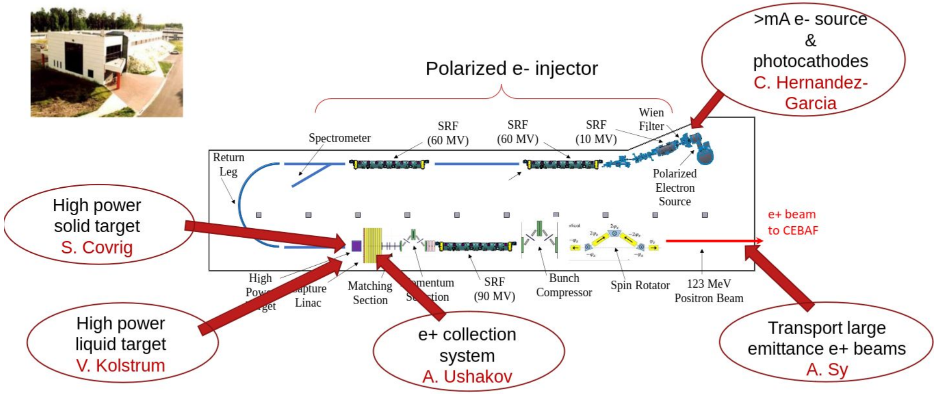
Future flagships: We recommend the expedited realisation of the antiproton experiment PANDA, and the support of European groups to contribute to the electron-ion experiment ePIC.

Theory / Computing

Positron Program (Physics) and Ce+BAF (accelerator) at Jefferson Lab

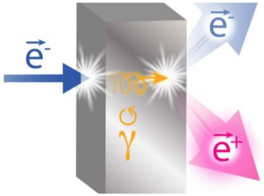


Machine Parameter	Electrons	Positrons
Hall Multiplicity	4	1 or more
Max. Energy (ABC/D)	11/12 GeV	11/12 GeV
Beam Repetition	249.5/499 MHz	249.5/499/1497 MHz
Duty Factor	100% cw	100% cw
Unpolarized Intensity	170 μA**	> 1 μA
Polarized Intensity	170 μA**	> 50 nA
Beam Polarization	> 85%	> 60%

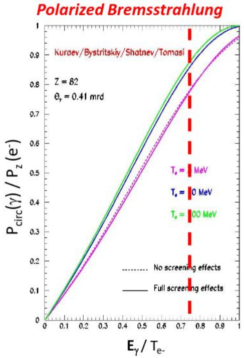


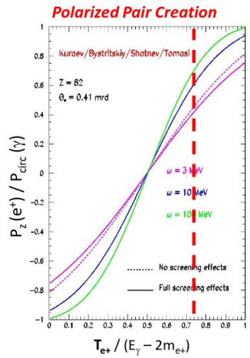
$$\vec{e}^- \to \vec{\gamma} \to \vec{e}^+ \ (+\vec{e}^-)$$

When a longitudinally polarized e⁻ beam strikes matter, e⁺ produced in the shower carrying ***>50% of the e⁻ beam energy*** *are significantly longitudinally* ***spin polarized****...*



...so why not take advantage of this?

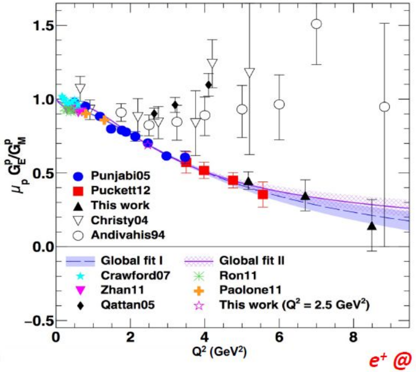


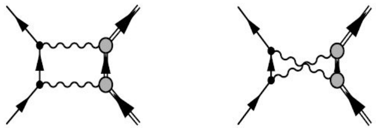


E.A. Kuraev, Y.M. Bystritskiy, M. Shatnev,

Positron Program (Physics) and Ce+BAF (accelerator) at Jefferson Lab

A.J.R. Puckett et al. PRC 96 (2017) 055203





$$\sigma_R = G_M^2 + \frac{\varepsilon}{\tau} G_E^2 \pm 2\left\{G_M \Re\left[f_0(\delta\tilde{G}_M, \delta\tilde{F}_3)\right] + \frac{\varepsilon}{\tau} G_E \Re\left[f_1(\delta\tilde{G}_E, \delta\tilde{F}_3)\right]\right\}$$

$$\frac{P_t}{P_l} \approx -\sqrt{\frac{2\epsilon}{(1+\epsilon)\tau}} \frac{G_E}{G_M}\left(1 \pm \left\{\frac{\Re[\delta\tilde{G}_M]}{G_M} + \frac{\Re[f_1(\delta\tilde{G}_E, \delta\tilde{F}_3)]}{G_E} - 2\frac{\Re[f_2(\delta\tilde{G}_M, \delta\tilde{F}_3)]}{G_M}\right\}\right)$$

Hard two-photon exchange (TPE) may be the cause of the form factor discrepancy at high Q^2.

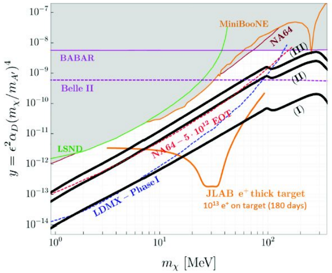
- If TPE, the electromagnetic structure of the nucleon would be parameterized by **3 generalized form factors** i.e. **8 unknow quantities**.
- TPE can only be calculated with model-dependent approaches.

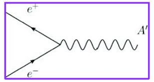
*e^+ @ JLab have the unique opportunity to bring a **definitive answer** about TPE.*

Direct Dark Matter Production

M. Battaglieri et al. EPJ A 57 (2021) 253

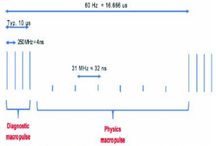
- A direct search of dark matter in the e^+e^-annihilation has been evaluted using a beam energy of 11 GeV and a 180 days data taking period.
- The measurement of an energy deposit smaller than the e^+ beam energy signs the production of the A'.



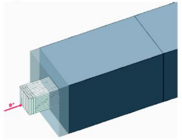


$$E_{miss} = E_{beam} - E_{CAL}$$

$$m_{A'} = \sqrt{2m_e E_{miss}}$$

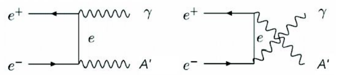


A specific time structure of the beam is required to avoid e^+ beam pile-up in the detector.



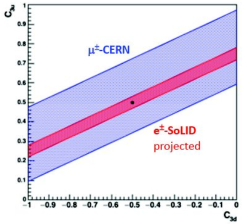
An active thick target completed with a hadronic calorimeter constitute the experimental set-up.

And Beyond...

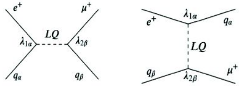


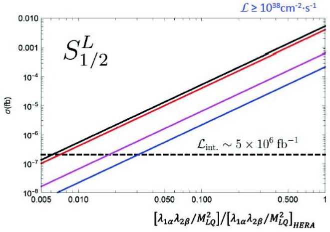
- *Testing standard model predictions*
  - Dark matter search
  - Axial-axial neutral current coupling
  - Charged lepton flavor violation ?
  - ...

$$\mathcal{L} = \frac{G_F}{\sqrt{2}}\sum_q \left[C_{1q}\,\bar{\ell}\gamma^\mu\gamma_5\ell\bar{q}\gamma_\mu q + C_{2q}\,\bar{\ell}\gamma^\mu\ell\bar{q}\gamma_\mu\gamma_5 q + C_{3q}\,\bar{\ell}\gamma^\mu\gamma_5\ell\bar{q}\gamma_\mu\gamma_5 q\right]$$



$$e^\pm + N \longrightarrow \mu^\pm + X$$

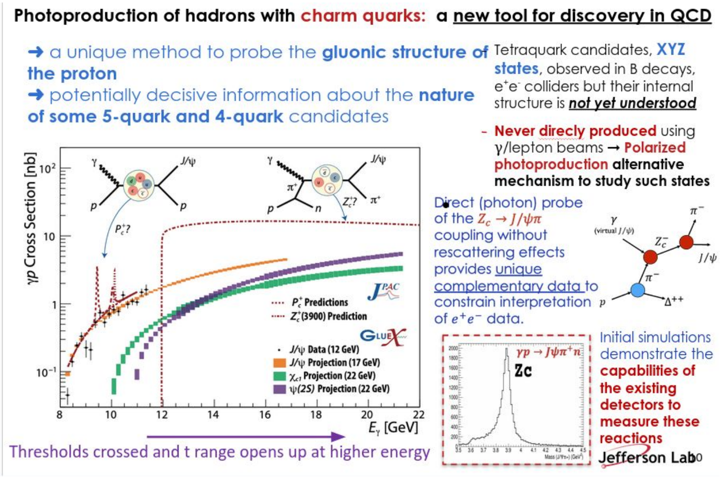


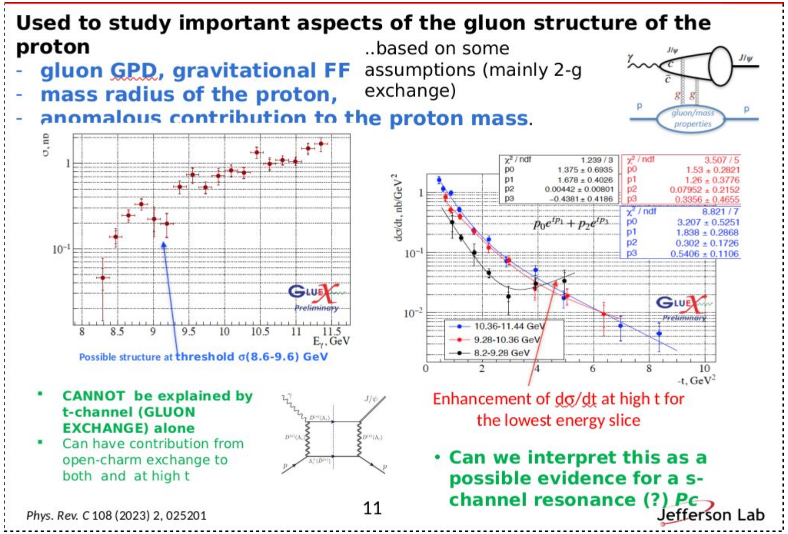


X. Zheng, J. Erler, Q. Liu, H. Spiesberger, EPJ A 57 (2021) 173 Y. Furletova, S. Mantry, EPJ A 57 (2021) 315
B. Wojtsekhowski et al. Jefferson Lab Proposal PR12+23-005 D. Mack Jefferson Letter-of-Intent PR12+23-005

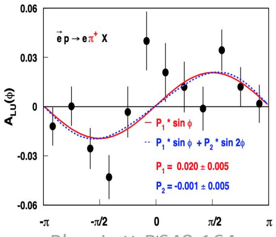
This list is not exhaustive but only indicative of the current proposals.

Luminosity Frontier with 22 JLab GeV



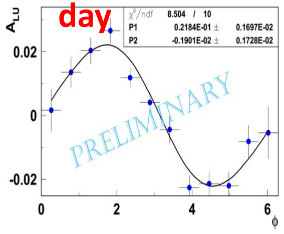


HERMES -



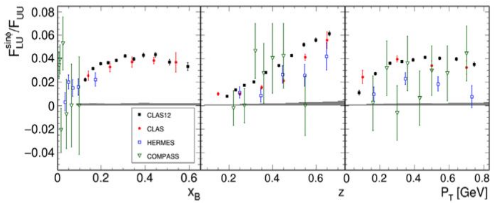
Phys.Lett.B648:164-170,2007

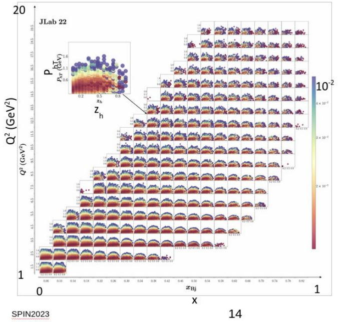
JLab – CLAS12 1 day



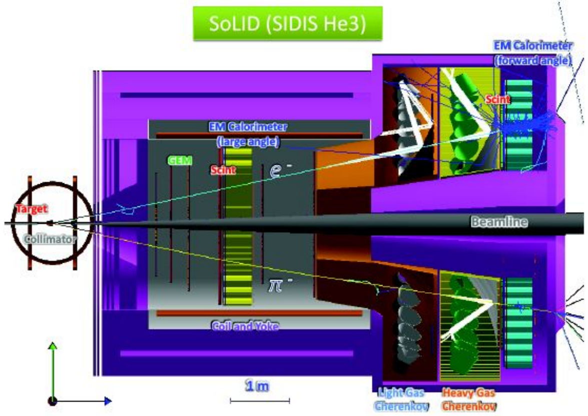
ep→e’π+ X

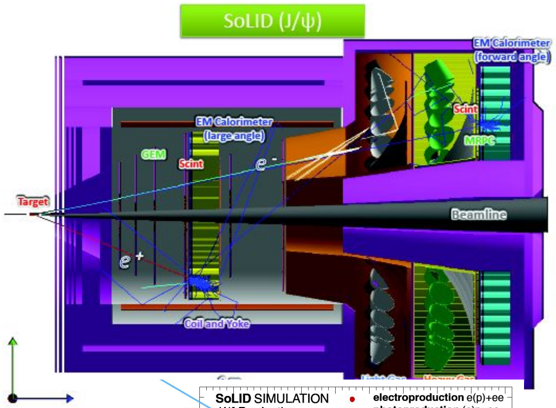
Phys. Rev. Lett. 128, 062005 (2022).

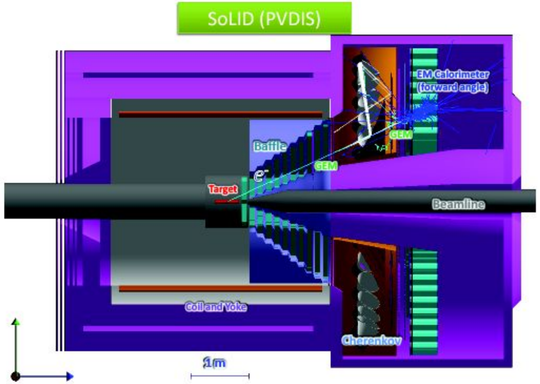


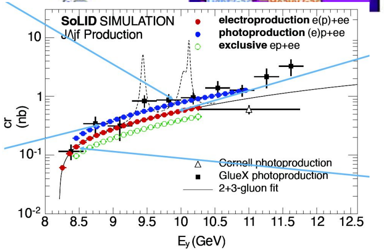


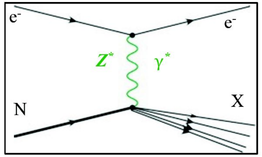
SoLID Experiment at JLab 12 GeV



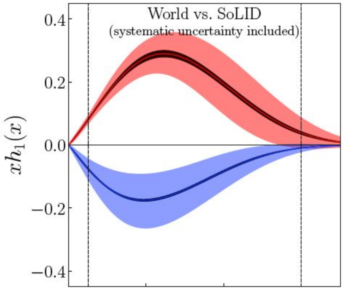




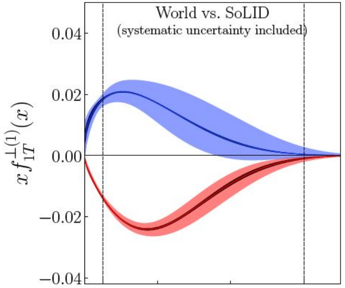




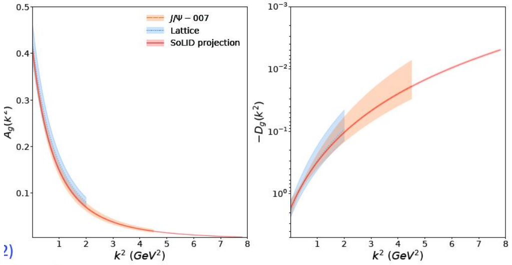
Transversity

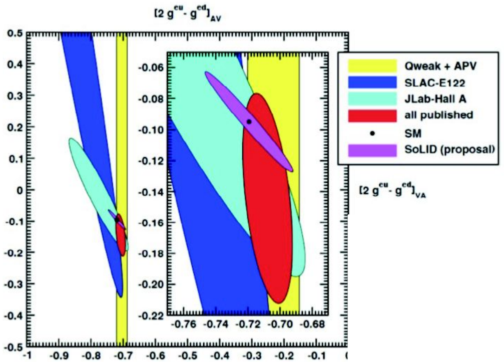


Sivers

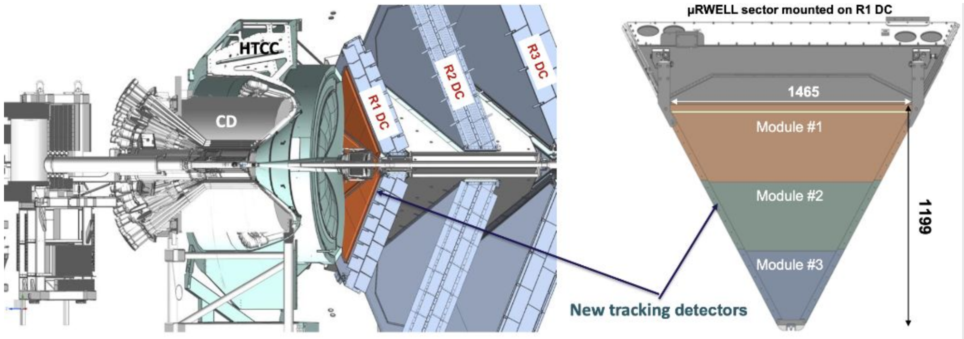


SoLID impact projections compared to J/psi-007





CLAS 12 Luminosity Upgrade at JLab 12 GeV

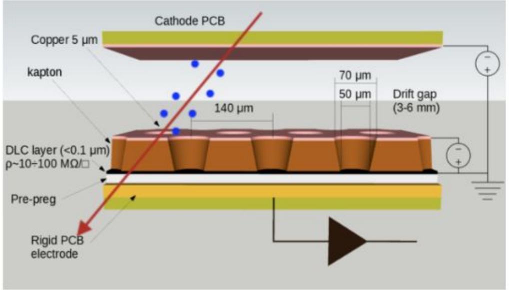


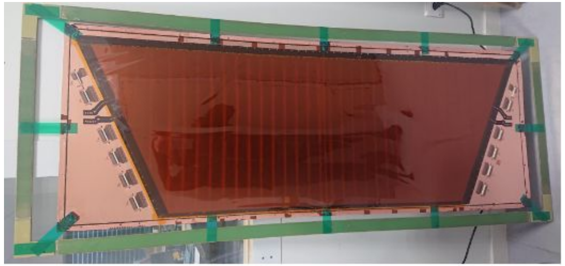
Design Luminosity:

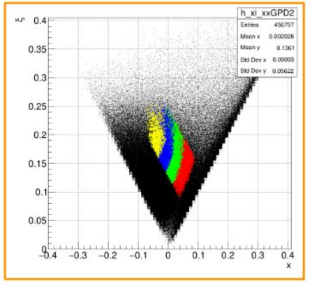
- **10^{35} $cm^{-2}s^{-1}$** → **10^{37} $cm^{-2}s^{-1}$** upgrade

Physics targets:

- LH_2, LD_2, LHe, LAr
- D, ^4He
- ^{12}C to ^{208}Pb
- Polarized NH_3, ND_3, ^6LiH, ^7LiD, ^3He-gas

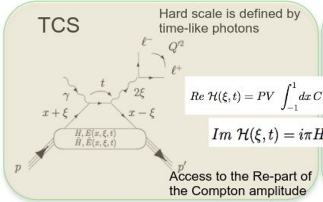




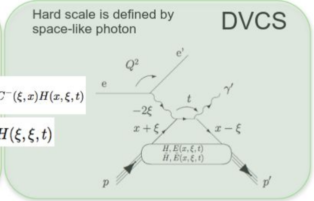


JLAB Flagship program – accessing GPDs through measurements of beam/target asymmetries and the cross sections of Compton processes (TCS and DVCS)

First experimental measurement with CLAS12 PRL 127, 262501 (2021)

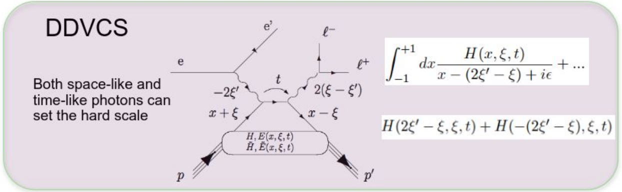


Started in 2001, PRL 87, 182002. Now is the flagship physics program

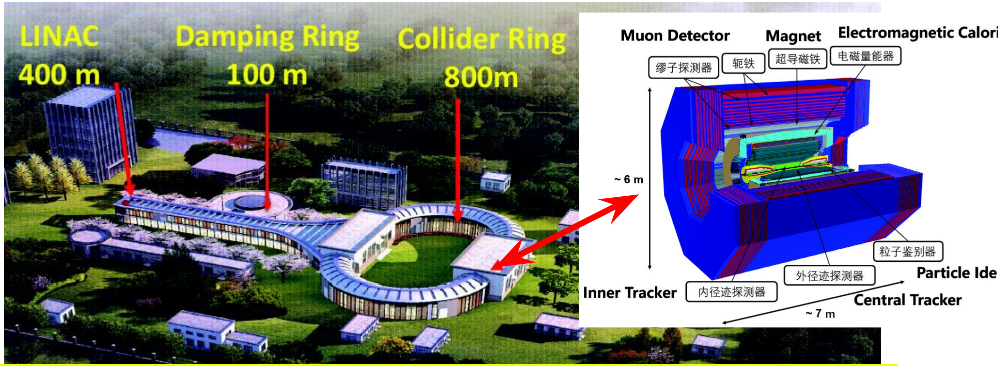


Jefferson Lab at the luminosity frontier is the only place in the world DDVCS can be measured!

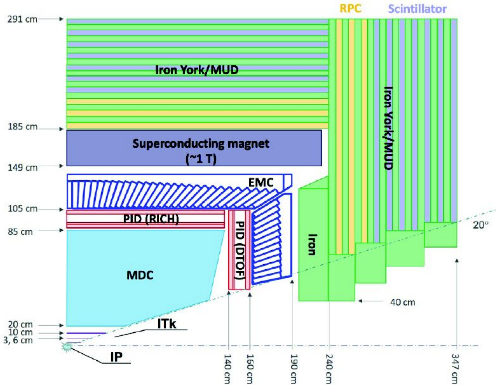
µCLAS12 in Hall B and SoLID in Hall A are the two proposed facilities capable of carrying out such measurements.



Super Tau-Charm Facility in China (2032)

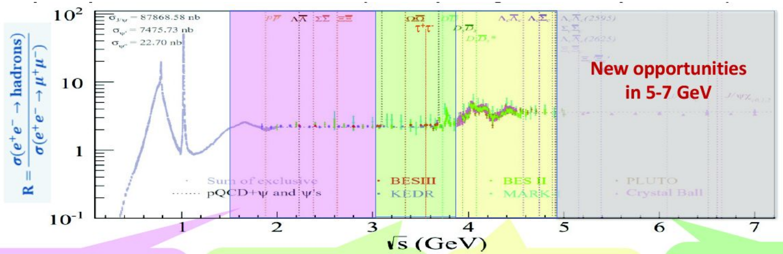


- E_{cm} = 2-7 GeV, $\mathcal{L} > 0.5\times10^{35}$ cm $^{-2}$ s $^{-1}$
- Potential for luminosity upgrade and a polarized electron beam



Solid Angle Coverage : 94%•4π (θ~20⁰)

- ❖ **Inner tracker** (two options)
  - MPGD: cylindrical MPGD
  - Silicon: CMOS MAPS
- ❖ **Central tracker**
  - Drift chamber
- ❖ **PID**
  - Barrel: RICH with CsI-MPGD
  - Endcaps: DIRC-like TOF (DTOF)
- ❖ **EMC**
  - pure CsI + APD
- ❖ **Muon detector**
  - RPC + scintillator strips
- ❖ **Magnet**
  - Super-conducting solenoid, 1 T



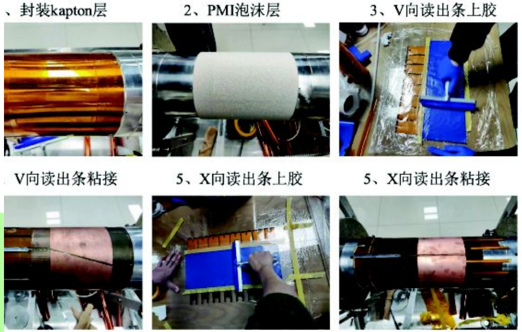
- Nucleon/Hadron form factors
- Y(2175) resonance
- Mutltiquark states with s quark
- MLLA/LPHD and QCD sum rule predictions

- Light hadron spectroscopy
- Gluonic and exotic
- LFV and CPV
- Rare and forbidden decays
- Physics with τ lepton

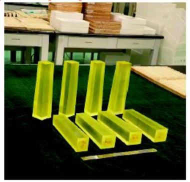
- XYZ particles
- Physics with D mesons
- f_D and f_{D_s}
- D_0-$\bar{D}_0$ mixing
- Charm baryons

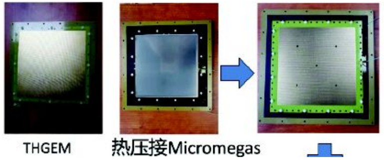
- New XYZ particle
- Hidden-charm pentaquark
- Di-charmonium state
- Charm baryons
- Hadron fragmentation

Cylindrical MPGD (uRWELL, uRGroove)

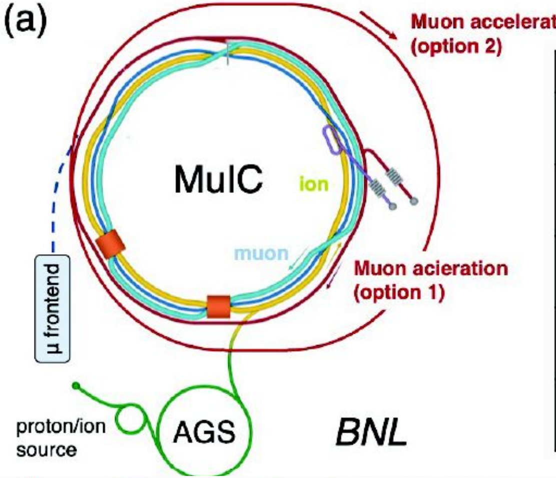


pCsI sprayed with WLS

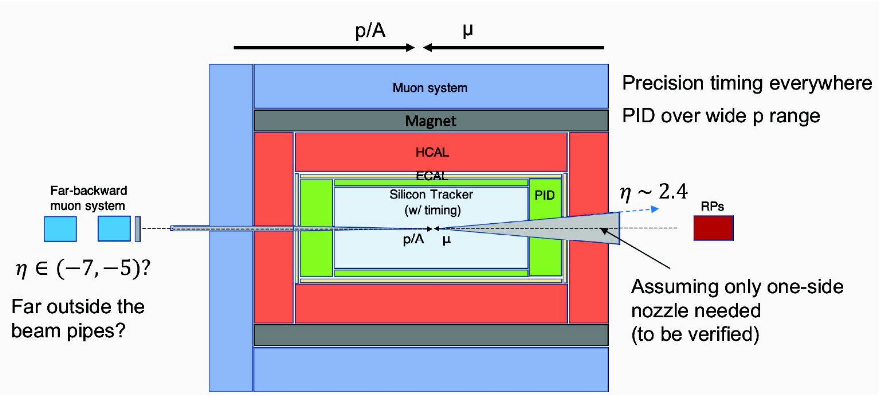




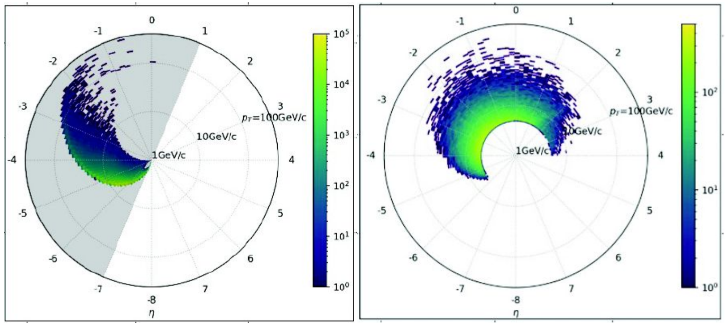
Muon-Ion Collider



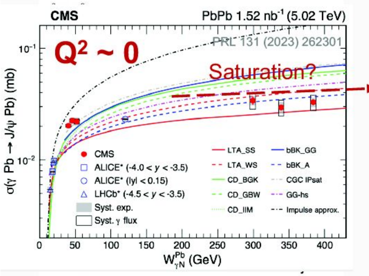
Parameter	2 (realistic)
Muon energy (TeV)	0.96
Muon bending magnets (T)	11 (HL-LHC)
Muon bending radius (m)	290
Proton (Au) energy (TeV)	0.275 (0.11/nucleon)
CoM energy (TeV)	1.03 (0.65)



$\sqrt{s}$ ~ 1TeV, 7-8x increase over EIC



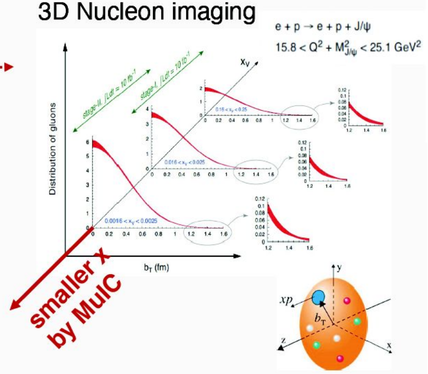
Non-linear QCD effects



MuIC to access a wide range of both x and Q^2

Origin of nucleon mass

3D Nucleon imaging

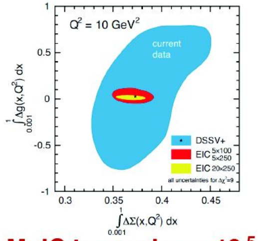


Nucleon spin with polarized beams

"Helicity sum rule"

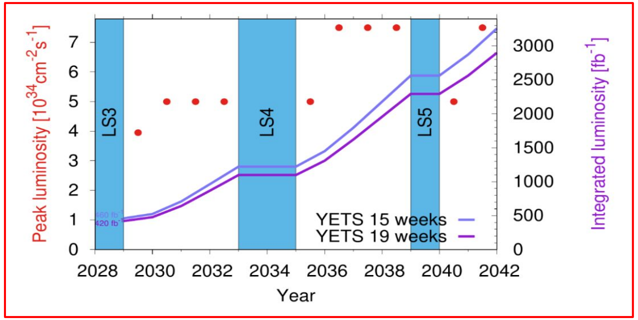
$$\frac{1}{2}\hbar = \frac{1}{2}\Delta\Sigma + \Delta G + \sum_q L_q^z + L_g^z$$

quark contribution, gluon contribution, orbital angular momentum



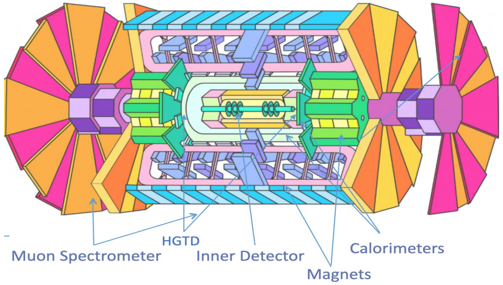
MuIC to reach x ~ 10^{-5}

LHC Upgrades

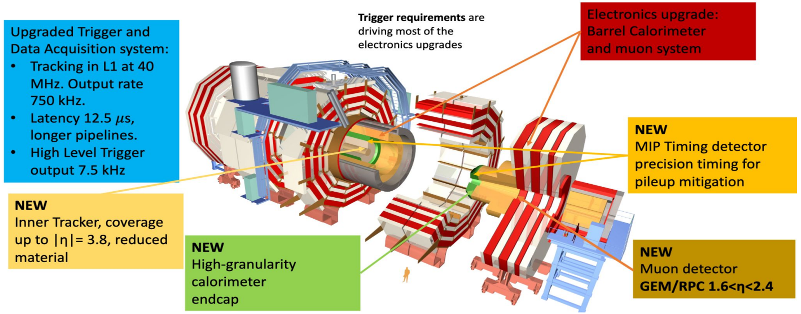


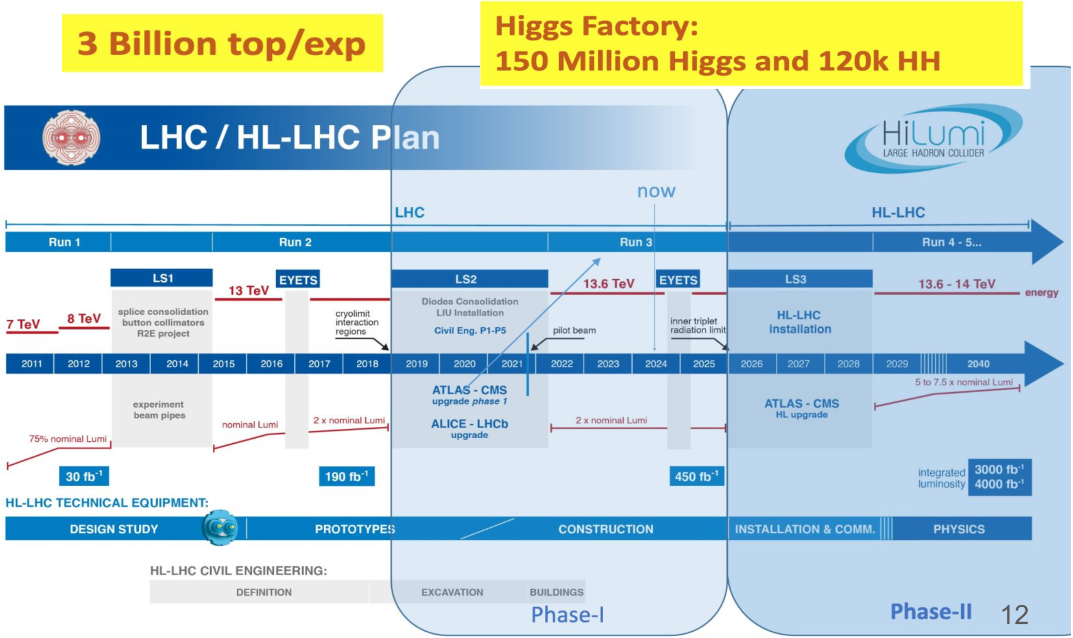
- The HL-LHC programs challenges the detector and detector electronics in many aspects, including high radiation doses and high pile-up
- Upgrades are underway to provide new detectors and read-out electronics to ensure the high efficiency and high-quality data taking in HL-LHC era
- Many projects entering pre-production or production phase

ATLAS



CMS

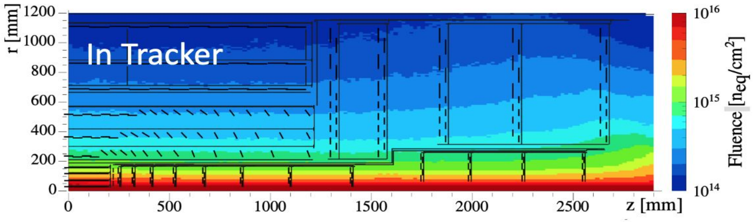


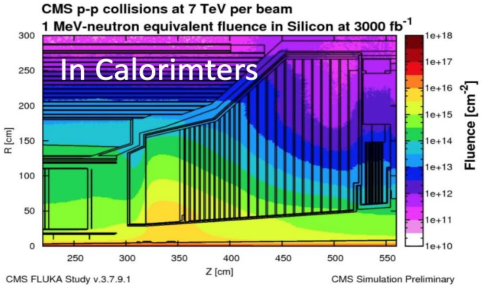


LHC Upgrades - CMS

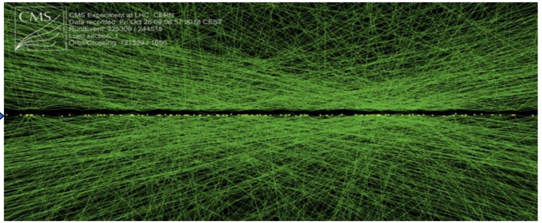
Expect unprecedented amount of radiation

- doses of up to **1 Grad**
- fluences up to **2×10^{16} n_{eq}/cm^2**
- Rate up to **3 GHz/cm²**

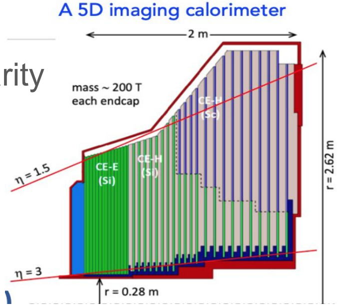


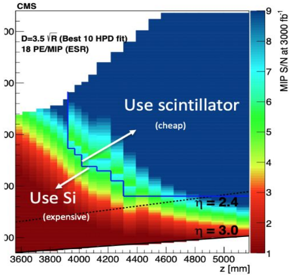


Higher Pileup (~200)



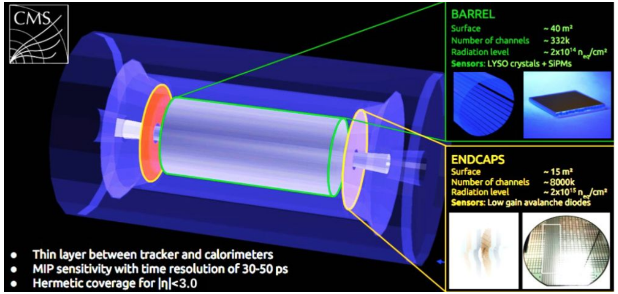
High Granularity Calorimeter



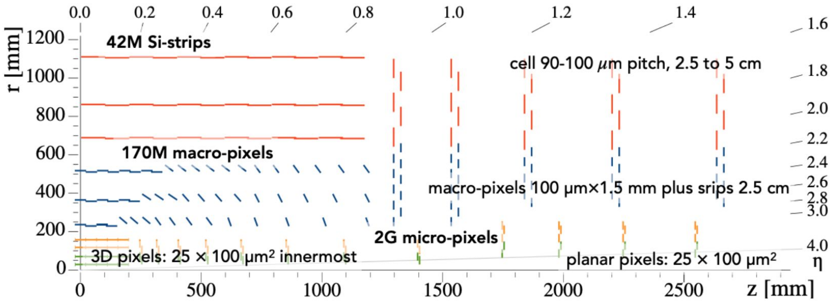


Timing Detector MTD (Barrel & Endcap)

4th dimension for pileup mitigation



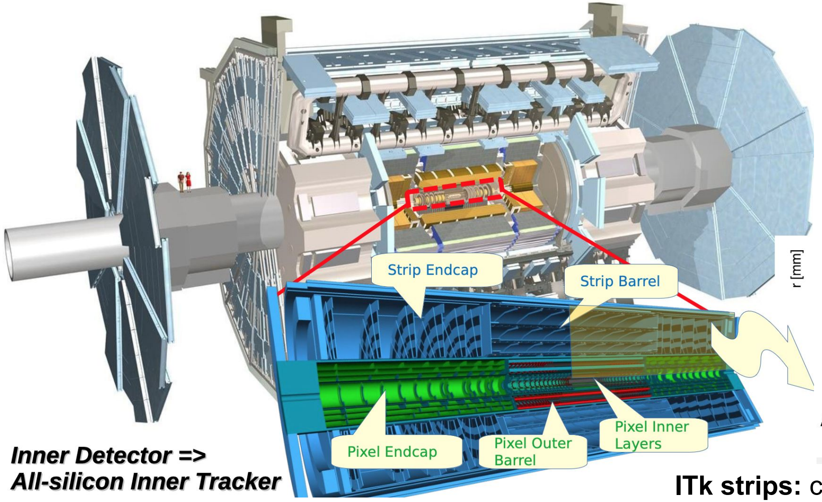
Upgraded Tracker

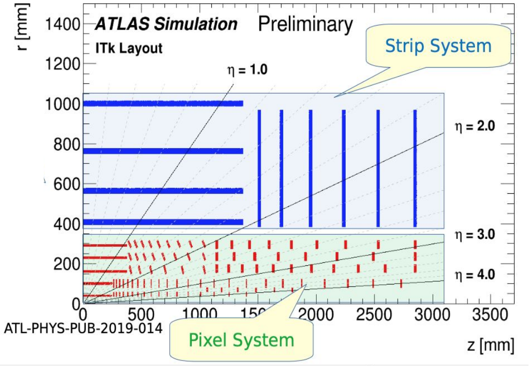


LHC Upgrades - ATLAS

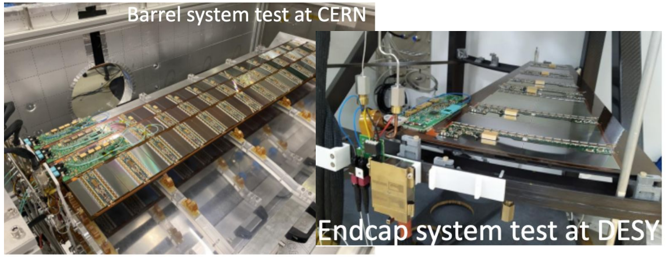
System	Phase-II upgrades
Tracker	Completely new Inner Tracker (ITk), comprised of Pixel and Strip sub-detectors
Calorimetry	On- and off-detector electronics replacement for 40MHz continuous readout
Muons	New muon chambers and upgraded electronics for continuous readout
Forward	New luminosity and timing detector (HGTD), upgrades for other detectors
Trigger & DAQ	New architecture, electronics and software

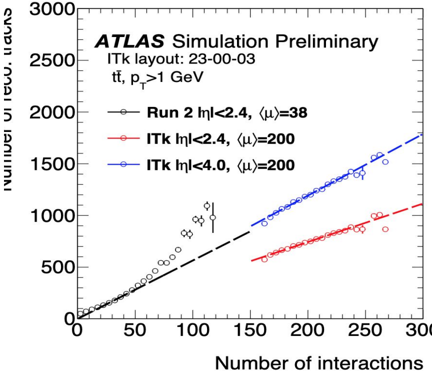
ATLAS Inner Tracker (ITk) - new all-silicon





ITk strips: complex system, production of multiple components, strict QA/QC, multiple institutes worldwide





ITk pixel: new sensor technology, readout FE chips, other ASICs.

Inner System
- L0-L1 layers of flat staves and rings:
  - 2600 modules
  - 2.4 m^2
- L0: 3D single modules, radius = 39mm
- L1: n-in-p planar quad modules
- Replaceable @2000 fb^{-1}

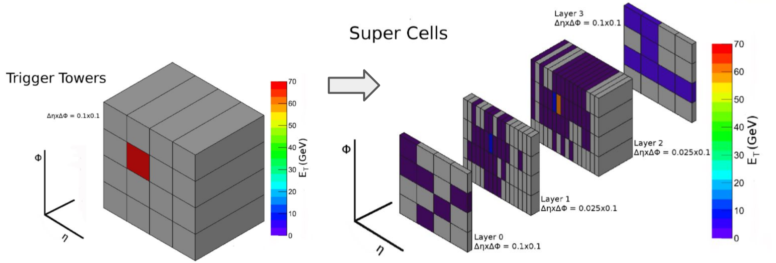
Outer Barrel
- L2-L3-L4 layers of flat staves (longerons) and inclined rings
- 4772 n-in-p planar quad modules
- 6.94 m^2

Outer End-cap
- L2-L3-L4 layers of rings
- 2344 n-in-p planar quad modules
- 3.64 m^2

LHC Upgrades - ATLAS

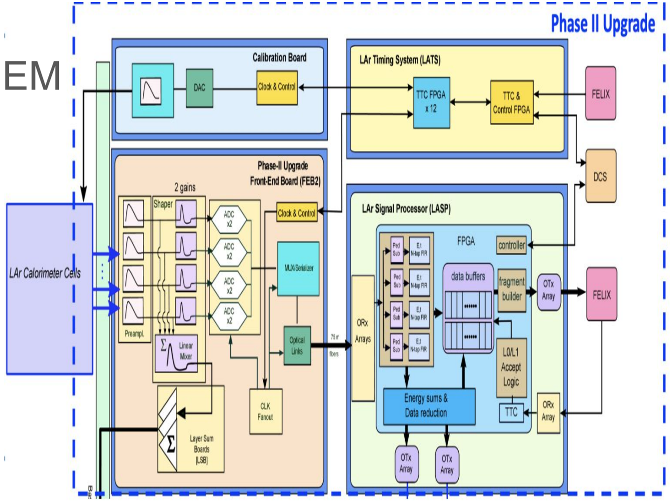
EM and Hadronic Calorimeters

- New on- and off-detector electronics

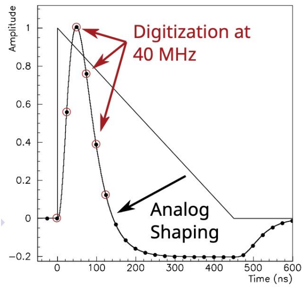


Legacy from Phase I Upgrade of EM LAr calorimeter:

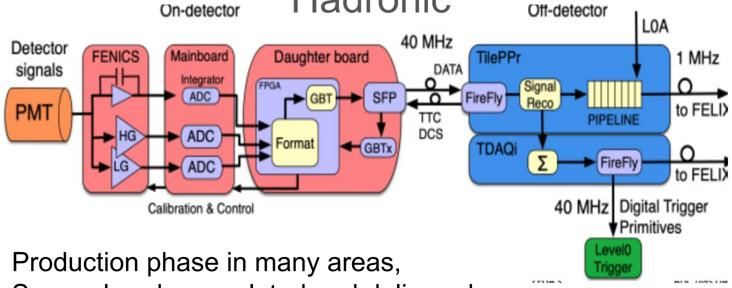
10-fold increase in granularity (5k trigger towers → 34k Super Cells)



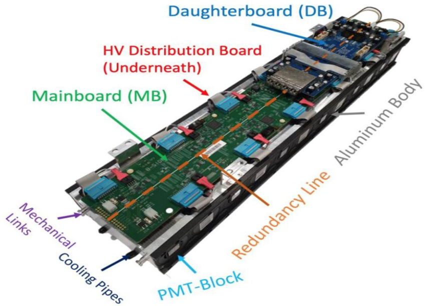
Machine Learning outperforms Optimal Filter, especially for overlapping signals, ongoing implementation in FPGA



Hadronic



Production phase in many areas,
Some already completed and delivered



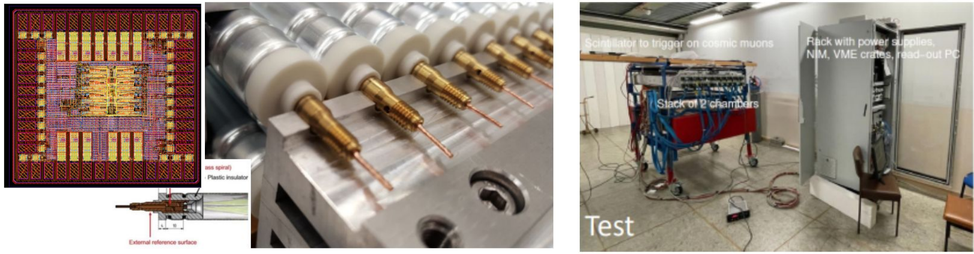
Trigger and DAQ

- Single-level HW trigger at 1 MHz
- Detector read-out with 10us latency at 5 TB/s (FELIX)
- 2.5-25 Gb/s optical links

LHC Upgrades - ATLAS

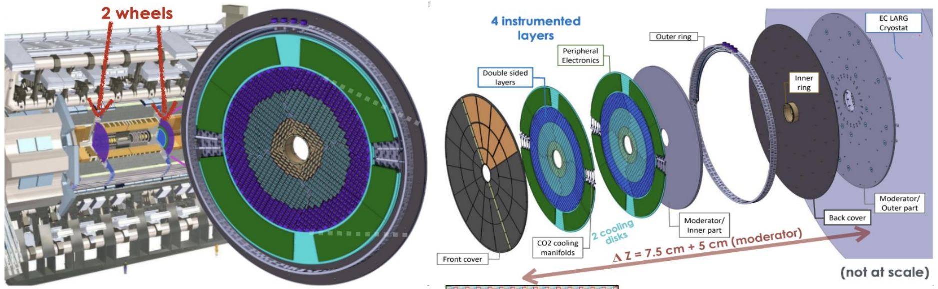
- Upgrade of several types of Muon Chambers
  - Barrel Inner (BI) RPC+sMDT
  - End-Cap Inner Layer (EIL) TGC
- Upgrade of readout electronics Upgrade of power systems
- Extensive integration tests in multiple sites

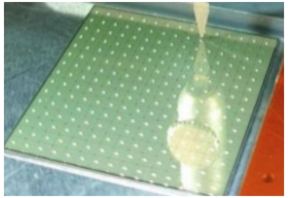
RPC FE ASIC prototype



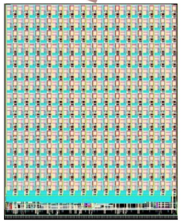
New sMDT chamber tubes and test of chambers after production

High Granularity Timing Detector

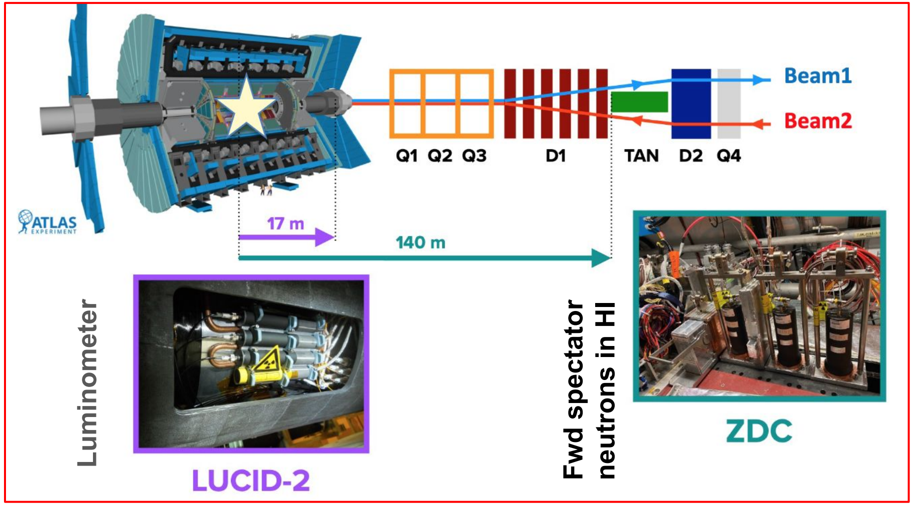




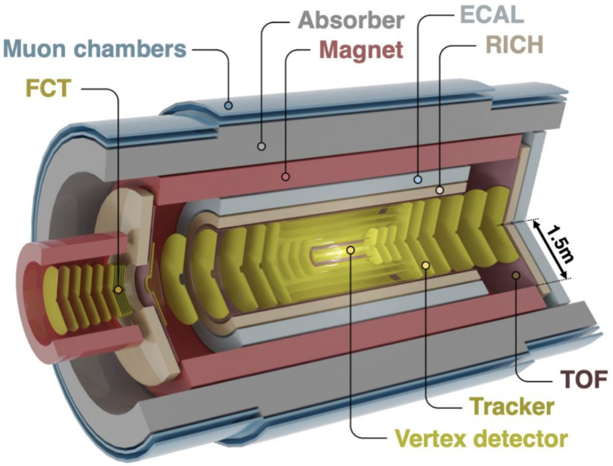
LGAD sensor



ALTIROC-A

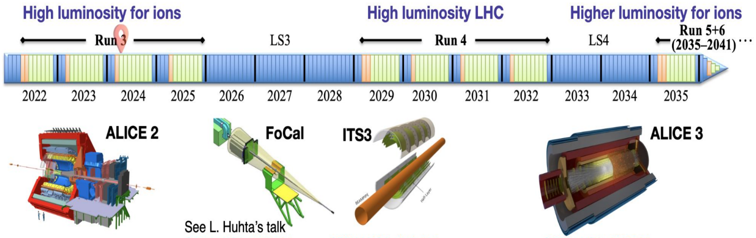


LHC Upgrades - ALICE



ALICE designed to study the microscopic dynamics of the strongly-interacting matter produced in heavy-ion LHC collisions

- Ambitious upgrade program

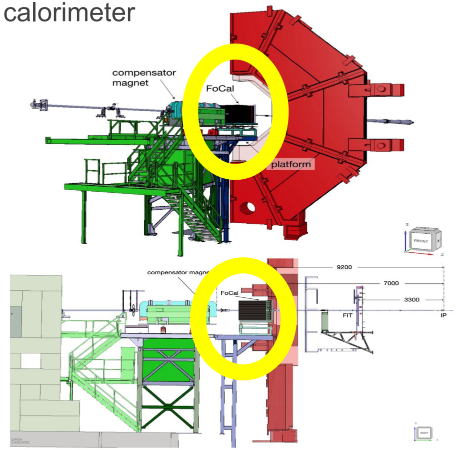


See L. Huhta's talk
CERN-LHCC-2020-009
CERN-LHCC-2024-004

CERN-LHCC-2019-018
CERN-LHCC-2024-003

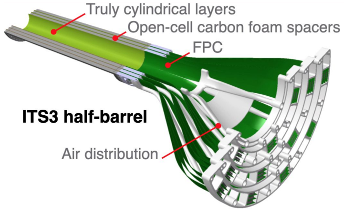
CERN-LHCC-2022-009

The Forward Calorimeter (**FoCal**): highly granular Si+W EM calorimeter combined with sampling hadronic calorimeter



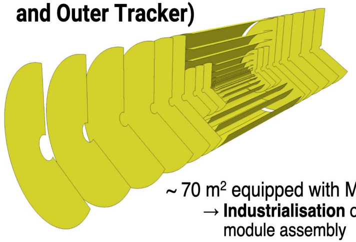
ITS3: new ultra-light, bent layers made of wafer-scale 65 nm MAPS

- Air cooled, low material (0.05% X_0)
- Interest in this novel technology by several other experiments, e.g. ePIC

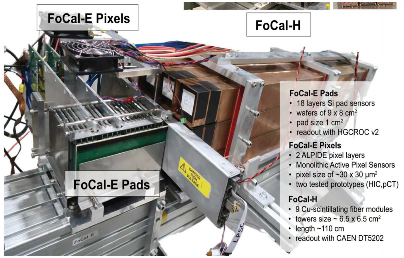


Thinned Wafers are bent and held together by carbon foam

Tracker (Middle layers and Outer Tracker)



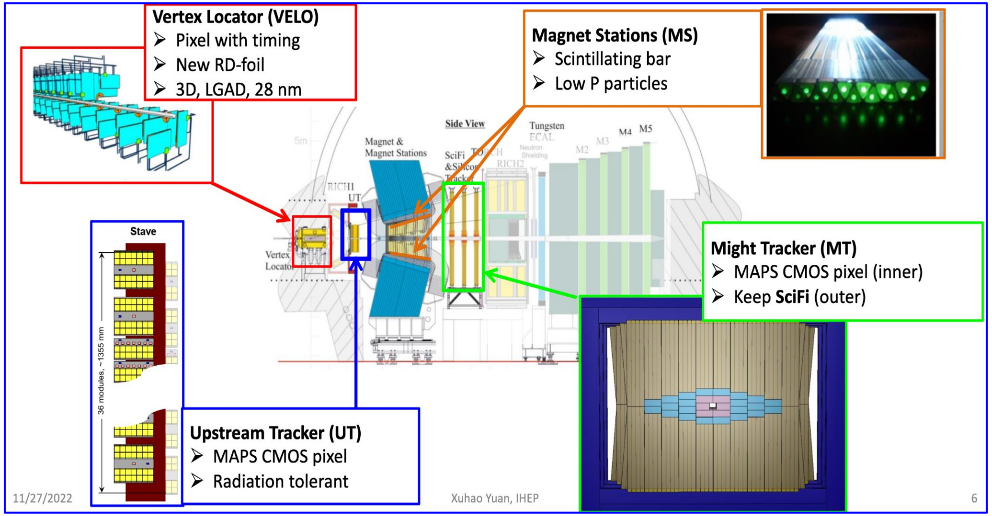
~ 70 m^2 equipped with MAPS!
→ **Industrialisation** of the module assembly



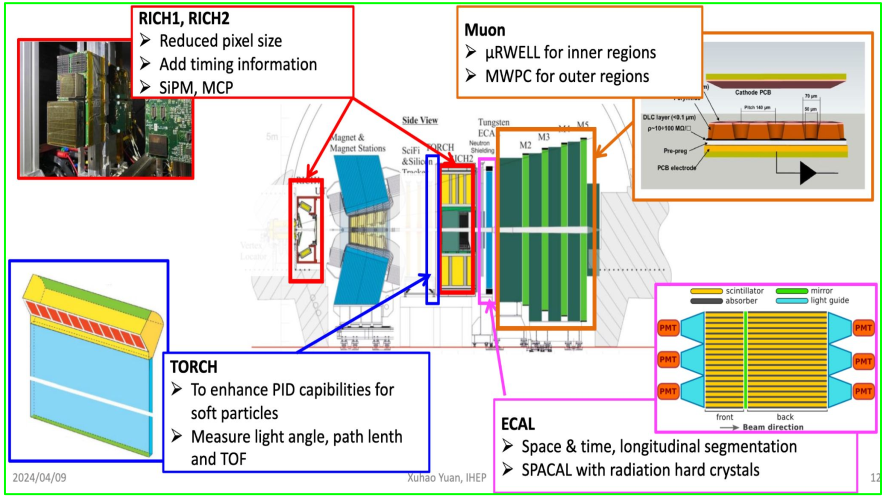
Test Beam

LHC Upgrades - LHCb

Tracking Detectors Upgrade II



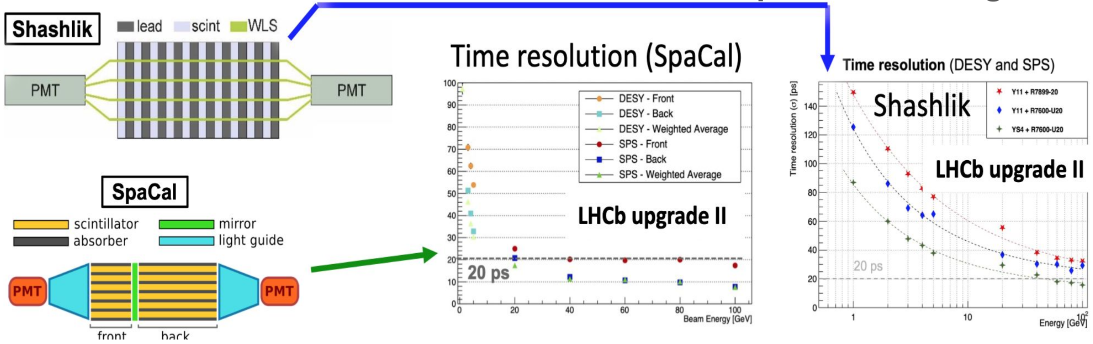
PID Detectors



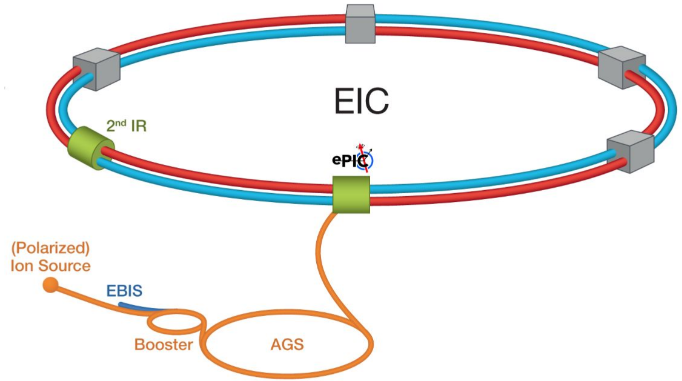
LHCb is focused on flavor physics and beyond

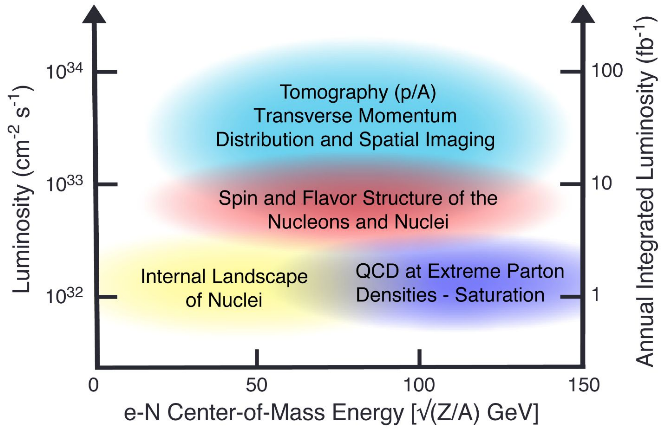
- Upgrade I: installation completed
- Upgrade II: starts in LS4, R&D now to fully exploit HL-LHC

5D Calorimeter with precision timing



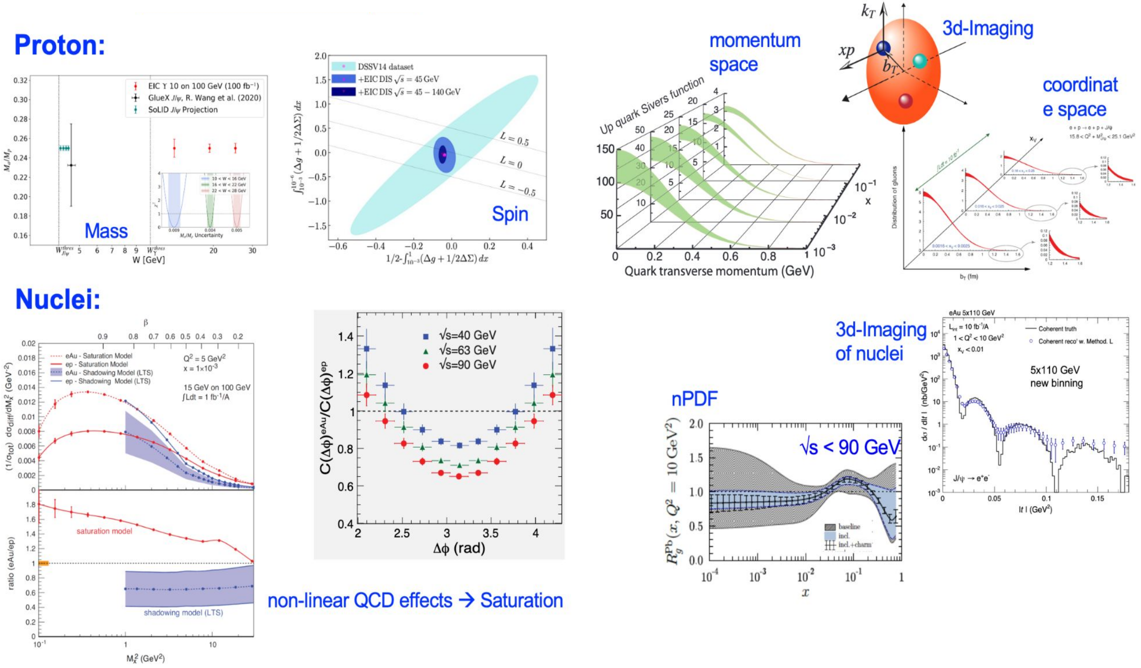
Electron Ion Collider



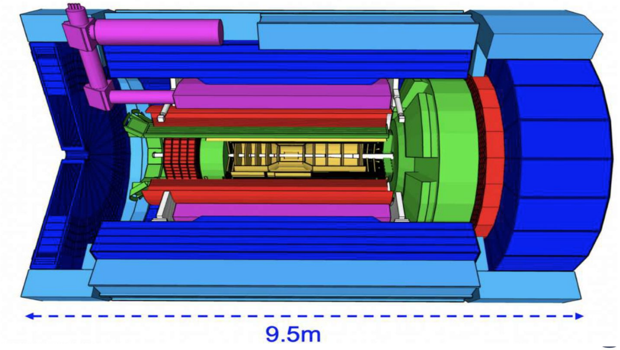


Electron-Ion Collider: The Next QCD Frontier

- 1st detector: ePIC
- 2nd detector at IP8 - still conceptual

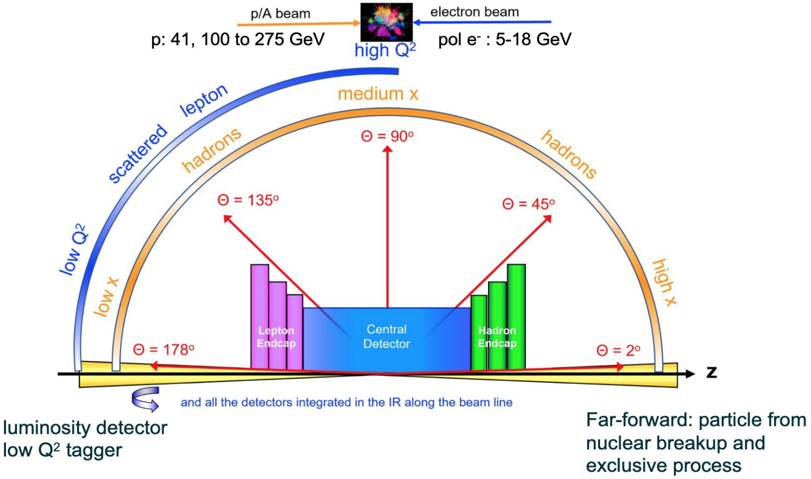


Electron Ion Collider - ePIC



Luminosity: 10^{33} - 10^{34} $cm^{-2}s^{-1}$

Center-of-mass energy: 28 - 140 GeV



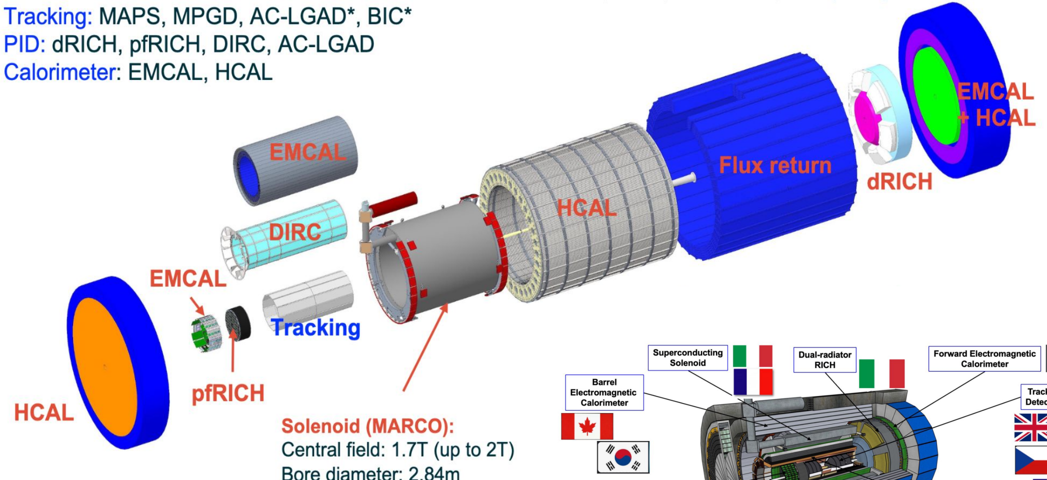
Length x Radius = 9.5m x 3.3m

ePIC detector geometry database: https://eic.jlab.org/Geometry/Detector/

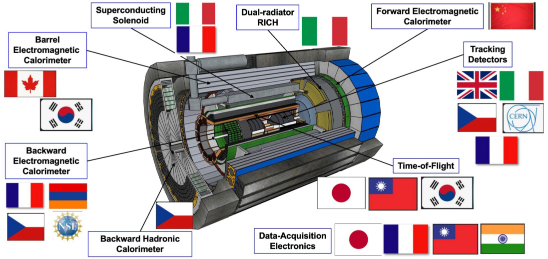
Tracking: MAPS, MPGD, AC-LGAD*, BIC*

PID: dRICH, pfRICH, DIRC, AC-LGAD

Calorimeter: EMCAL, HCAL



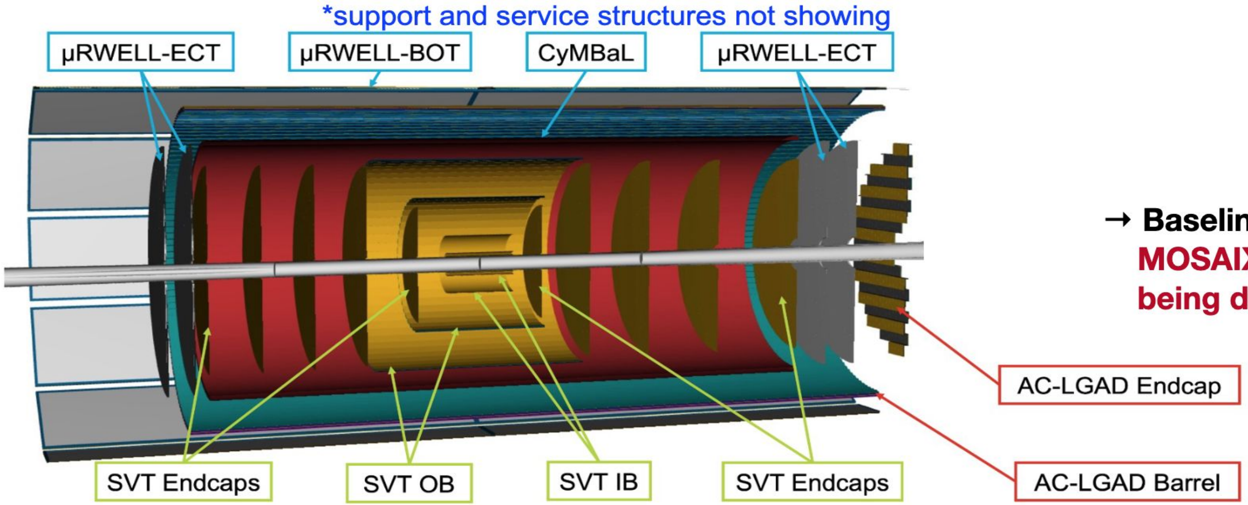
ePIC Detector Overview @ DIS2024



- ePIC is scheduled to begin running in 2032
- CD3 & Construction to begin in earnest in 2025
- A 2nd Detector at IR8 is foreseen with generic, expanded and unique capabilities (R&D funds available)

Electron Ion Collider - ePIC

Tracking Systems



Requirements:
- High pattern recognition efficiency
- High spatial resolution
- Low material budget
- Good time resolution

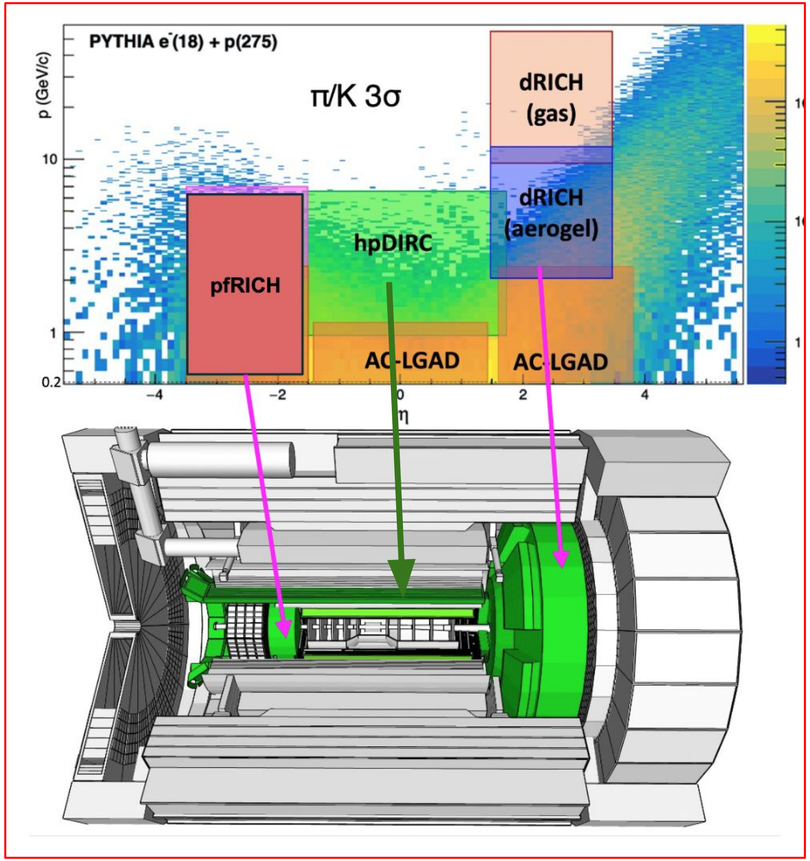
→ **Baseline technological choice for the sensor:**
MOSAIX sensor in 65 CMOS technology being developed for the ALICE ITS3 upgrade

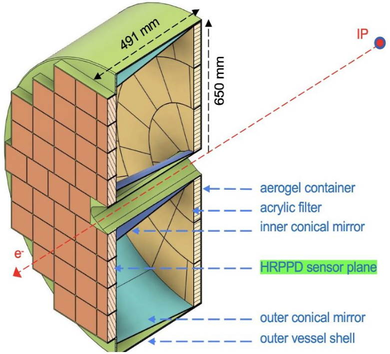
SVT sensor area is much larger (~8m²)!
→ Adapt the ITS3 MOSAIX to develop EIC-Large Area Sensors (LAS)

Silicon Vertex Tracker (SVT):
- Monolithic Active Pixel Sensor (MAPS): ~20x20um
- 3 vertex barrels: ITS3 curved wafer-scale sensor, 0.05% X/X_0
- 2 outer barrels: ITS3 based Large Area Sensors (EIC-LAS), 0.55% X/X_0
- 5 disks (forward/backward), EIC-LAS, 0.24% X/X_0

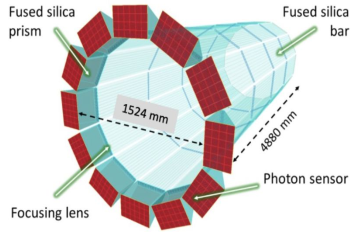
Electron Ion Collider - ePIC

PID Systems

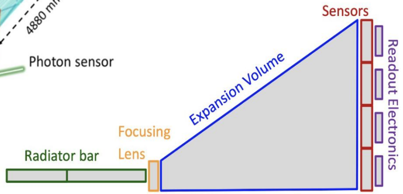


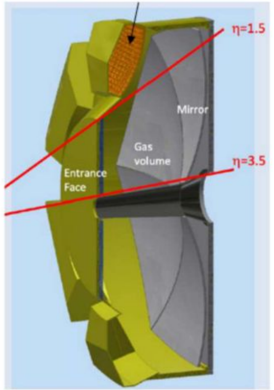


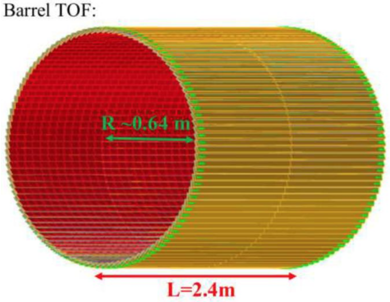
pfRICH



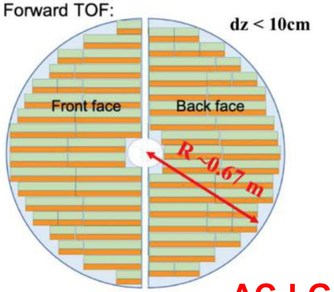
hpDIRC







500 umX1cm strips
(1%X0)



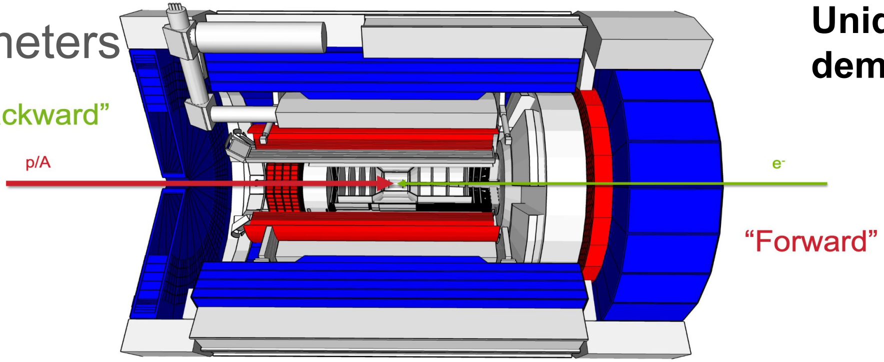
500 umX500um pixels
(~3%X0)

AC-LGAD sensors:

- Space resolution: 30 μm
- Time resolution: 20 ps

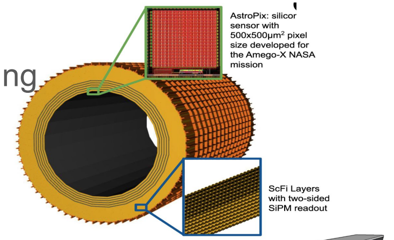
Electron Ion Collider - ePIC

Calorimeters

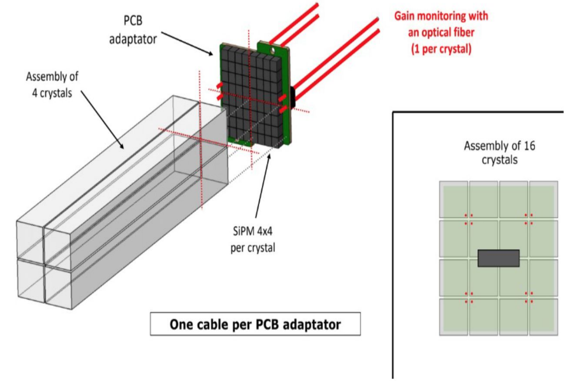


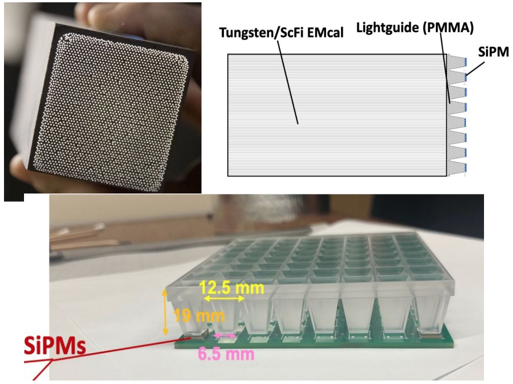
Unique calorimetry designs to meet the varied demands of the different detector regions

Barrel EM: Hybrid sampling Pb/SciFi + Silicon pixel sensors (AstroPix MAPS)

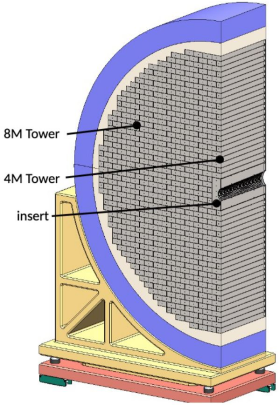


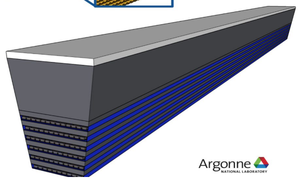
Backward EM: PbWO4 read out by SiPM

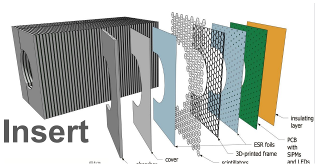




Fwd EM: Tungsten + SciFi SPACAL







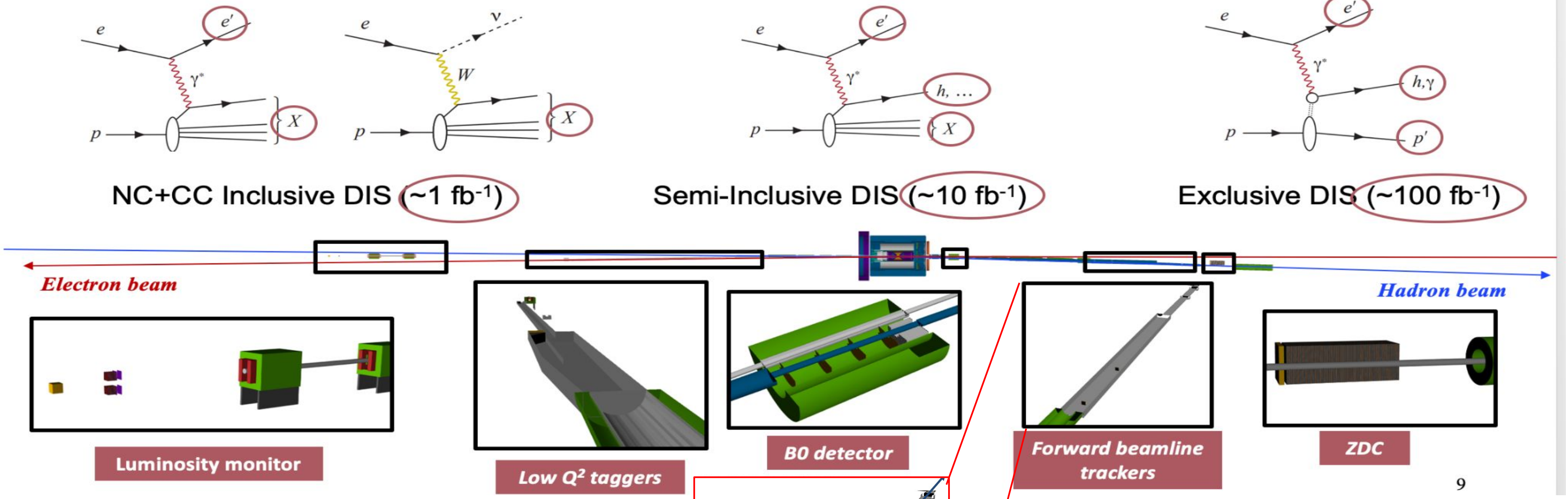
Fwd Insert

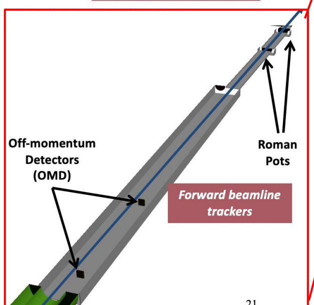
Fwd HAD: Steel + Scintillator SiPM-on-tile

- Pioneered by CALICE analog HCal
- Ideal for particle-flow measurements!

Electron Ion Collider - ePIC

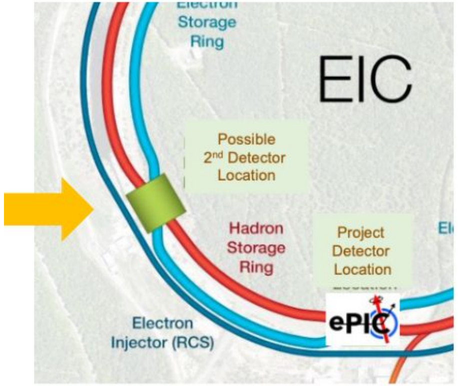
- The extended detector's array required to enable primary physics objectives:





Far Forward - Far Backward Detectors:
integral part of the ePIC physics program

Detector II at EIC

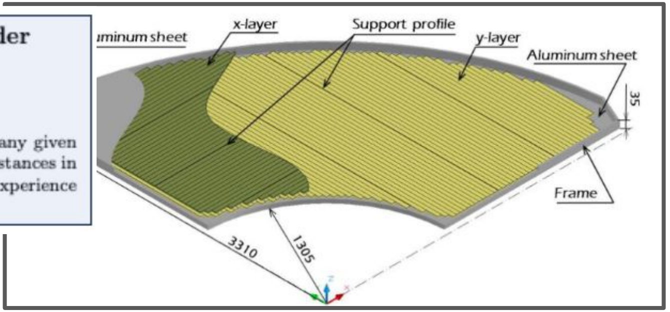


Motivation for Two Detectors at a Particle Physics Collider

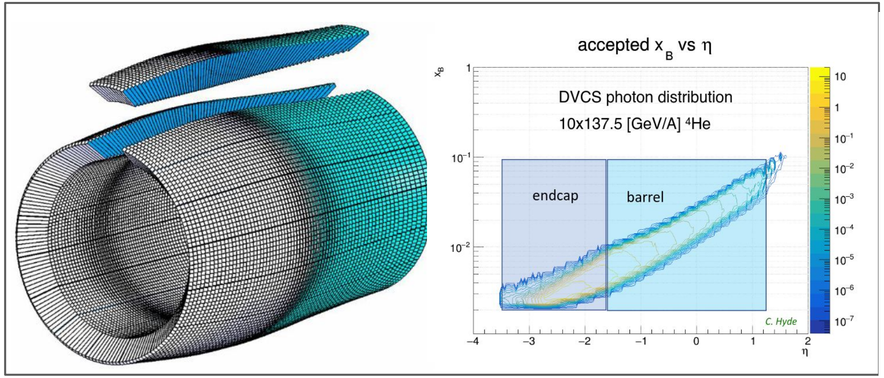
Paul D. Grannis* and Hugh E. Montgomery†
(Dated: March 27, 2023)

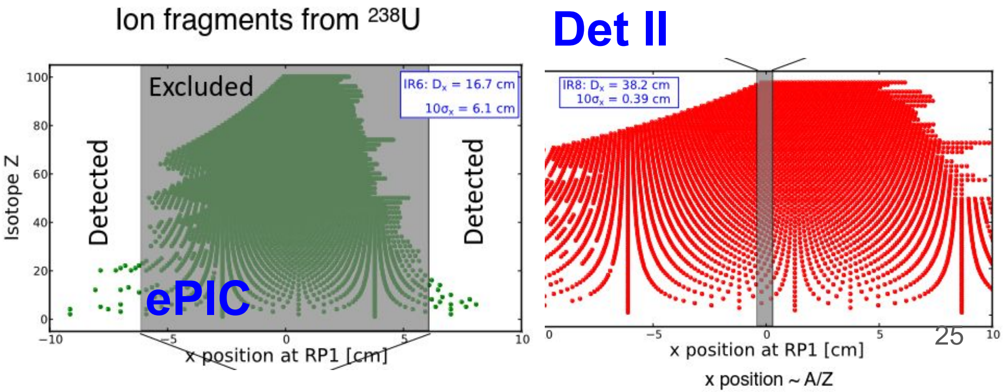
It is generally accepted that it is preferable to build two general purpose detectors at any given collider facility. We reinforce this point by discussing a number of aspects and particular instances in which this has been important. The examples are taken mainly, but not exclusively, from experience at the Tevatron collider.

Enhanced μ detection

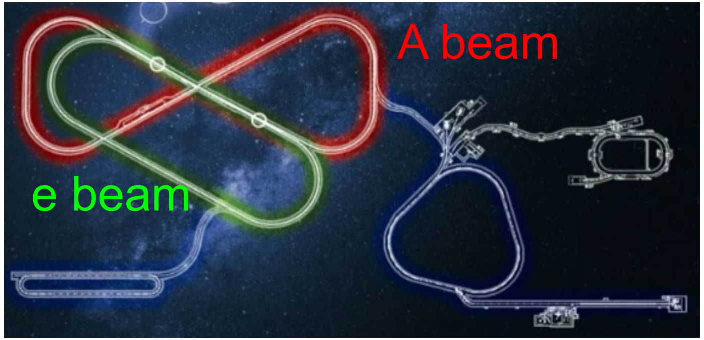


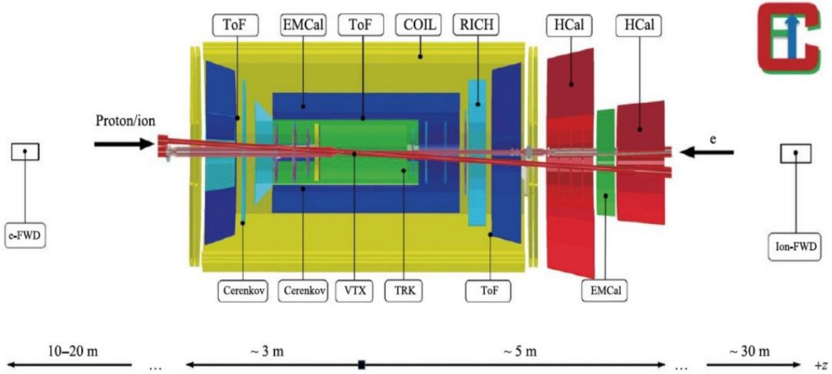
High resolution Calorimeter



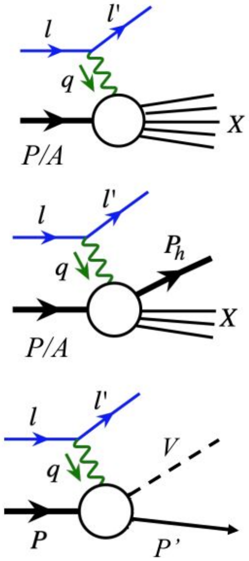


EIcC: Electron Ion Collider in China





- Energy in c.m.: 15 ~ 20 GeV
- Electron beam: 3.5 GeV, polarization ~ 80%
- Proton beam: 20 GeV, polarization ~ 70%
- Luminosity: $\gtrsim 2 \times 10^{33}$ cm$^{-2}\cdot$ s^{-1}
- Other available polarized ion beams: d, $^{3}He^{++}$
- Available unpolarized ion beams: $^{7}Li^{3+}$, $^{12}C^{6+}$, $^{40}Ca^{20+}$, $^{197}Au^{79+}$, $^{208}Pb^{82+}$

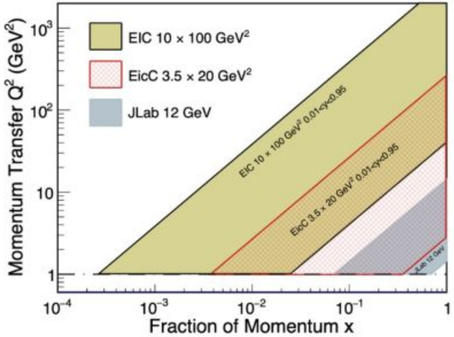


Nucleon spin structure:
EicC is optimized to systematically explore the gluon and sea quarks in moderate x regime
At a crucial place between JLab and EIC-US

Partonic structure in nuclear environment:
Parton distribution in nuclei at moderate x
Fast parton/hadron interaction with cold nuclear matter

Exotic hadron states:
Independent confirmation of hidden-charm pentaquarks and search for hidden-bottom analogues
Exotic hadron production: final particles in mid-rapidity

Proton mass / quarkonium production:
Systematic investigation of Υ near threshold production
Complementary kinematic coverage to EIC-US
Combine with J/ψ production at JLab

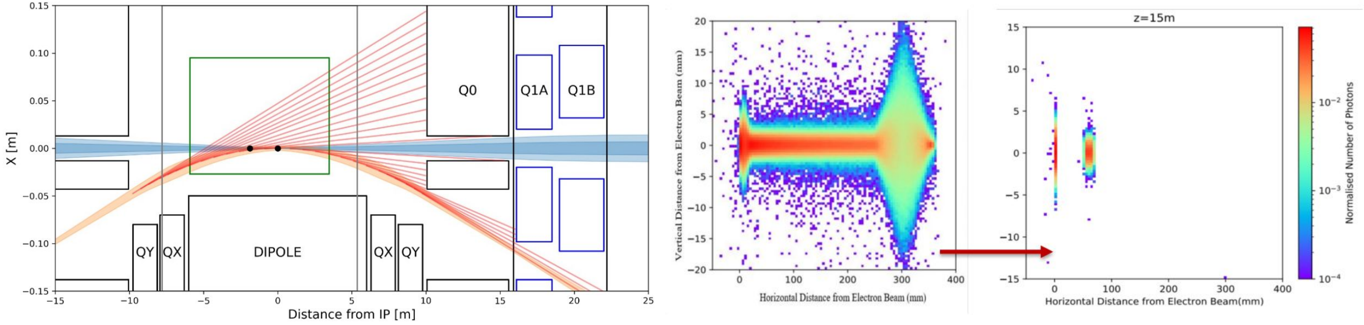


LHeC

Standalone Higgs, Top, EW, BSM programme
→ General purpose particle physics detector
→ Good performance for all high p_T particles
→ Heavy Flavour tagging

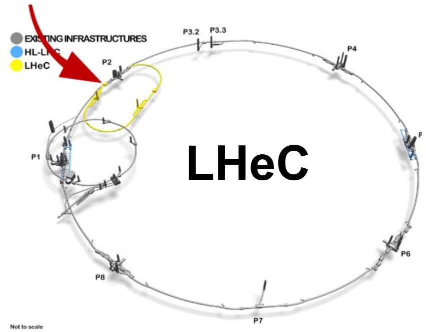
Precision proton PDFs, including very low x parton dynamics in ep,eA
→ Dedicated DIS exp't
→ Hermeticity
→ Hadronic final state resolution for kinematics
→ Flavour tagging / PID
→ Beamline instruments

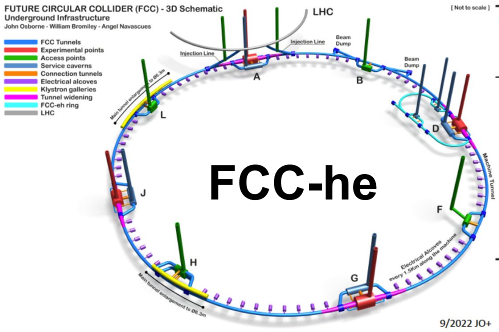
6



Synchrotron mitigation with elliptical beampipe, collimators and absorption on the Q0

LHeC and FCC-eh



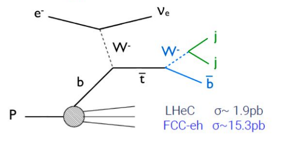


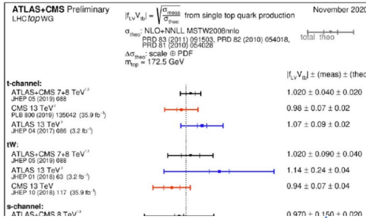
Parameter	Unit	LHeC				FCC-eh	
		CDR	Run 5	Run 6	Dedicated	E_p=20 TeV	E_p=50 TeV
E_e	GeV	60	30	50	50	60	60
N_p	10^{11}	1.7	2.2	2.2	2.2	1	1
ϵ_p	μm	3.7	2.5	2.5	2.5	2.2	2.2
I_e	mA	6.4	15	20	50	20	20
N_e	10^9	1	2.3	3.1	7.8	3.1	3.1
β^*	cm	10	10	7	7	12	15
Luminosity	10^{33} cm^{-2}s^{-1}	1	5	9	23	8	15

$$\text{DIS at } \sqrt{s} \simeq 1.3/2.2/3.5 \text{ TeV}, \quad \int \mathscr{L}dt \sim 1-2 \text{ ab}^{-1} \sim 1000 \times \text{HERA}$$

Top physics: CKM

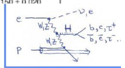
- At the LHeC, limits on several CKM matrix elements can be set using single top production (V_{tb} to 1% at LHeC and FCC-eh): polarisation essential.

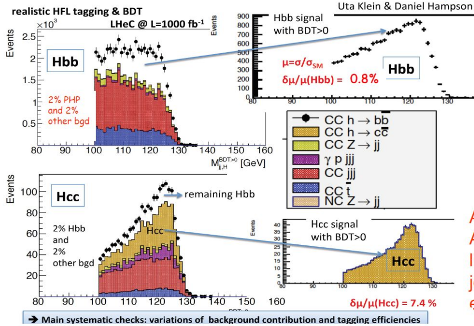




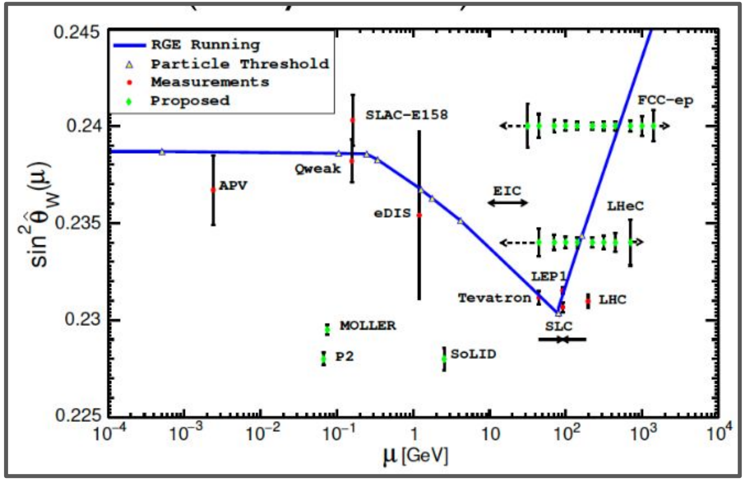
$$V_{CKM} = \begin{pmatrix} V_{ud} & V_{us} \\ V_{cd} & V_{cs} \\ V_{td} & V_{ts} \end{pmatrix}$$

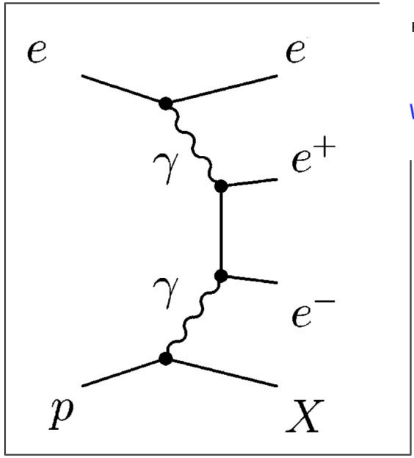
Higgs in ep – clean S/B, no pile-up



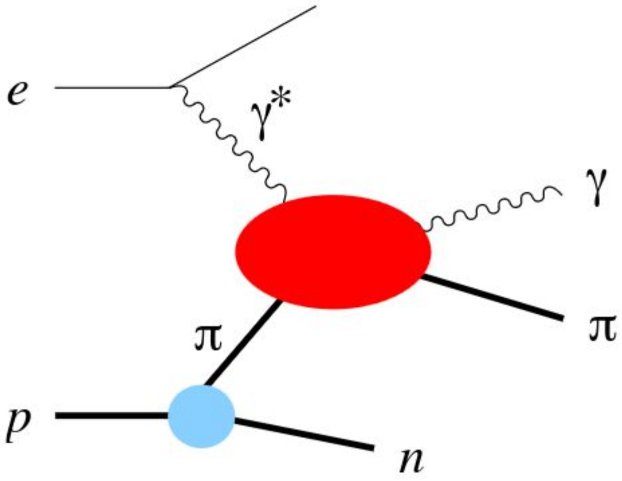


Assuming ATLAS light jet misID efficiencies





Backward DVCS on the pion in Sullivan processes



Different regions → different kinematics → different structure functions!

- Forward region → small t-channel: GPDs;
- Backward region → large t-channel but small u-channel: Transition Distribution Amplitudes;

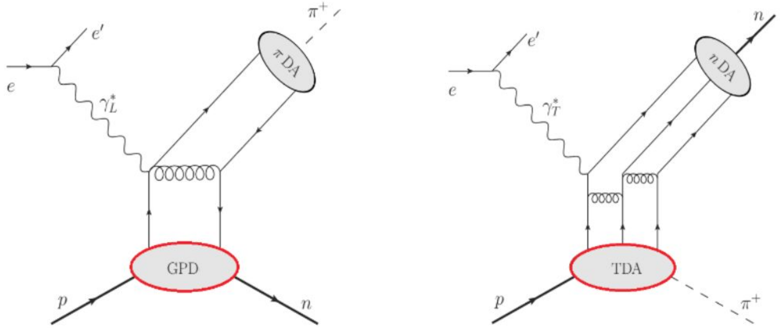
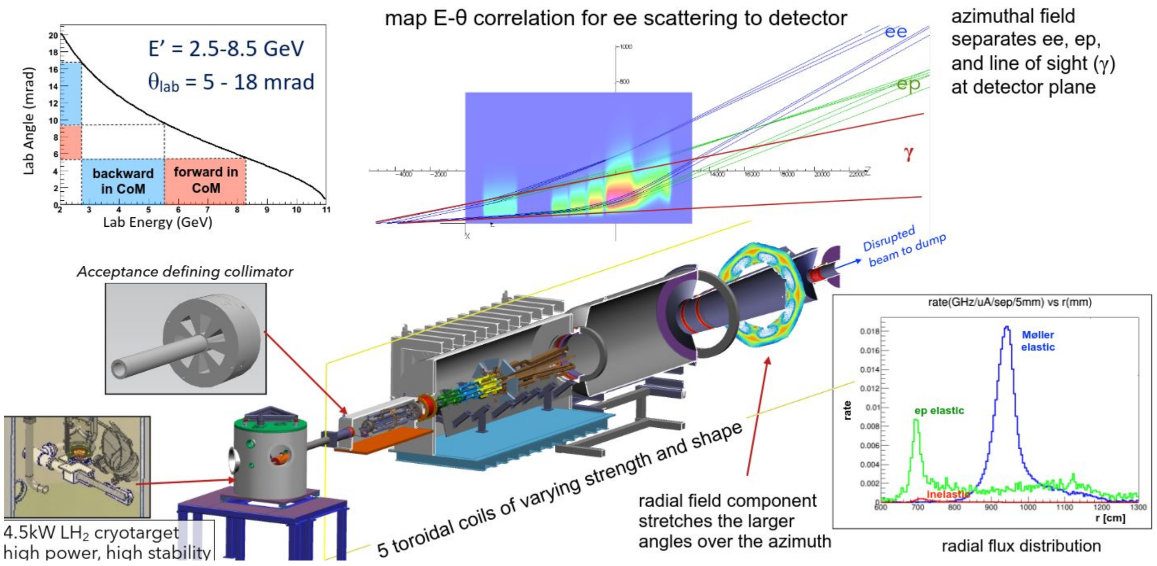
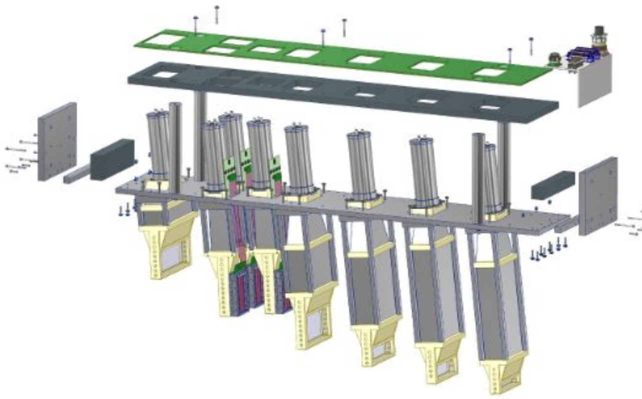
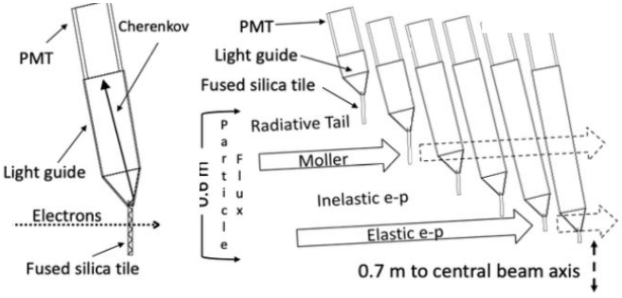


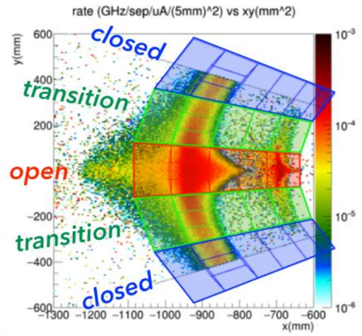
Figure: Exclusive $ep \to en\pi^+$ process description (S. Diehl and Joo, 2020).

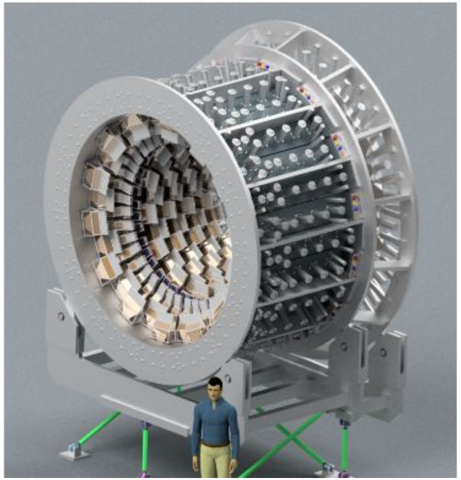
Moller Experiment at 12 GeV Jefferson Lab





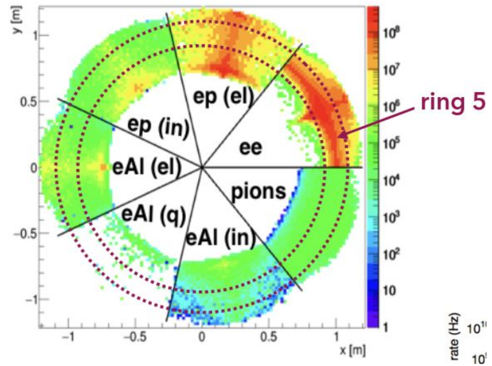


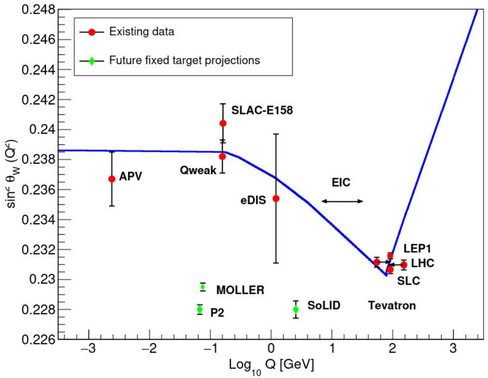




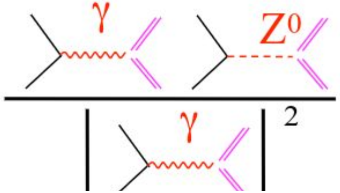
Moller Experiment Cont.

Illustration of signal and background distributions





$$A_{PV} = \frac{\sigma_R - \sigma_L}{\sigma_R + \sigma_L} \sim$$



$$\propto \frac{|\mathcal{M}_Z|}{|\mathcal{M}_\gamma|}$$

High luminosity and acceptance *Møller Rate ~ 130 GHz*

- 125cm, 4.5kW LH_2 target
- 65 μA beam current at 11 GeV
- 85% polarization
- "large" acceptance (~100% of high FOM kinematics)

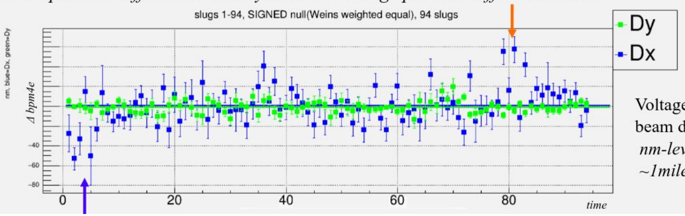
Integrate time

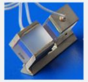
- 344 beam days (~3-4 calendar years)
- Radiation resistance for materials and electronics

Monitor position differences and try to drive average position difference down

Sign Corrected Data

$D_x = \Delta x/2 = (x_0 - x_1)/2$



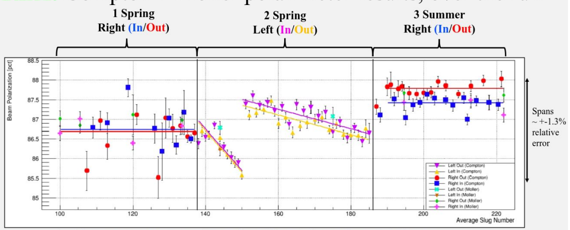


Voltage controlled beam direction

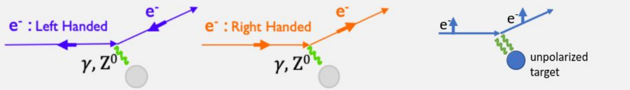
nm-level control

~1mile downstream

CREX: Compton + Moller polarimeter results, over the run



3. Transverse Beam Polarization



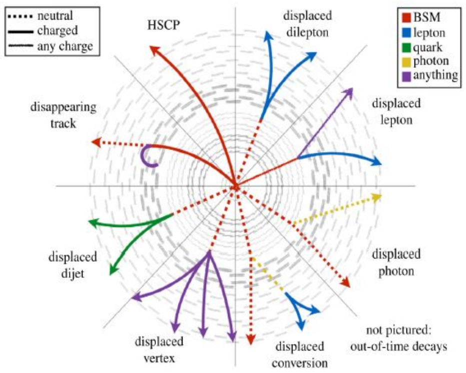
A_{phys} extraction requires effort on multiple fronts:

- $R_{radcorr}$ (radiative correction)
- R_{accept} (acceptance)
- R_{Q^2} (Q^2-scaling)
- P_L (beam polarization)
- $\frac{1}{1-\sum_i f_i}$ (Overall background dilution)
- $P_L \sum_i f_i A_i$ (backgrounds)
- A_{corr} (Corrected Asymmetry)
- A_{beam} (Beam corrections)
- **A_{trans} (Transverse asymmetry correction)**
- A_{nonlin} (Detector nonlinearity)
- A_{blind} (Blinding factor)

$$A_{phys} = R_{radcorr}\, R_{accept}\, R_{Q^2} \frac{A_{corr} - P_L \sum_i f_i A_i}{P_L(1-\sum_i f_i)}$$

$$A_{corr} = A_{det} - A_{beam} - A_{trans} - A_{nonlin} - A_{blind}$$

International Large Detector Experiment

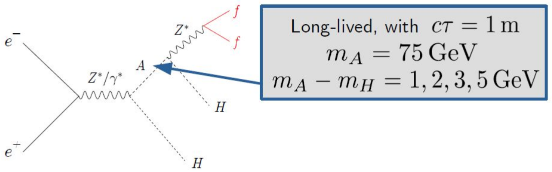


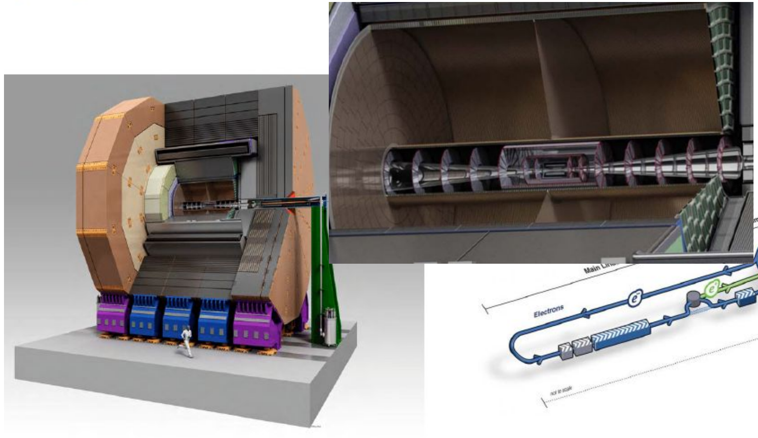
https://doi.org/10.1098/rsta.2019.0047

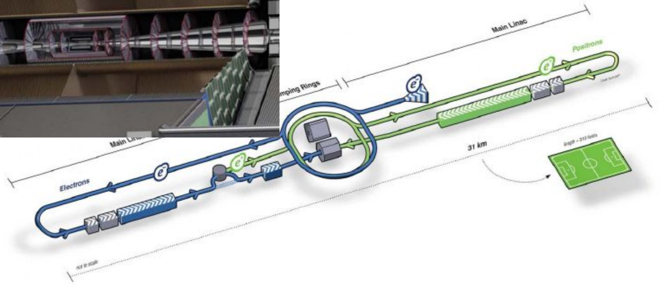
		Small coupling	Small phase space	Scale suppression
SUSY	GMSB			✓
	AMSB		✓	
	Split-SUSY			✓
	RPV	✓		
NN	Twin Higgs	✓		
	Quirky Little Higgs	✓		
	Folded SUSY		✓	
DM	Freeze-in	✓		
	Asymmetric			✓
	Co-annihilation		✓	
Portals	Singlet Scalars	✓		
	ALPs			✓
	Dark Photons	✓		
	Heavy Neutrinos			✓

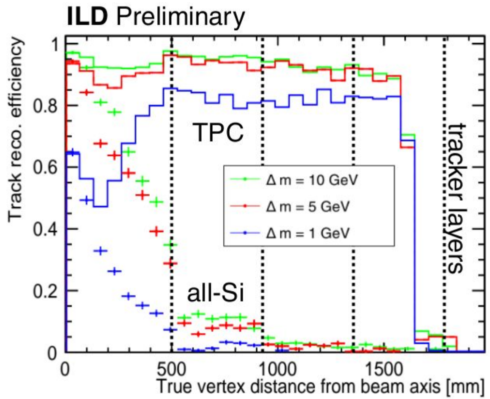
1810.12602

→ heavy scalar LLP (A) and DM (H) pair-production with small mass splitting, $Z^* \to \mu\mu$









Thank you and see you in the future!

Beautiful Room of WG6

Take away message from WG6: future is bright! (very busy)