A detector for top energy DIS

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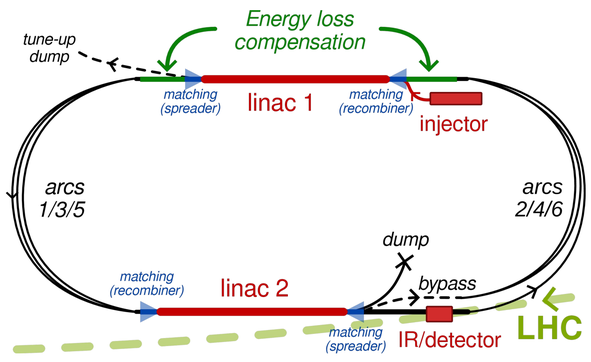
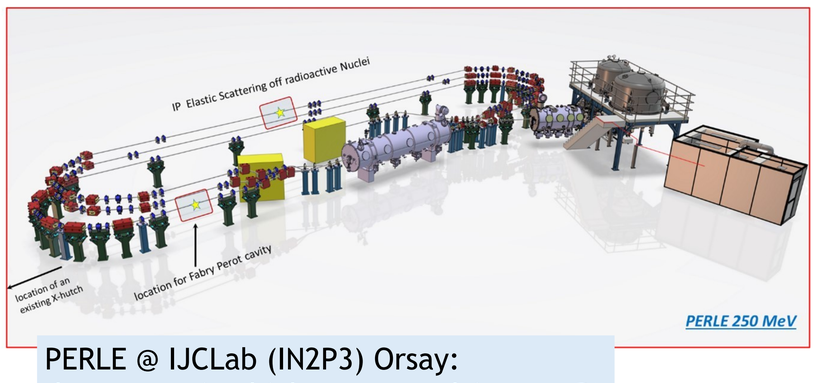
The LHeC Collider for ep/eA

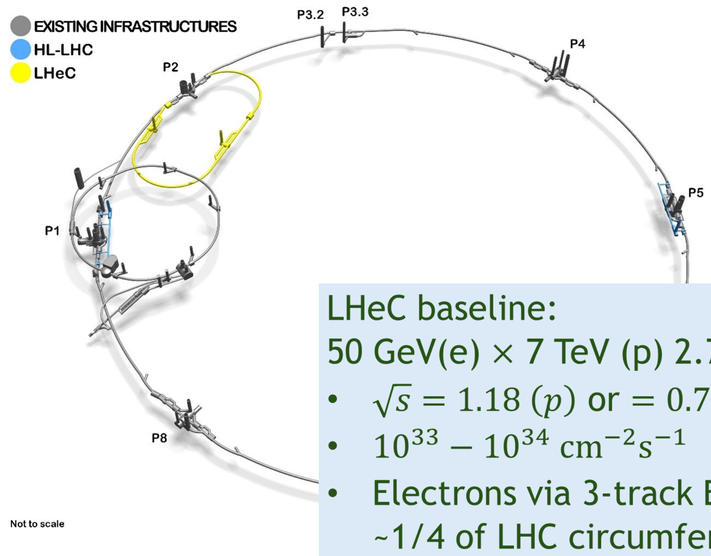
- Electrons from dedicated Energy Recovery Linac (ERL)
- Hadrons from LHC (FCC-hh beam for FCC-eh)



3-turn race track ERL for 50 GeV e^-



PERLE @ IJCLab (IN2P3) Orsay:
demonstrating high-power multi-turn ERL

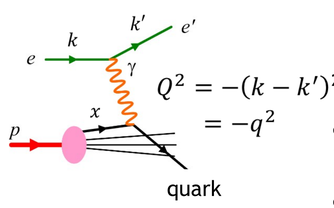


LHeC baseline:
50 GeV(e) × 7 TeV (p) 2.76 TeV/nucl. (A)

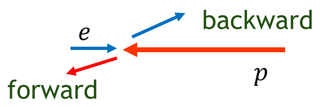
- $\sqrt{s} = 1.18\ (p)$ or $= 0.74\ (\mathrm{A})$ TeV
- $10^{33} - 10^{34}\ \mathrm{cm}^{-2}\mathrm{s}^{-1}$
- Electrons via 3-track ERL
  ~1/4 of LHC circumference

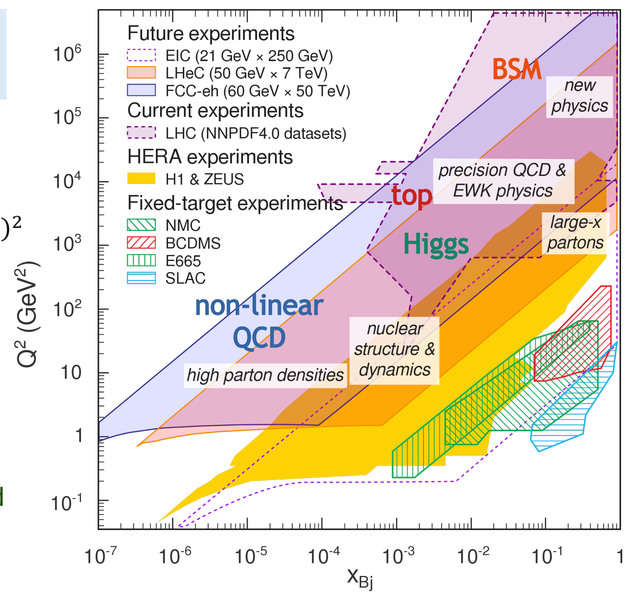
Detector Requirements for ep Collisions

DIS kinematic plane and physics subjects



$$x = \frac{Q^2}{p \cdot q} \quad y = \frac{p \cdot q}{p \cdot k}$$
$$sxy = Q^2$$





high-y events:
e^- and jet overlap

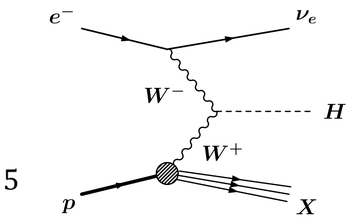
need high granularity in backward Calo

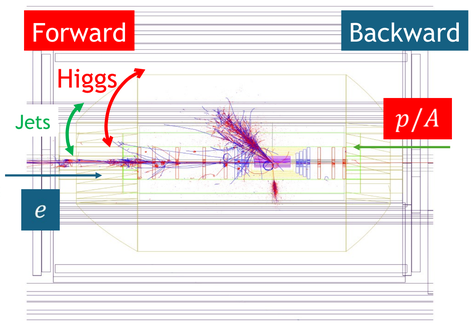
low-y events:
scattered quark goes forward

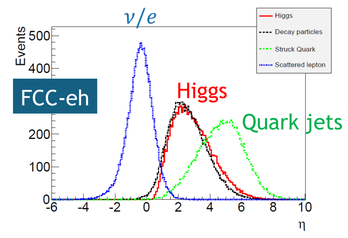
need good coverage

Main Physics Targets and Detector Requirements

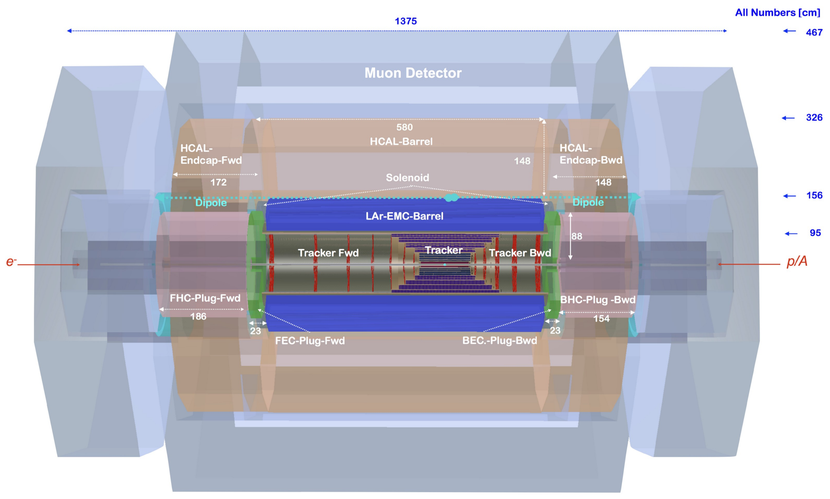
- Higgs production and EW processes through charged-current and neutral current DIS
  - Neutrino through E_T^{miss} : need high resolution calorimetry
  - High-mass system goes forward: rapidity coverage for $\eta > 5$
- Inclusive DIS in entire kinematic plane for QCD analysis (PDF)
  - need backward coverage for low-Q^2 events
- Flavour tagging for Higgs, PDF, top …
  - for HF jets in $\eta > 3$







The LHeC Baseline Detector



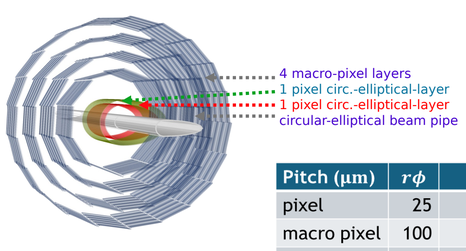
From 1 to 179 degrees

- **tracker**: incl. extended forward wheels
- **EM calorimeter**:
  LAr (barrel)
  Si-Pb / Si-W (endcap)
- Solenoid and dipole
- **HCAL**:
  Fe/Pb-sci. (barrel)
  Si-W (endcap forw.)
- **Muon system** embedded in return yoke
- Forward/backward **near-beam detectors** instrumentation

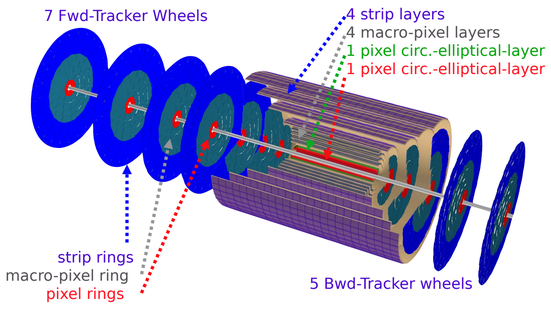
- Expected pileup ~ 0.1 / crossing
- Moderate radiation: $\ll 10^{14}\ 1\mathrm{MeV}\ n_{eq}$

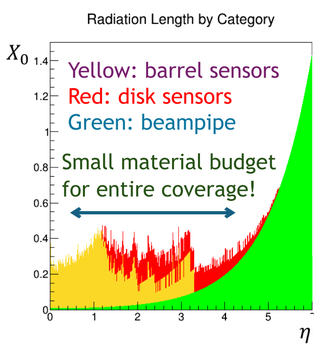
All-silicon tracker

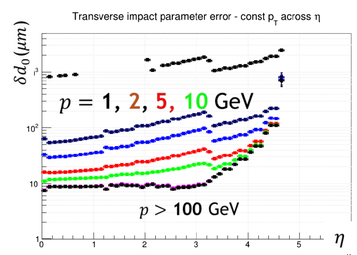
- HV-CMOS sensors:
  low material (< 0.1mm thick)
- good coverage:
  5-8 layers for $-3.5 < \eta < 4$
  2 hits for $-4.2 < \eta < 5$
- elliptic beam pipe
  + bent sensors along the pipe shape for flavour tagging



Pitch (μm)	$r\phi$	z
pixel	25	50
macro pixel	100	400
strip	100	10-50mm



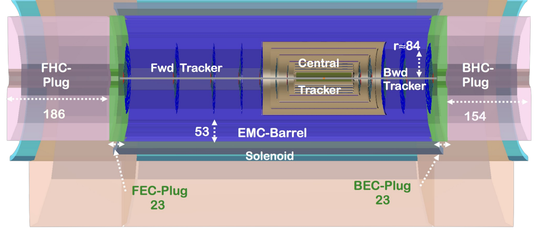




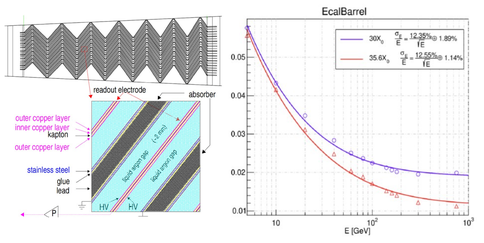
~ 30 μm resolution for high p tracks at $\eta \sim 4$

High-granularity calorimetry

- Barrel EM: LAr inside solenoid with shared cryostat, minimising material
- Barrel HadCal: sci. tile for good E resolution
- Endcap EM+Had: fine-segmented silicons for active sensor, for rad hardness, granularity and SW compensation
- Incorporating developments for Higgs factories & CMS HGCAL and Alice FoCal experience



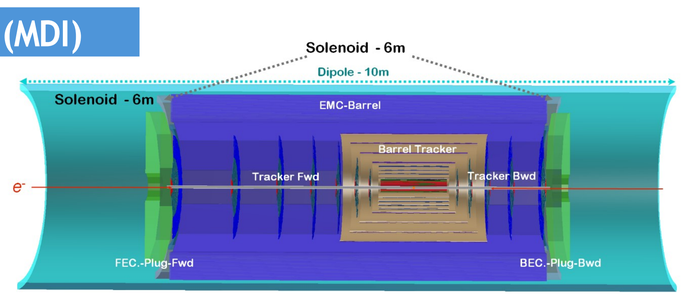
Covering $-4.8\ (e^-\ \mathrm{side}) < \eta < 5.5$

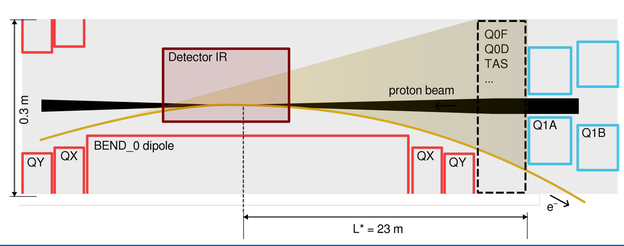


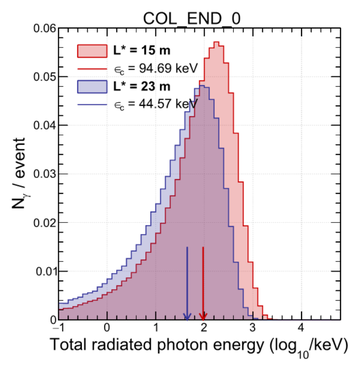
Baseline configuration		η coverage	angular coverage
EM barrel + small η endcap	LAr	$-2.3 < \eta < 2.8$	$6.6° - 168.9°$
Had barrel+Ecap	Sci-Fe	(~ behind EM barrel)	
EM+Had very forward	Si-W	$2.8 < \eta < 5.5$	$0.48° -$
EM+Had very backward	Si-Pb	$-2.3 < \eta < -4.8$	$-179.1°$

Machine-Detector Interface (MDI)

- Dipole magnet integrated in the detector to bend electron beam
  - beam-2 p and e brought in head-on collisions
- Detector needs to be away and shielded from the synchrotron radiation fan
  - optimisation to lower the critical energy and total power for SR: longer IR section helps a lot (15→23m)
  - shielding scheme being developed with full simulation by G4







Resource Estimate

Detector cost: total 360 MCHF (first estimate)

- Extrapolated from recent detector upgrade cost for LHC experiments
- large fraction comes from Si sensors for forward calorimeters: cost reduction possible, through sampling, granularity, reuse of detectors

Computing resources:
O(10%) of ongoing LHC experiments

- Streaming DAQ + online event selection
- Depending on rate to tape (10kHz), compression scheme, MC/data ratio etc.

Summary & Outlook

- LHeC baseline detector is based most recent but available technology
- Challenges remain in MDI
  - for detector protection & increasing detector angular coverage
  - further SR optimisation and development for shielding scheme
- Full simulation + software to prepare using common tools (DD4Hep, Key4Hep etc.)