EICL: Luminosity detectors for future electron-ion colliders

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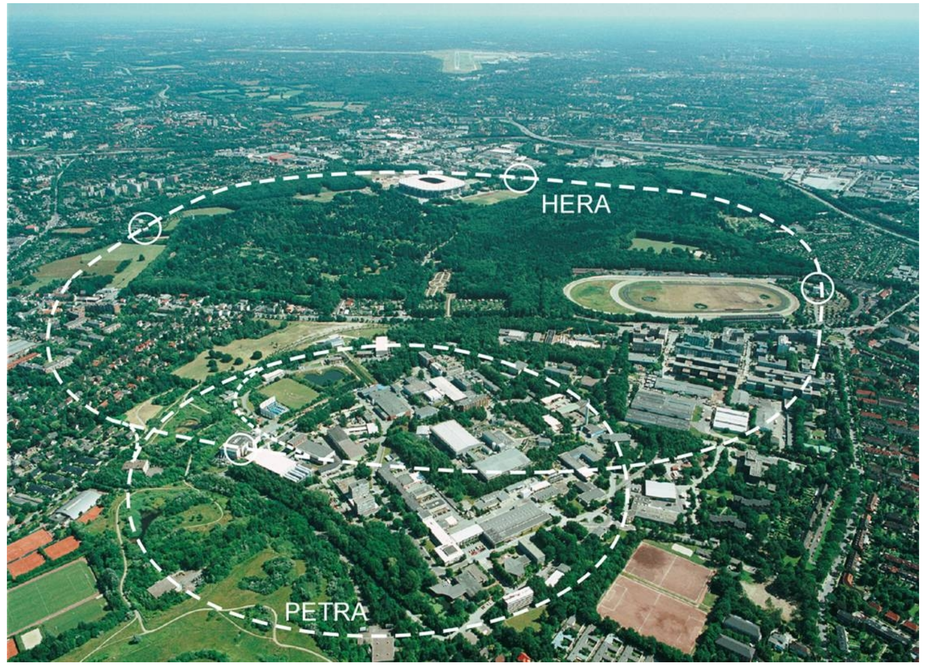
Hadron Physics in Horizon Europe
Town meeting
July 1-3, 2025

JOHANNES GUTENBERG UNIVERSITÄT MAINZ

JG|U

UNIVERSITY of York

Lepton-ion colliders key element in hadronic physics



HERA at DESY, Germany
(1992-2007)

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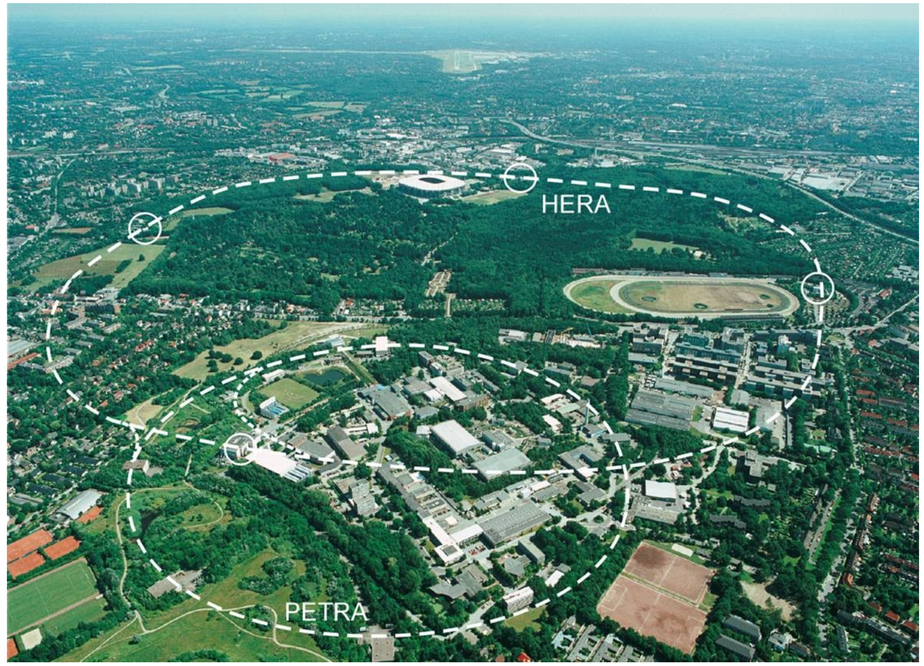

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In-progress, first science
expected mid-2030s

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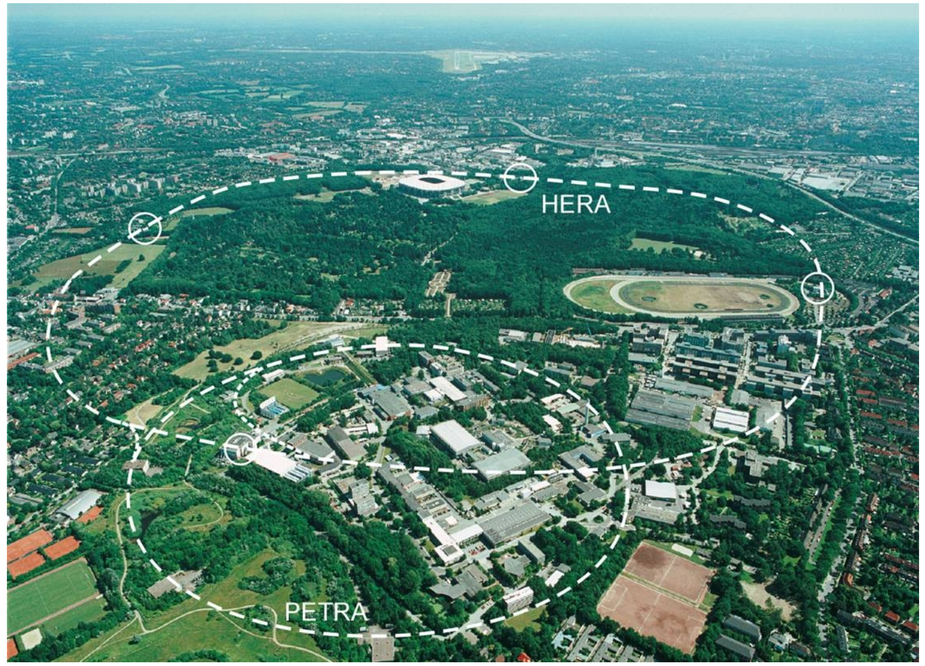

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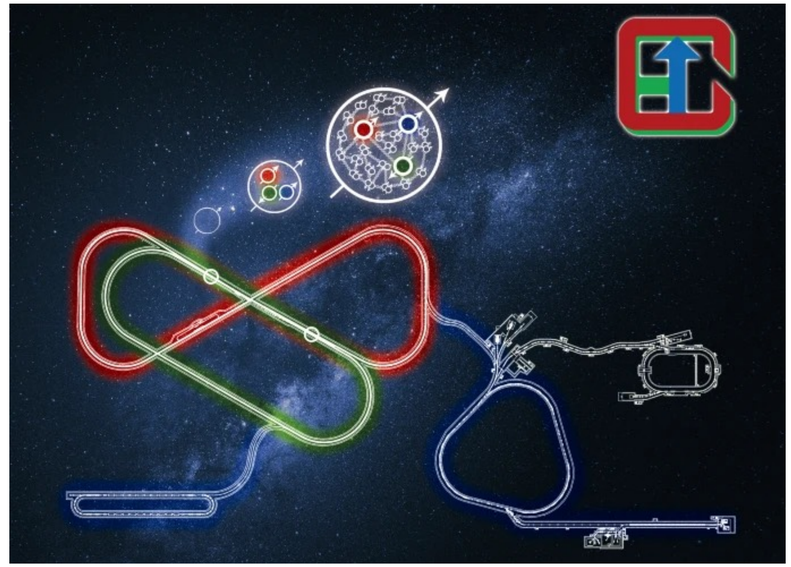
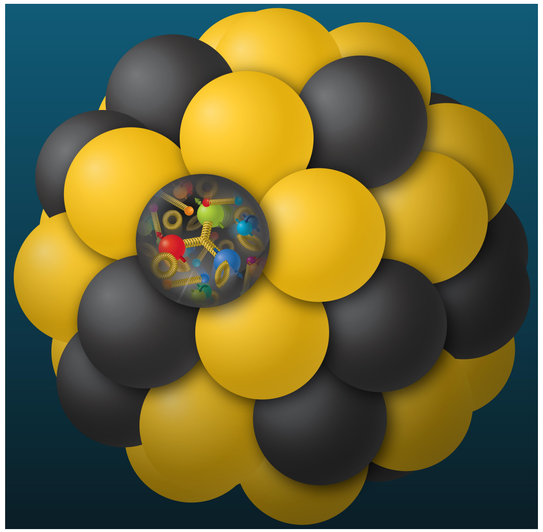
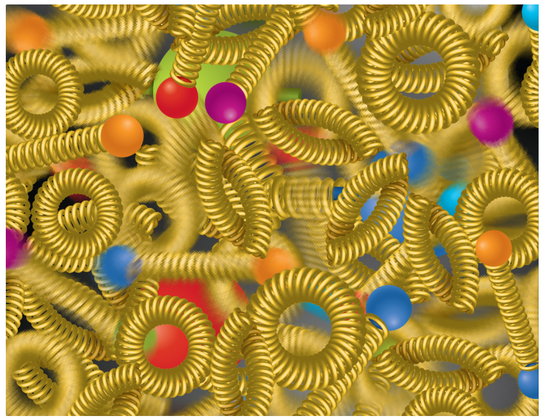


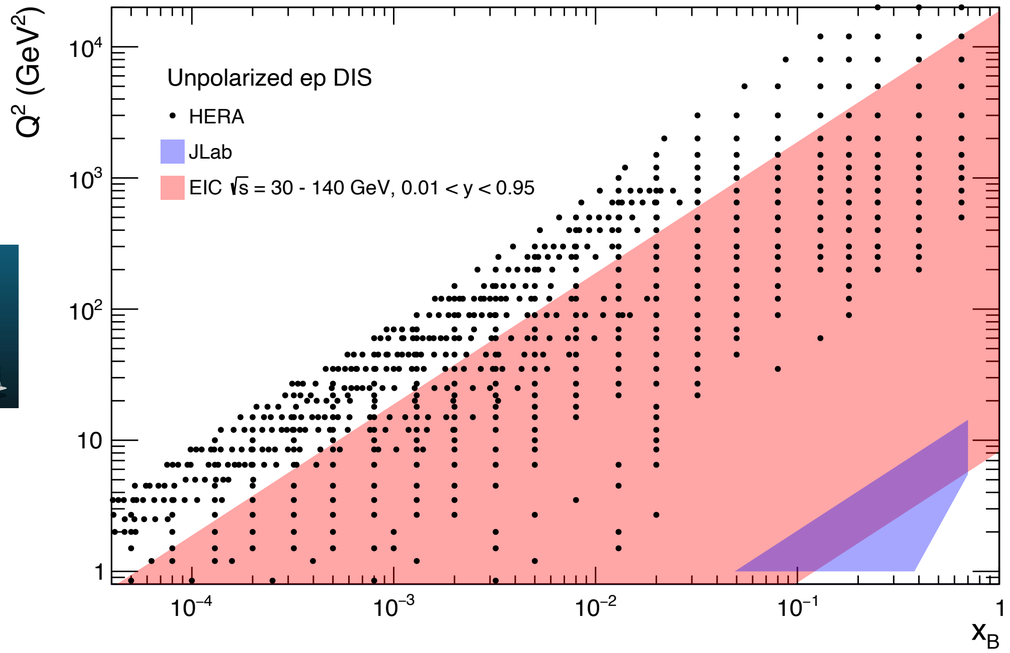
EIC-China
In development

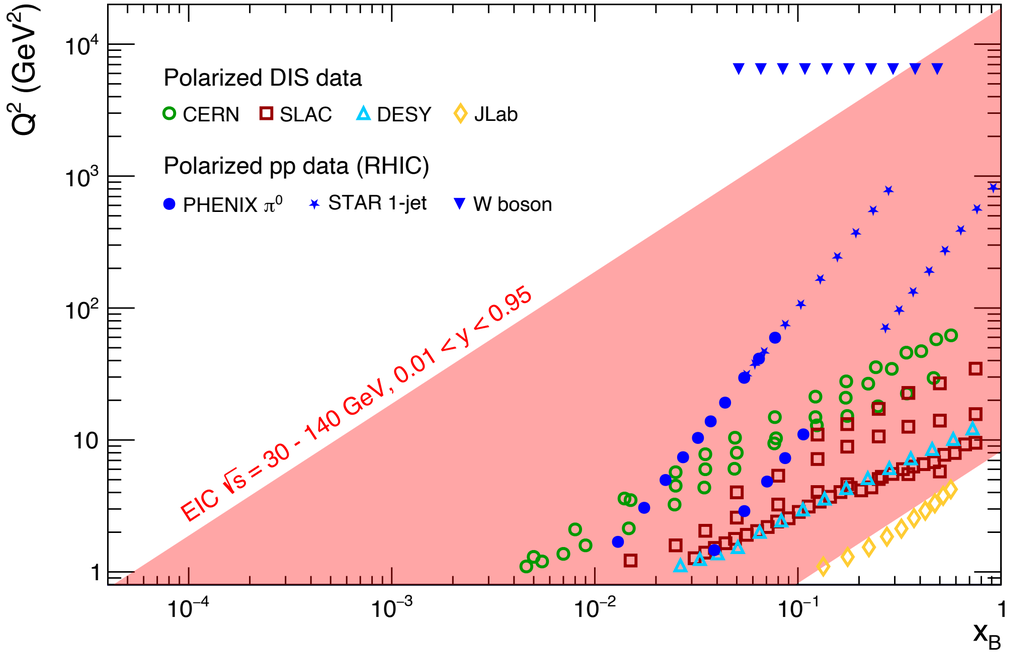
EIC provides a novel way to study emergence of nucleons/nuclei from QCD

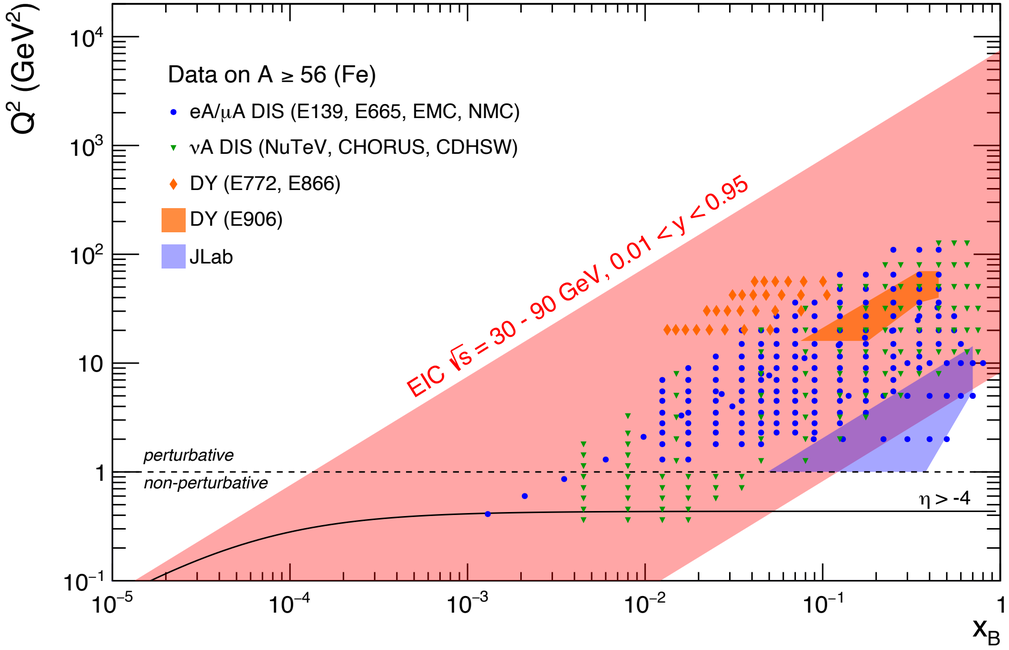
- How do the mass & spin of the nucleon arise?
- What is the 3D structure of the nucleon?
- How do quarks and gluons interact in the nuclear medium?
- What are the properties of dense gluons matter?

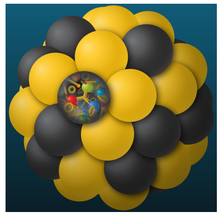


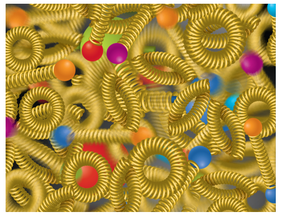



Unpolarized ep DIS
HERA
JLab
EIC √s = 30 - 140 GeV, 0.01 < y < 0.95
Q² (GeV²)
x_B


Polarized DIS data
CERN
SLAC
DESY
JLab
Polarized pp data (RHIC)
PHENIX π⁰
STAR 1-jet
W boson
EIC √s = 30 - 140 GeV, 0.01 < y < 0.95
Q² (GeV²)
x_B


Data on A ≥ 56 (Fe)
eA/μA DIS (E139, E665, EMC, NMC)
νA DIS (NuTeV, CHORUS, CDHSW)
DY (E772, E866)
DY (E906)
JLab
EIC √s = 30 - 90 GeV, 0.01 < y < 0.95
perturbative
non-perturbative
η > -4
Q² (GeV²)
x_B

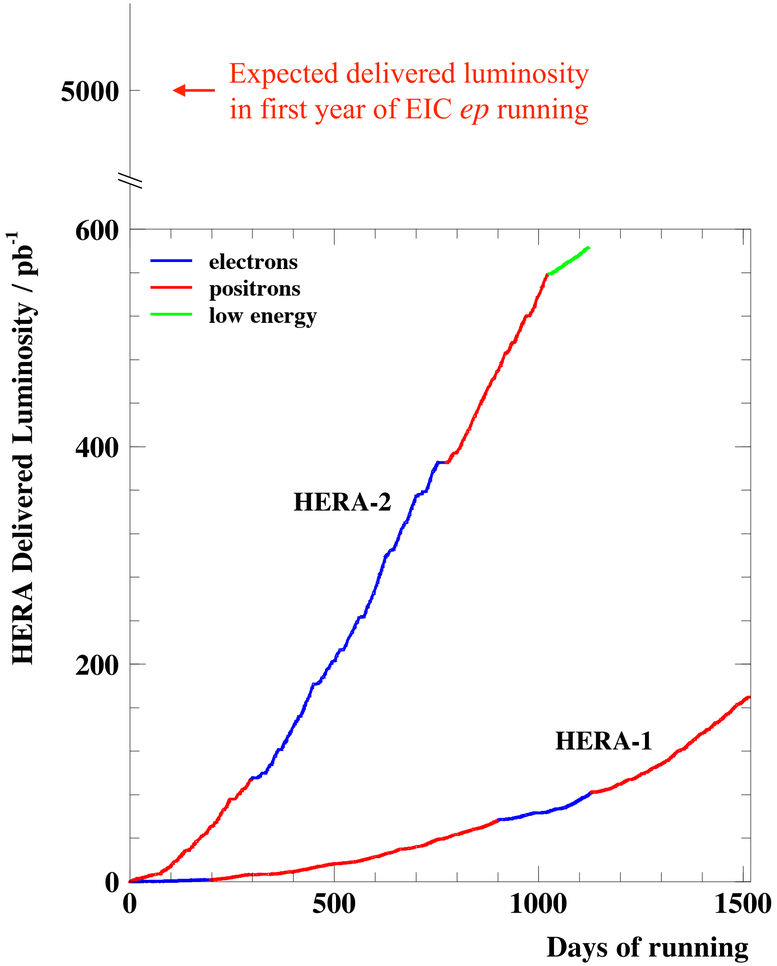




High-precision luminosity critical for next-gen colliders

- EIC (BNL) will exceed HERA's total integrated luminosity in <1 year
  → *Systematics limited!*
- Luminosity is a key parameter in nearly all physics analyses
  → *Physics impact limited by precision!*

- *High-precision* luminosity critical for future collider facilities
  → EIC goal: ≤1% (absolute), 10^{-4} (relative bunch-to-bunch)
- This must be accomplished at unprecedentedly *high luminosities*



HERA demonstrated luminosity measurement with bremsstrahlung

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- Pure QED process
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- HERA precision:
  - 1% at HERA-I
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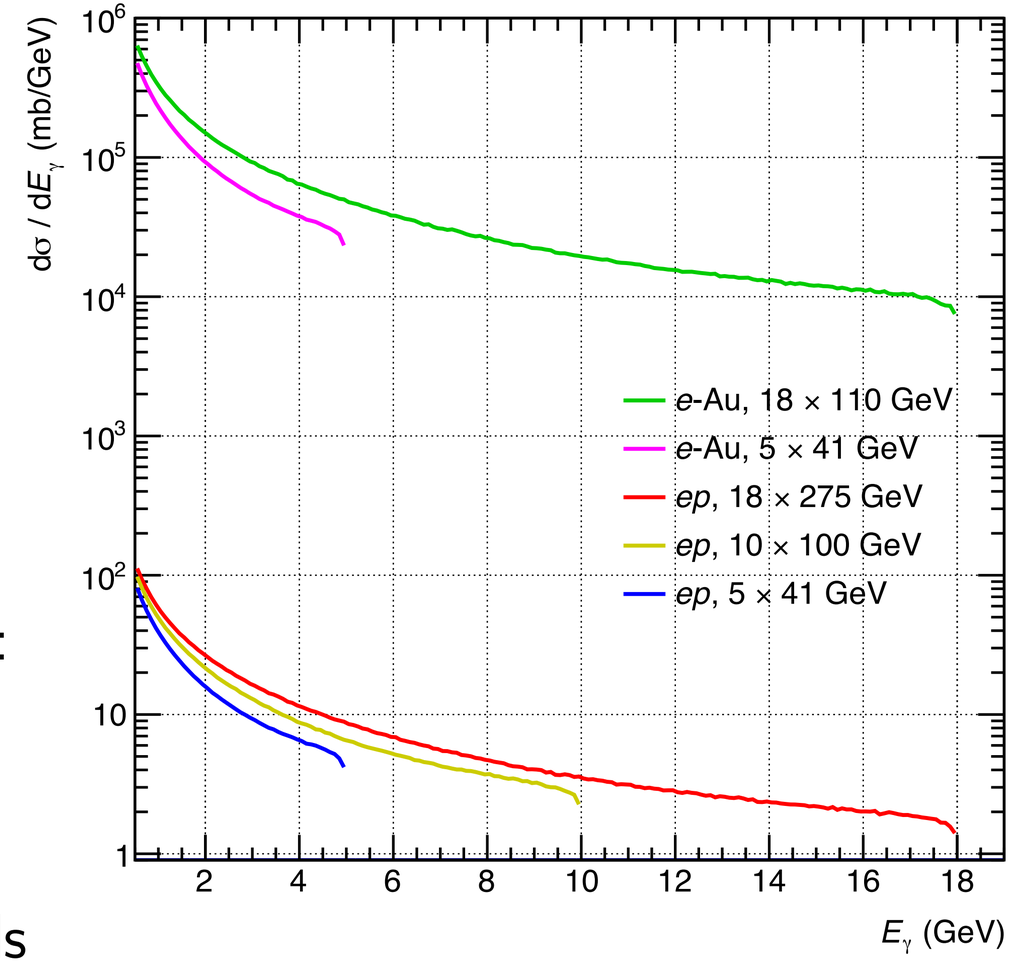
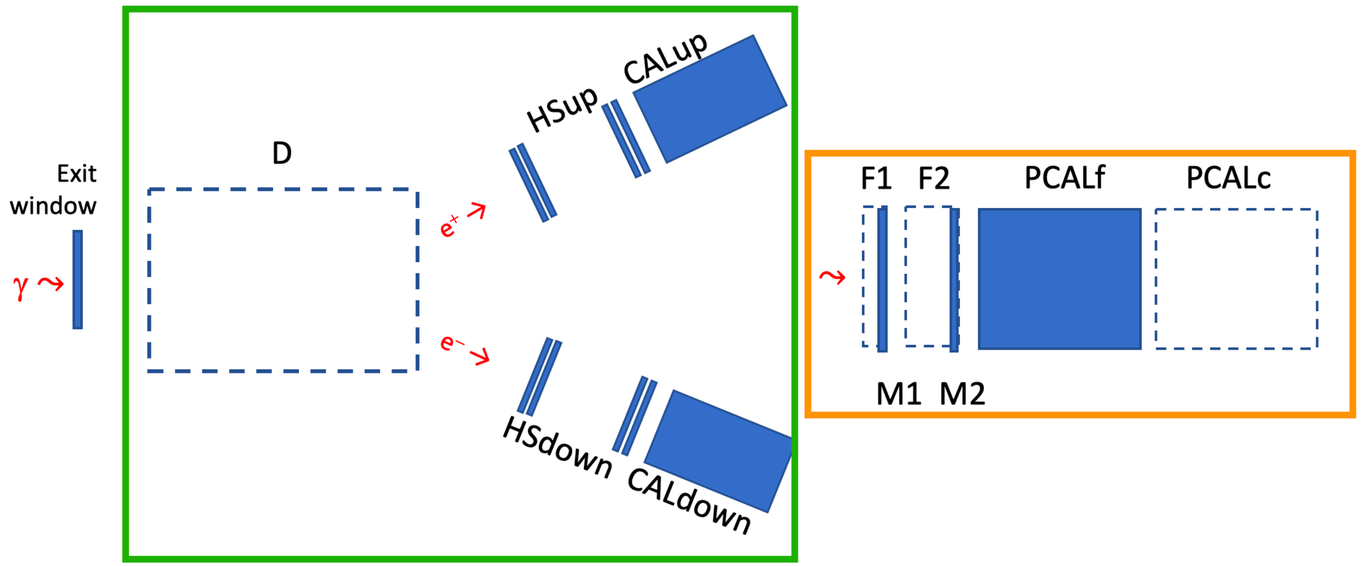


Applicable at next-generation facilities, with challenges:

- Event pileup, even worse for heavy ions ($\sigma_{Brem} \propto Z^2$)
- Increased synchrotron radiation background
- Large integrated dose requires radiation-hard materials
- High bunch rate requires fast timing/readout

Address challenges with two-detector luminosity monitor

Pair spectrometer: detect $e^{\pm}$ pairs produced in exit window



Direct photon detector: detect bremsstrahlung photons

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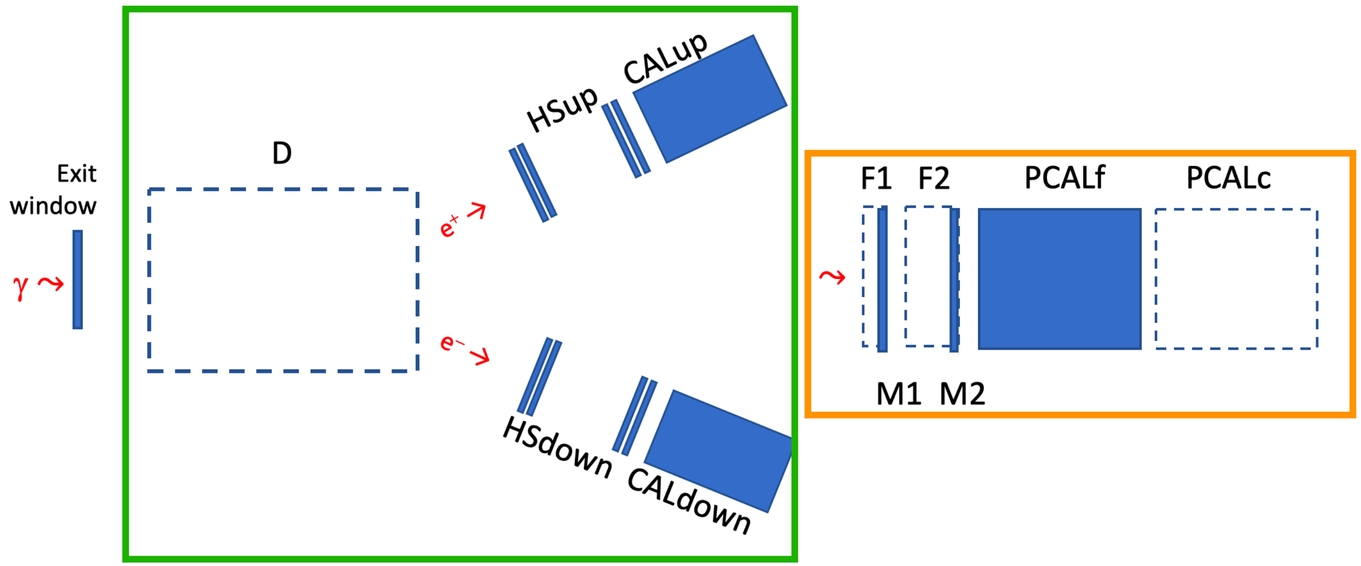
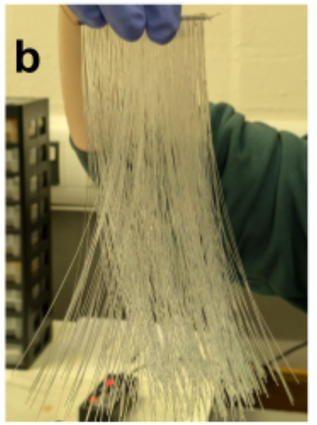


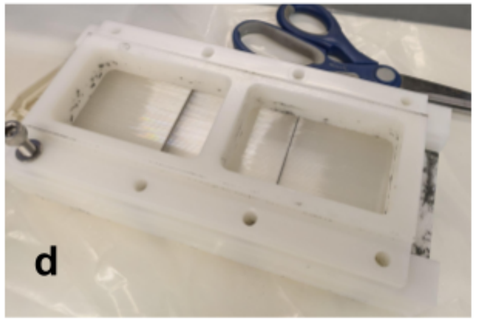
Direct photon detector: detect bremsstrahlung photons

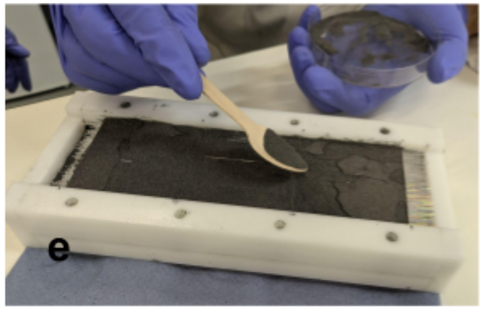
- Both systems to use tungsten/fiber-array calorimeters
- Fibers read out with silicon photomultipliers (SiPM)
- Mesh design allows shower profile reconstruction
  → better disentangle multi-hit events

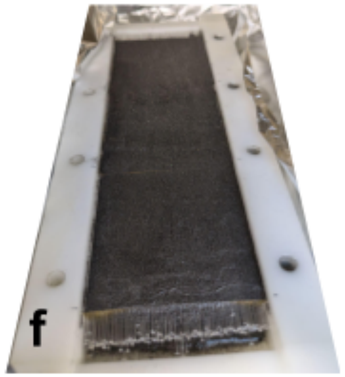
Development of DPD

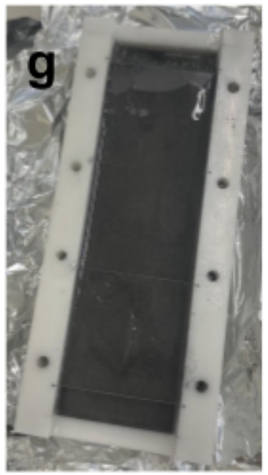
- Setup developed at U. York to fabricate PSpec modules
  - Scintillating fibers in tungsten powder absorber

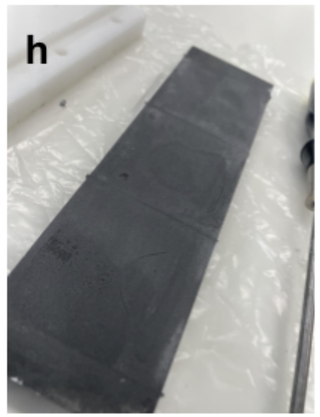












Development of DPD

- Setup developed at U. York to fabricate PSpec modules
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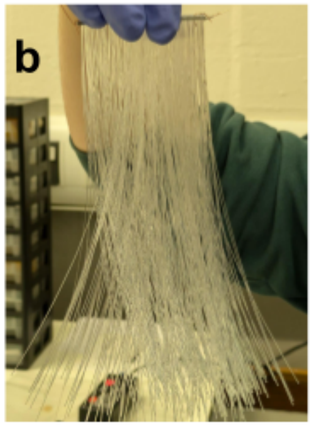
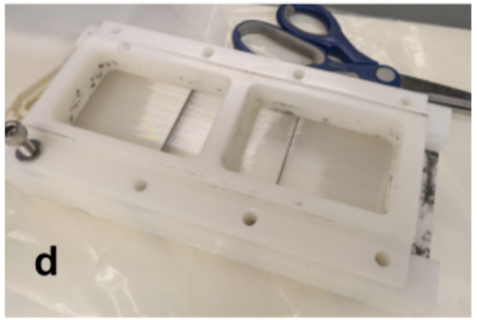
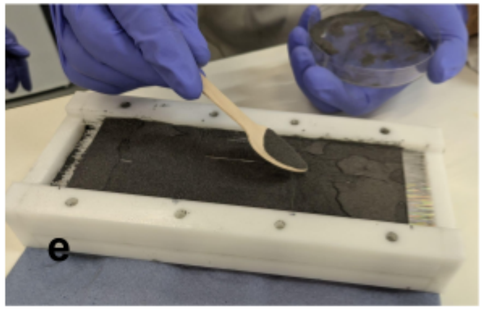
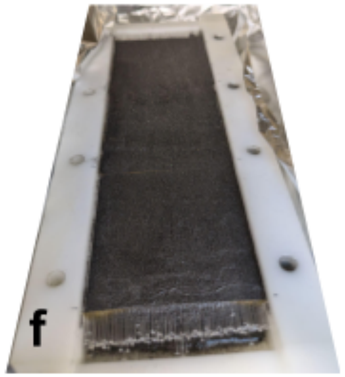
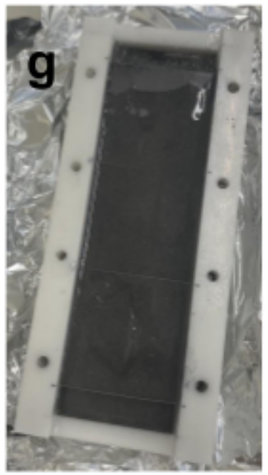
- Need to develop DPD calorimeters
  - DPD exposed to much higher dose
    → must use radiation-hard quartz fibers
  - Fibers read out with fast SiPMs
  - Initial simulations/design of modules required
  - Fabricate first modules with U. York setup
  - Test module to ensure signal size/speed
    → must stay well within 10 ns window!

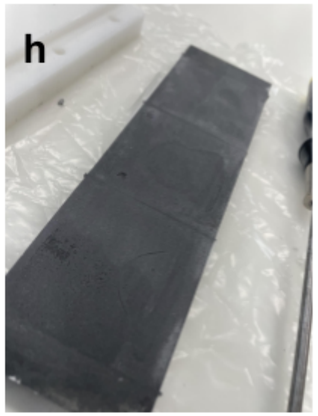












Proposed program

Objectives:

- Develop, fabricate quartz-fiber photon calorimeter module for luminosity detectors
- Test module with photon beam at MAMI to verify signal size/speed, benchmark simulation
- Optimize design of full DPD with simulation

Partner institutions:
Johannes Gutenberg-Universität Mainz
University of York
Czech Technical University Prague
Brookhaven National Laboratory
Jefferson Laboratory

Requested resources:

1 PhD student for 3 years (180.000 EUR)

5.000 EUR for materials/equipment

5.000 EUR for travel between Mainz/York

Direct cost: 190.000 EUR

Total cost: 237.500 EUR