PERLE DIAGNOSTICS

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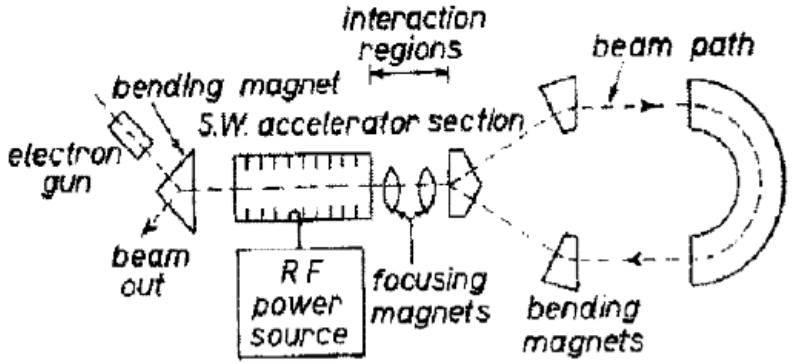
OUTLINE

- PERLE Genesis
- PERLE Targets, Team, Timeline and Configurations
- PERLE Injector
- PERLE Diagnostics
  - Injector Diagnostics
  - Ring Diagnostics

PERLE Genesis (1)

Accelerating two beams, colliding them, and then dumping them is extremely inefficient.

Maury Tigner, A Possible Apparatus for Electron Clashing-Beam Experiments, N.Cim 10(1965)1228



Recirculation lattice to recycle kinetic beam energy of a decelerating beam for acceleration of a newly injected low energy beam.

Avoid synchrotron loss initiated emittance growth as in storage rings.

Minimize power consumption (by an order of magnitude) and dump at E_{inj}

"There will be no future large-scale science project without an energy management component, an incentive for energy efficiency and energy recovery among the major objectives"

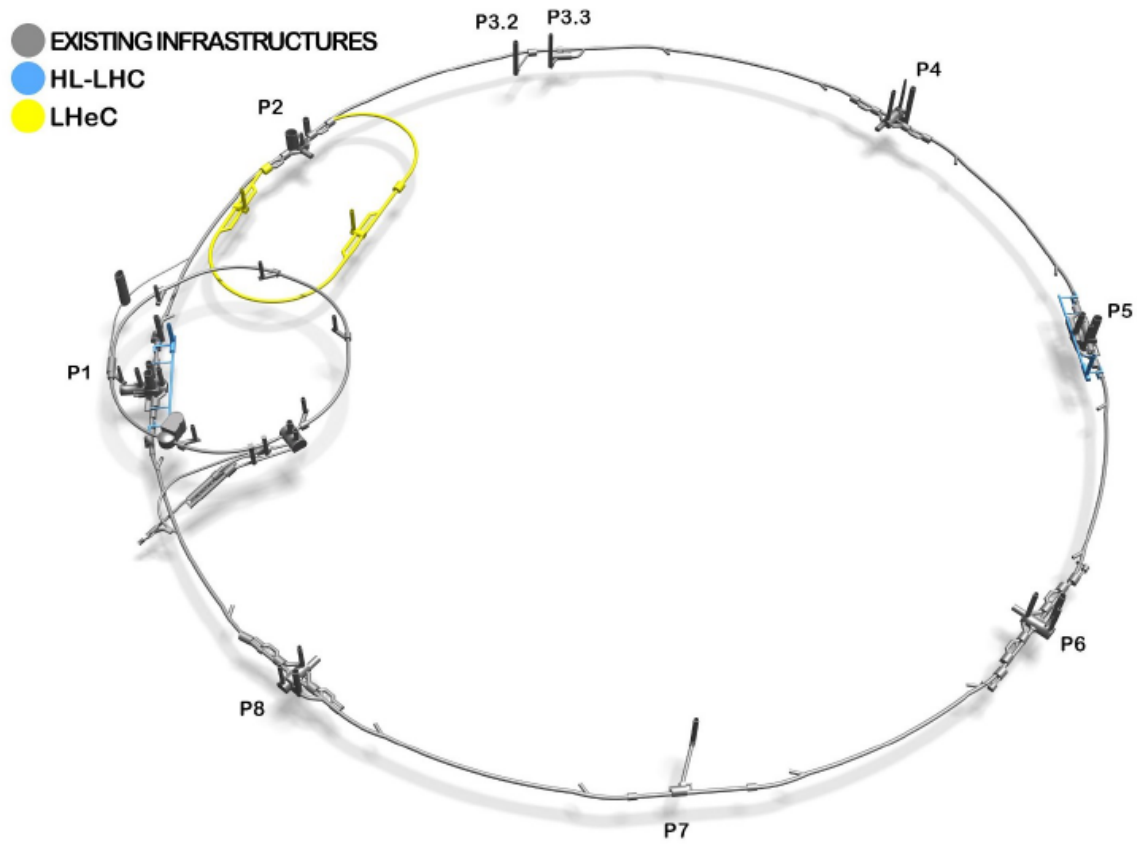
Frédérick Bordry, Director for Accelerators and Technology at CERN (2019)

PERLE Genesis (2)

M. Klein, Status Report on LHeC to ECFA (CERN, 28 Nov **2008**)

LHeC Study Group, Report on the Physics and Design Concepts for Machine and Detector (CERN, 13 Jun **2012**)

Parameter	Unit	LHeC Electron	LHeC Proton
Beam energy	GeV	50.0	7000.0
Beam current	mA	20.0	1400
Bunches per beam		1188	2808
Bunch population	10^{10}	0.3	22.0
Bunch charge	nC	0.50	35.24
Normalised emittance at IP	mm.mrad	30.0	2.5
Betatron function at IP	cm	10.0	10.0
RMS bunch length	cm	0.06	7.55
Installed RF voltage	GV	17.2*	0.016
Beam-beam disruption		14.3	1×10^{-5}
Luminosity	$cm^{-2}.s^{-1}$	6.5×10^{33}	



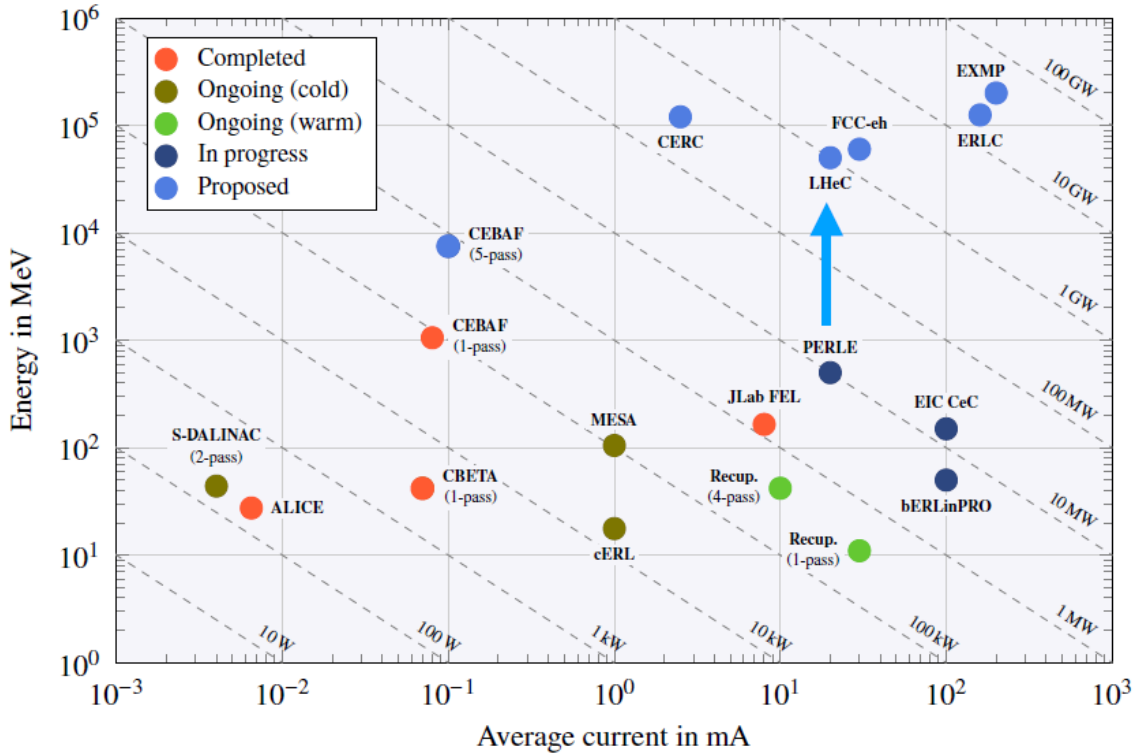
High power electron beam based on three-turn ERL racetrack utilising 100 MW electrical power consumption as a result of the high energy recovery efficiency. ERL circumference equivalent to one-third of the LHC. The ERL could be realised in staged phases.

PERLE Genesis (3)

For LHeC there is a need of a hub to explore a broad range of accelerator phenomena and to validate technical choices improving accelerators efficiency in **an unexplored operational power regime** on the pathway of the ERL technology development for future energy and intensity frontier machines.

PERLE (Powerful ERL for Electrons):

Demonstrator facility to explore and validate a broad range of accelerator phenomena & technical choices on the pathway to the **LHeC** and other new frontier machines realisation.



PERLE Targets

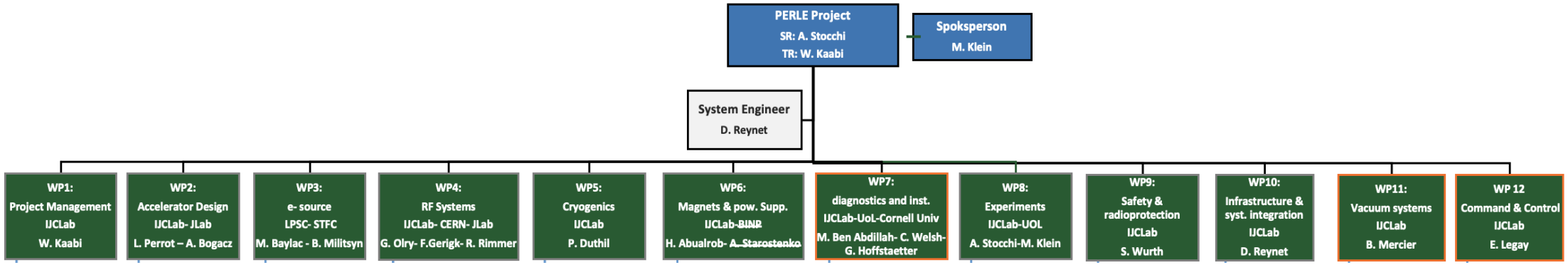
Main challenges: Multi-turn, high bunch charge, high power energy recovery, …

- 2 Linacs (Four 5-Cell 801.58 MHz SC cavities)
- 3 turns (164 MeV/turn)
- Max. beam energy 500 MeV
- I = 20mA

Target Parameter	Unit	Value
Injection energy	MeV	7
Electron beam energy	MeV	500
Normalised Emittance	mm mrad	6
Average beam current	mA	20
Bunch charge	pC	500
Bunch length	mm	3
Bunch spacing	ns	25
RF frequency	MHz	801.58
Duty factor		CW

Matching the LHeC parameters

PERLE Team



Denis Reynet	System Engineers + Infrastructure (IJCLab)
Luc Perrot	Beam Dynamics (IJCLab)
Maud Baylac	Gun Installation and Operation (LPSC)
Guillaume Olry	RF System (IJCLab)
Patxi Duthil	Cryogenic (IJCLab)
Hadil Abualrob	Magnets (An-Najah / IJCLab)
Mohammed Ben Abdillah	Diagnostics and Instrumentations (IJCLab)
Sébastien Wurth	Security Issues (IJCLab)
Bruno Mercier	Vacuum System (IJCLab)
Eric Legay	Command and Control (IJCLab)

PERLE Timeline for TDR phase and beyond

Technical Design phase (TDR)

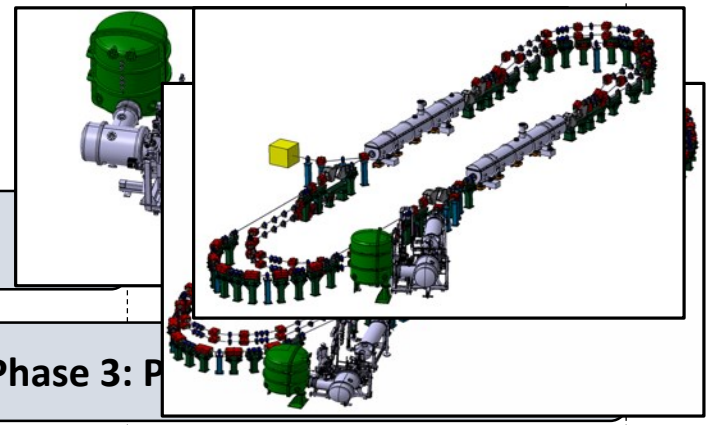
Prepare to Build phase (P2B)

Installation phases

Phase 1: Installation of the injection line

Phase 2: PERLE 250 MeV version

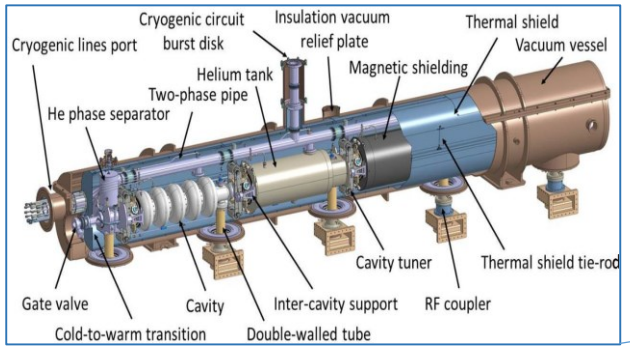
Phase 3: P



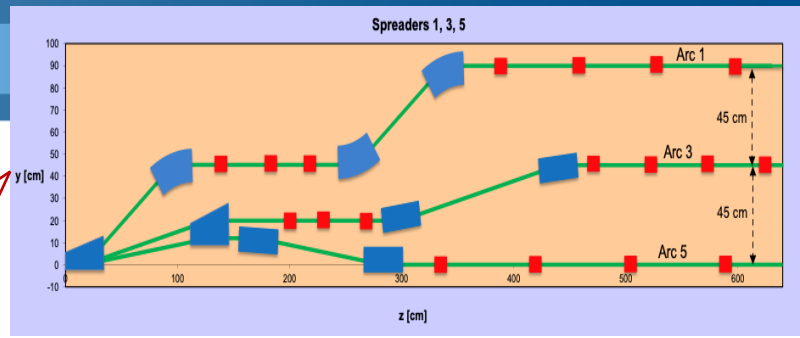
2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031

PERLE final Configuration

PERLE: first multi-turn ERL, based in SRF technology, designed to operate at 10MW (20 mA, 500 MeV) power regime



- Cryomodule with 4 five-Cell cavities
- Total gradient 82 MeV
- 3 acc & 3 decc beams at different energies travelling in the CM.

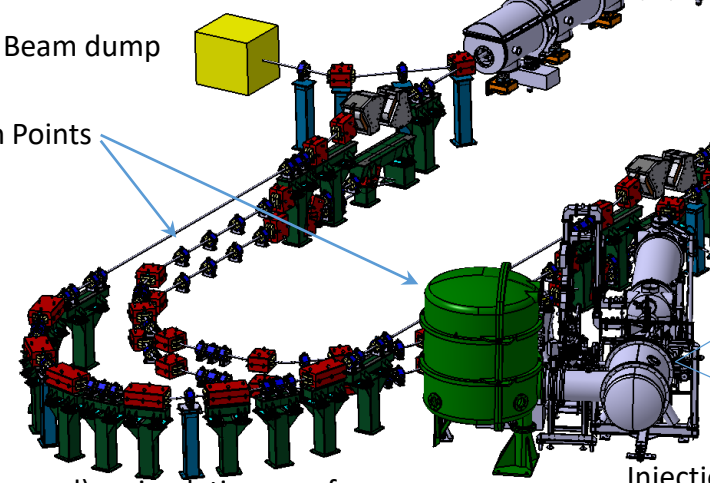


Switchyard: vertical separation/recombination of beams at different energies

3 staked recirculation arcs for beams at different energies (Arcs 1, 3, 5).

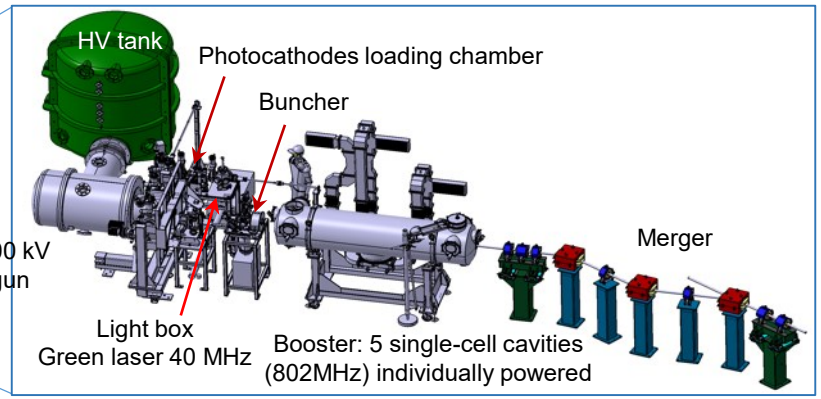
Beam dump

Interaction Points

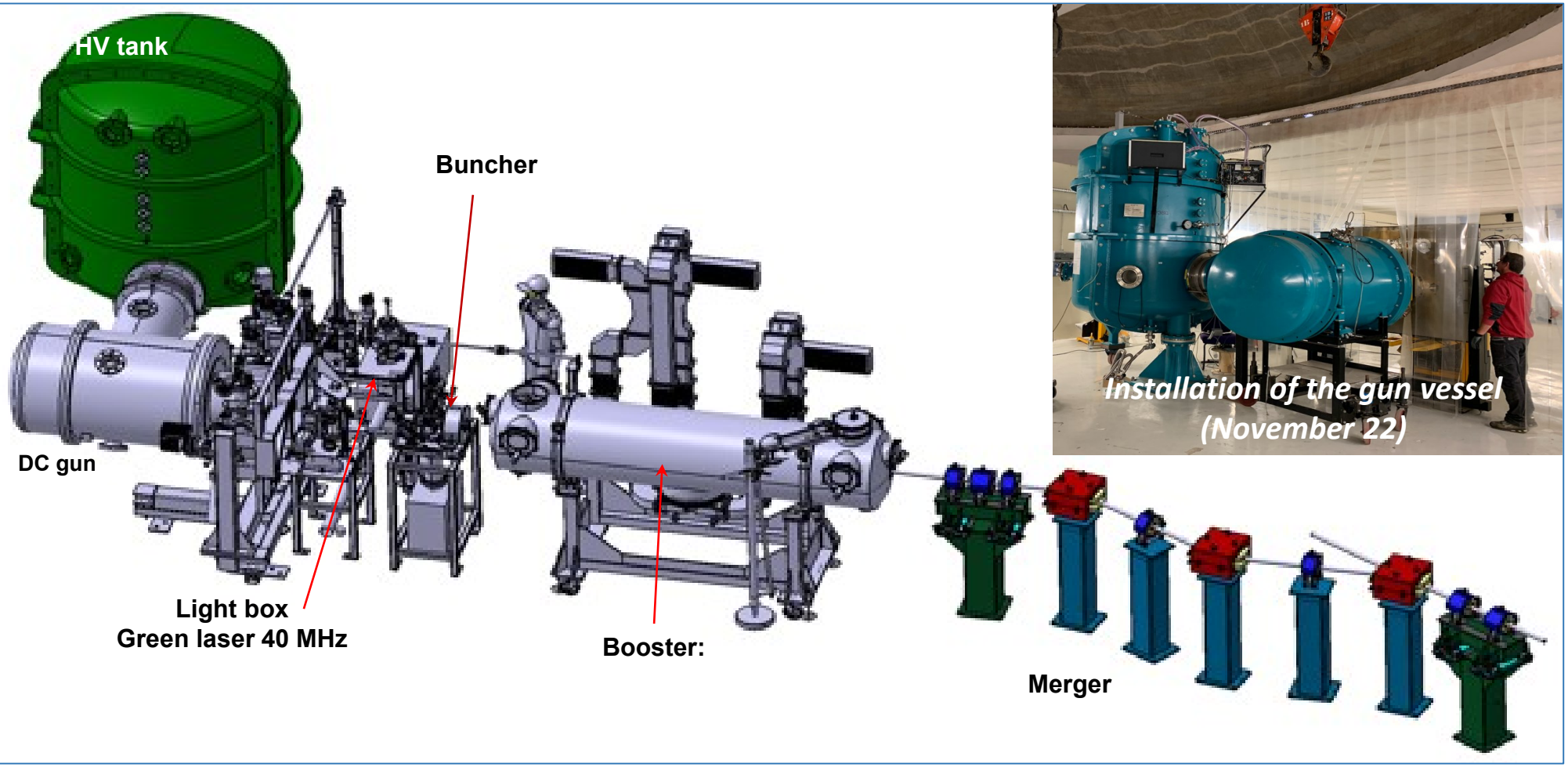


3 staked (& inversed) recirculation arcs for beams at different energies (Arcs 2, 4, 6)

Injection line delivering 500pC bunches at 7 MeV.



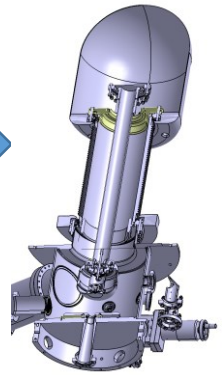
PERLE Injector



PERLE injector: what should be monitored?

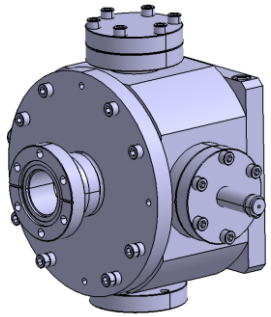
Laser

Cathode



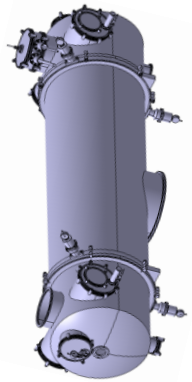
$$\begin{pmatrix} X \\ Y \\ \sigma_X \\ \sigma_Y \\ Q \end{pmatrix}$$

Buncher



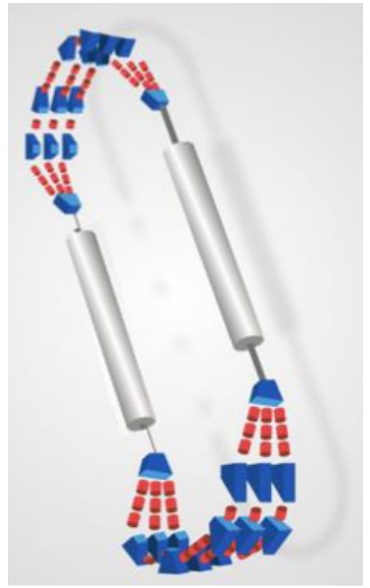
$$\begin{pmatrix} X \\ Y \\ \sigma_X \\ \sigma_Y \\ Q \end{pmatrix}$$

Booster



$$\begin{pmatrix} X \\ Y \\ \sigma_X, \sigma_Y, \sigma_Z \\ E, \Delta E \\ Q \\ Emittance \end{pmatrix}$$

ERL



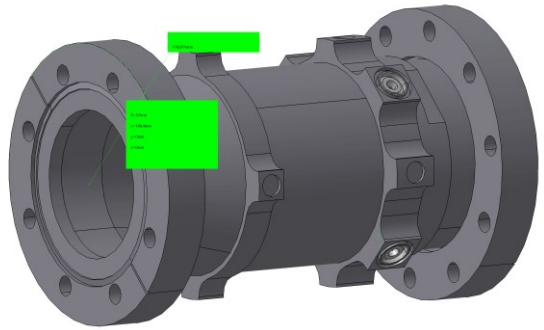
BEAM LOSS

Instrumentation before the booster

- FCT / ICT for current measurement
- BCM for charge measurement

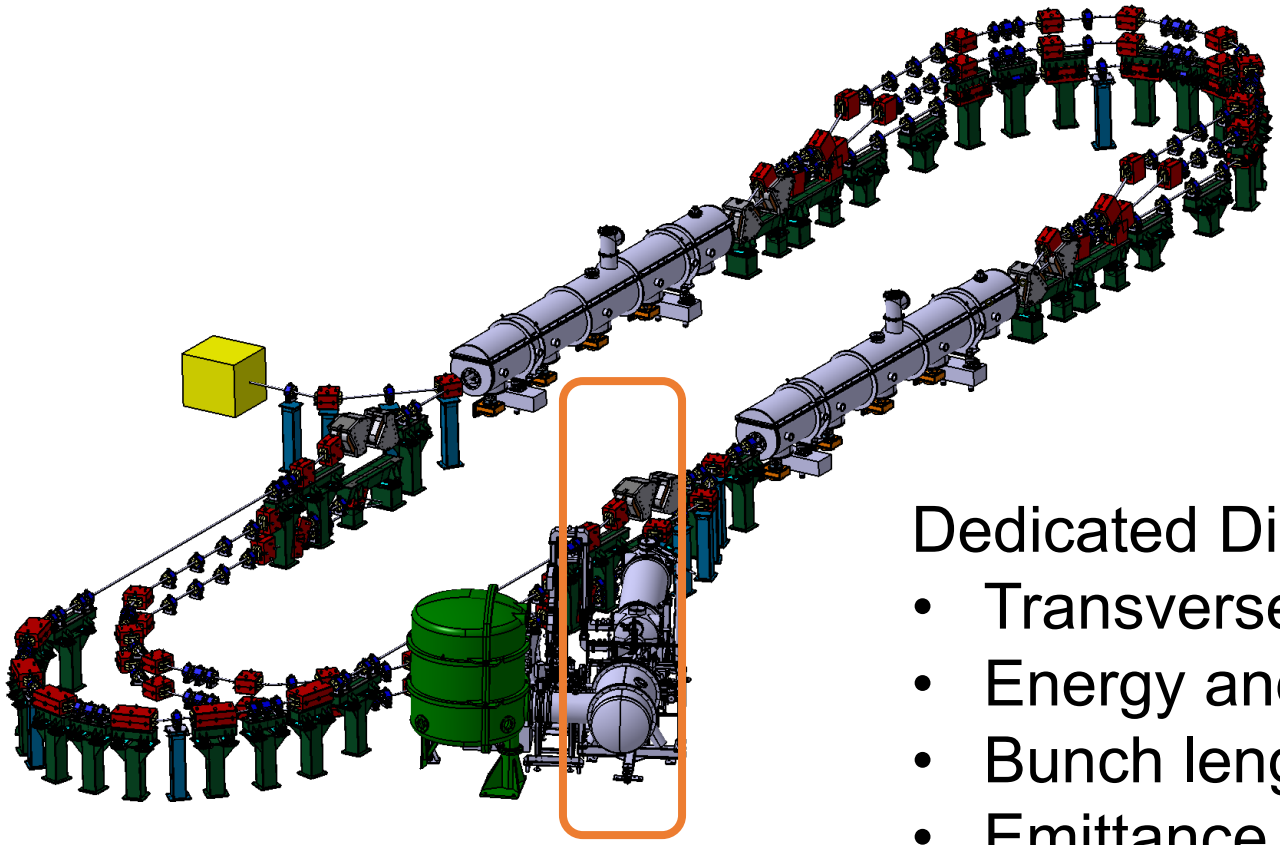
Courtesy Bergoz

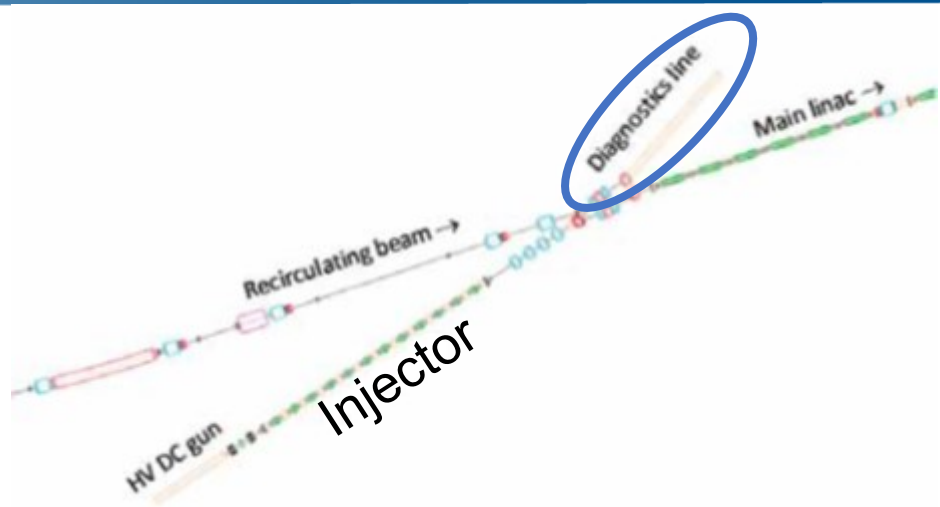
- BPM (stripline/button) for position measurement
- BLM for loss measurement



Tasks to be allocated

Instrumentation after the Booster: Diagnostics Line



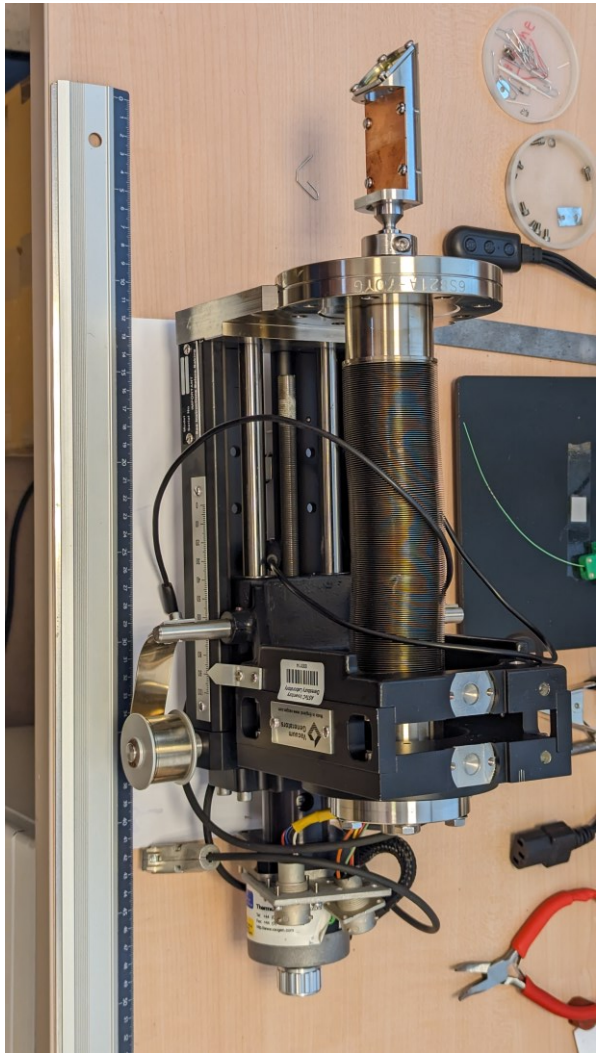


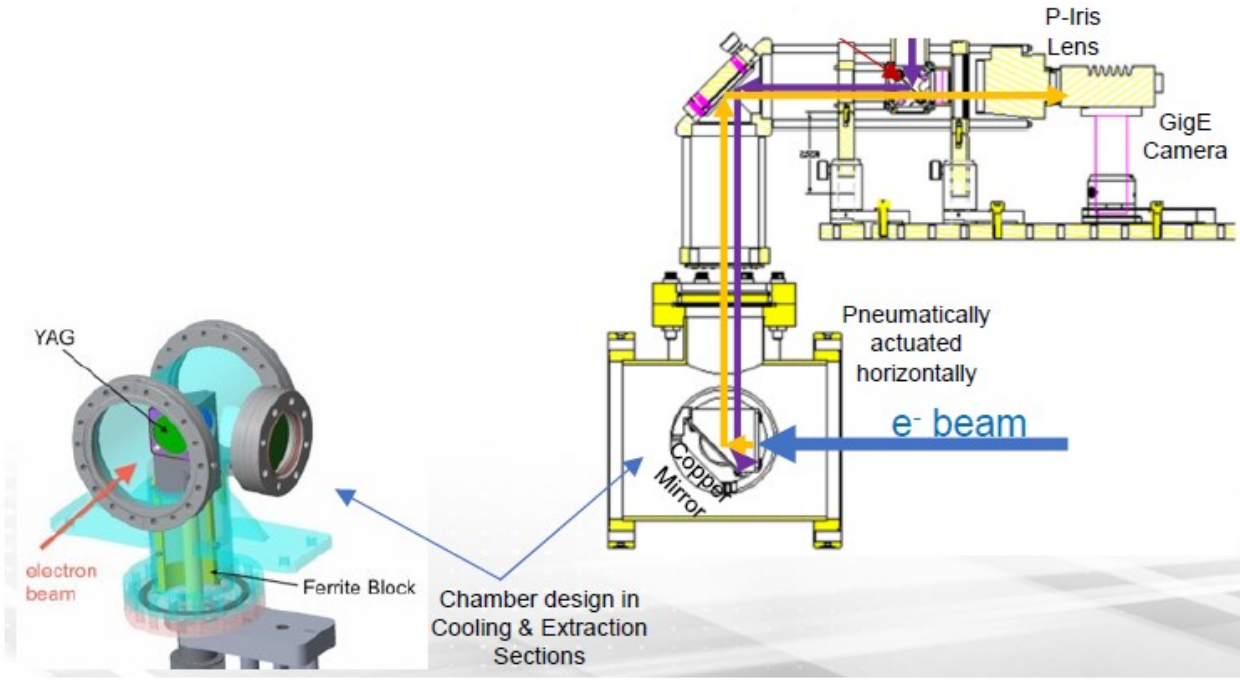
Dedicated Diagnostics line needed for:

- Transverse profile measurement
- Energy and energy spread measurement
- Bunch length measurement
- Emittance measurement

Warning: Housing issues within the ERL!!!

Diagnostics Line: Transverse Profile measurement





Diagnostics Line: Energy and Energy spread measurement

Solution 1: Dipole + viewer: beam position and size on the viewer are in relation respectively with beam energy and beam energy spread.

Solution 2: Energy spread to be measured with BPMs located in the merger section.

Diagnostics Line: longitudinal length measurement

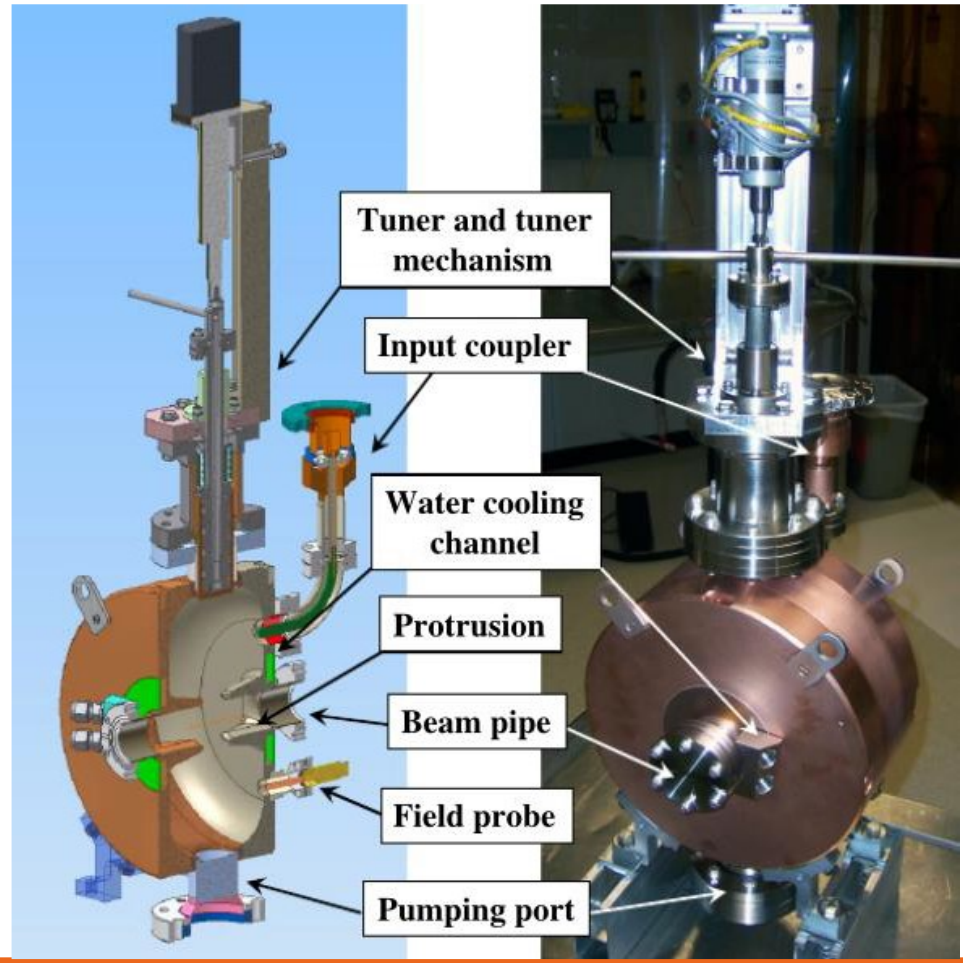
- **Streak Camera**

- **Deflecting cavity+ Viewer:**

The cavity operates in CW mode for low energy beam
A deflecting angle of 12 mrad allows a resolution of 400 fs on a YAG view screens located approximately 1m downstream from the cavity

Task to be allocated

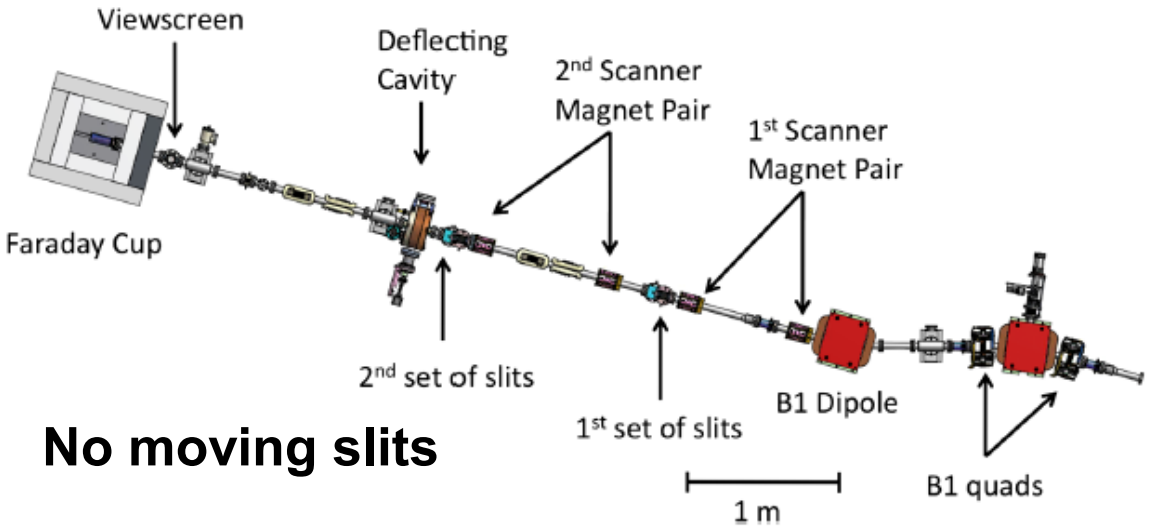
Courtesy: CBeta



Diagnostics Line: Emittance measurement

1. **Quadrupole scan technique**: It is based on the fact that the squared rms beam radius is proportional to the quadrupole “strength”

2. Multi-slit system:



No moving slits

Courtesy: CBeta

Dual Station Actuator retrofitted for new dual axis mask.

Task to be allocated

Courtesy: LEReC

PERLE injector: Optional measurements

- Cathode Imaging & Exit Laser Instrumentation
- Gun HV Ripple Monitor
- Anode Bias & Ion Clearing
- Halo Monitoring
- Faraday Cup
- DCCT

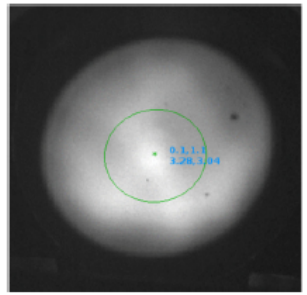
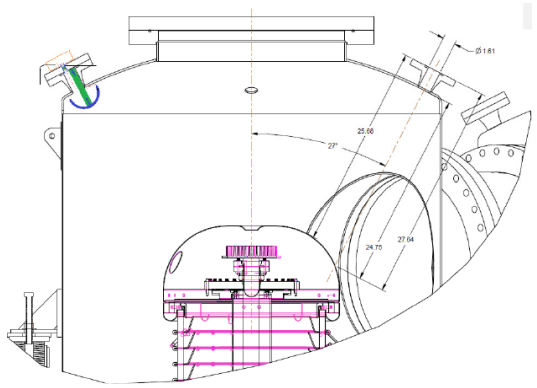
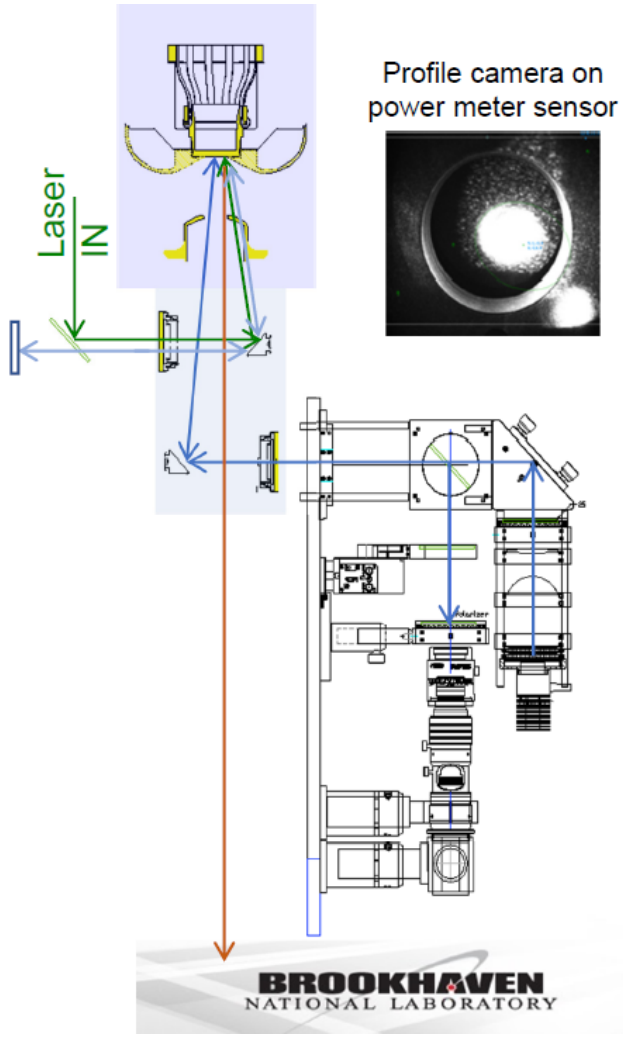


Image of QE map on profile monitor with LED illumination

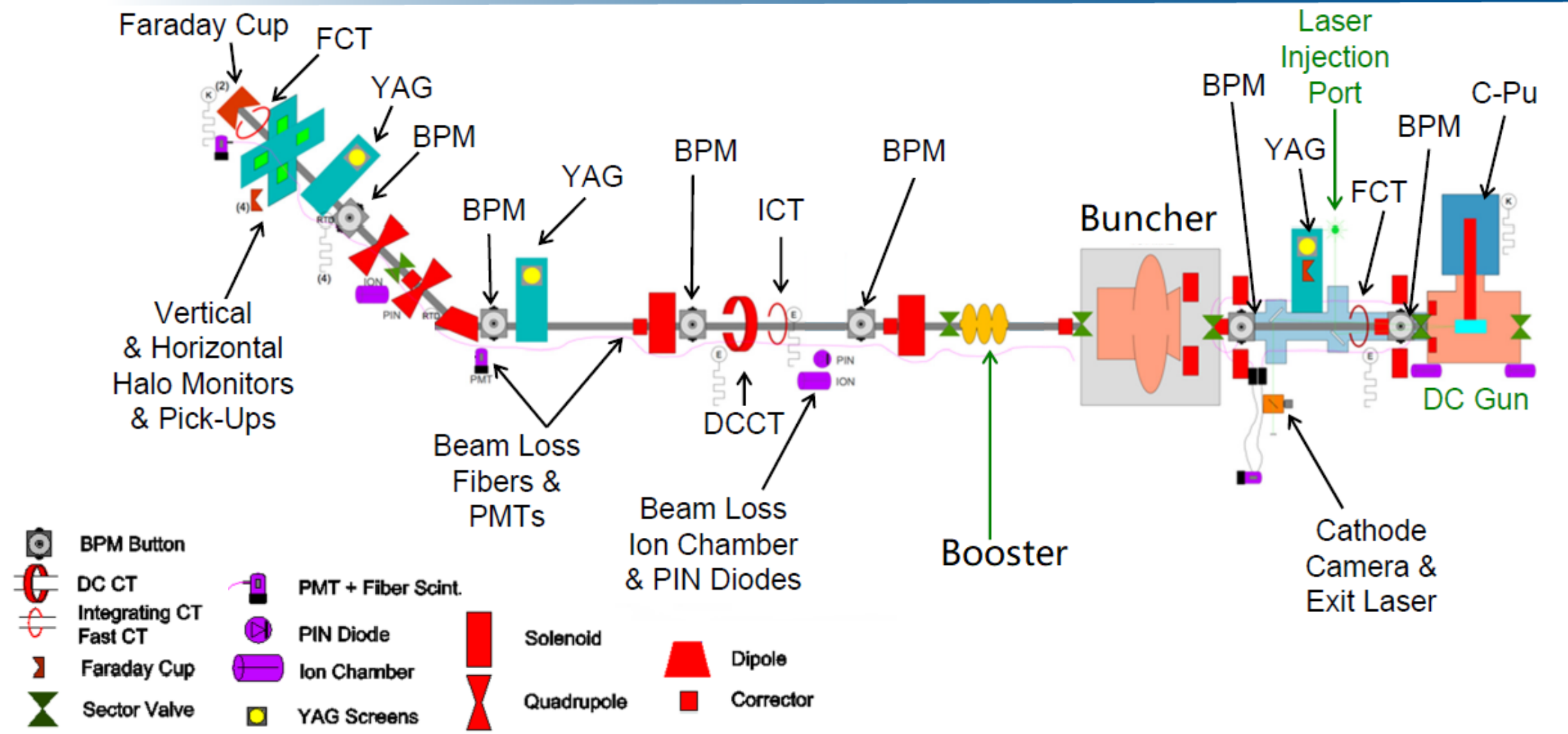




Profile camera on power meter sensor

BROOKHAVEN NATIONAL LABORATORY

PERLE Injector diagnostics: Exhaustive example

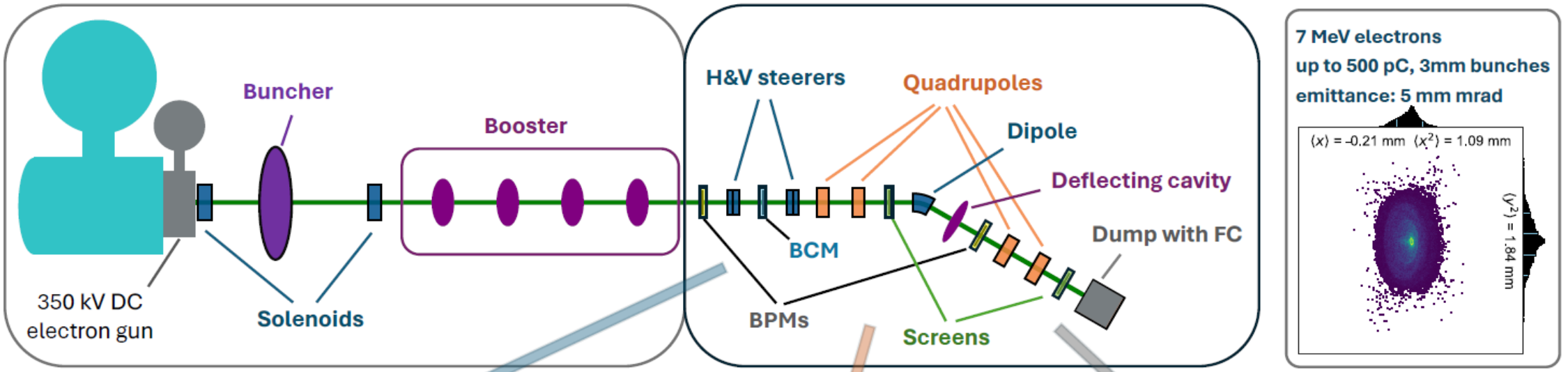


PERLE Injector: detailed diagnostics line

Injector

Diagnostic line

Beam parameters



Misalignment correction

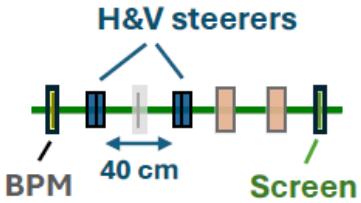
2 combined H&V steerers

placed after the Booster

drift between: 40 cm

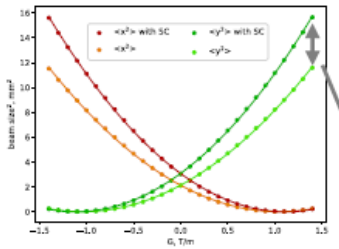
magnetic length: 5 cm

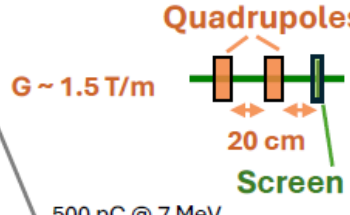
deflection angle: 10 mrad



magnetic field: 5 mT → 4 mm correction in both planes

Quad-scan

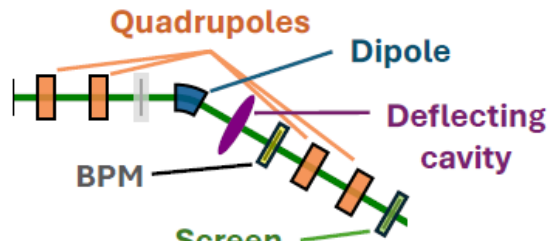




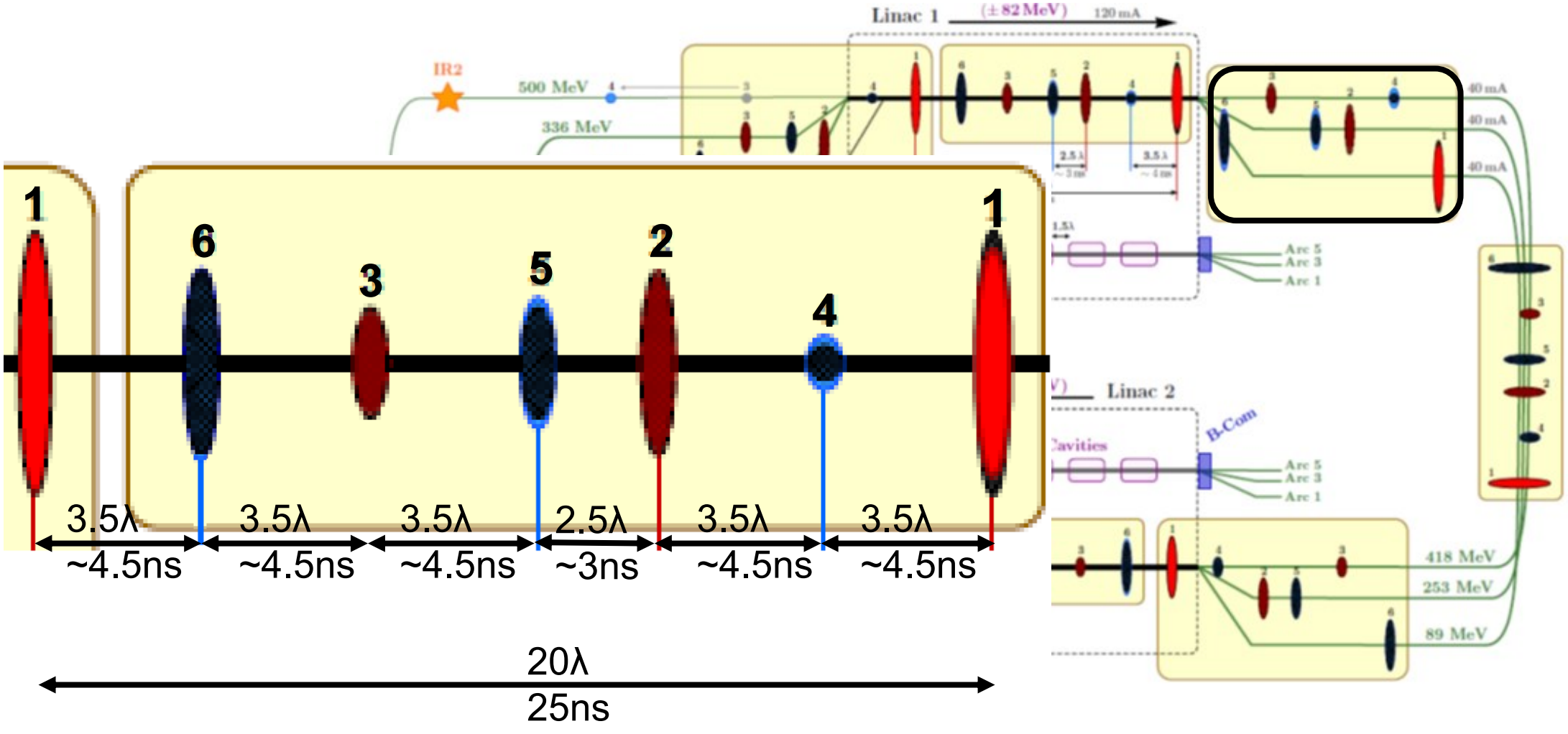
500 pC @ 7 MeV

→ space-charge effect

Energy spread & longitudinal size



PERLE Ring diagnostics: Beams locations in steady state



PERLE Ring diagnostics: BPM electronics

- Task: position, current and phase measurement (*)
- Type: Button BPM
- Number ~ 30 (TBD)
- Main issues with BPM electronics:

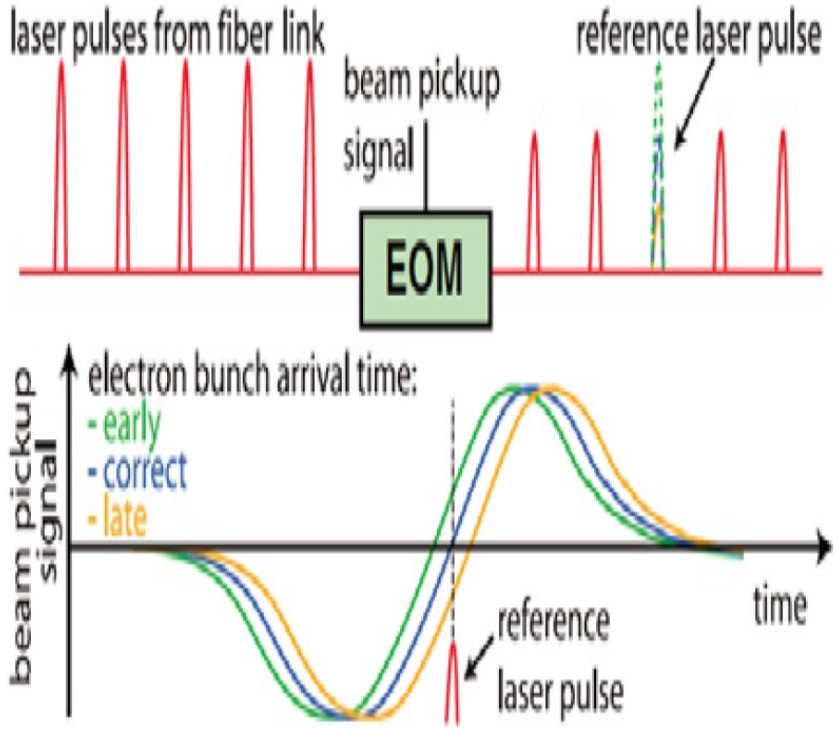
Task to be allocated

  - Two beams for each BPM located in an arc
  - Six beams for each BPM located in the Linac line
  - Button signal reflections and cable lengths
  - Commissioning schemes: low current, low output power, low duty cycle…

Solutions (not exhaustive):

Bunch Arrival Monitor: BPM reports bunch arrival time phase relative to the 0.8 GHz reference signal

ElectroOptical Modulation: The timing of the reference laser is adjusted so that one pulse arrives at the time of the zero-crossing of the electrical signal when it passes the EOM.

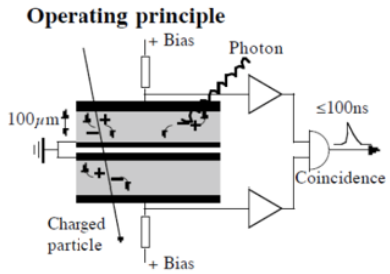


PERLE Ring diagnostics: BLMs

Beam Loss measured locally

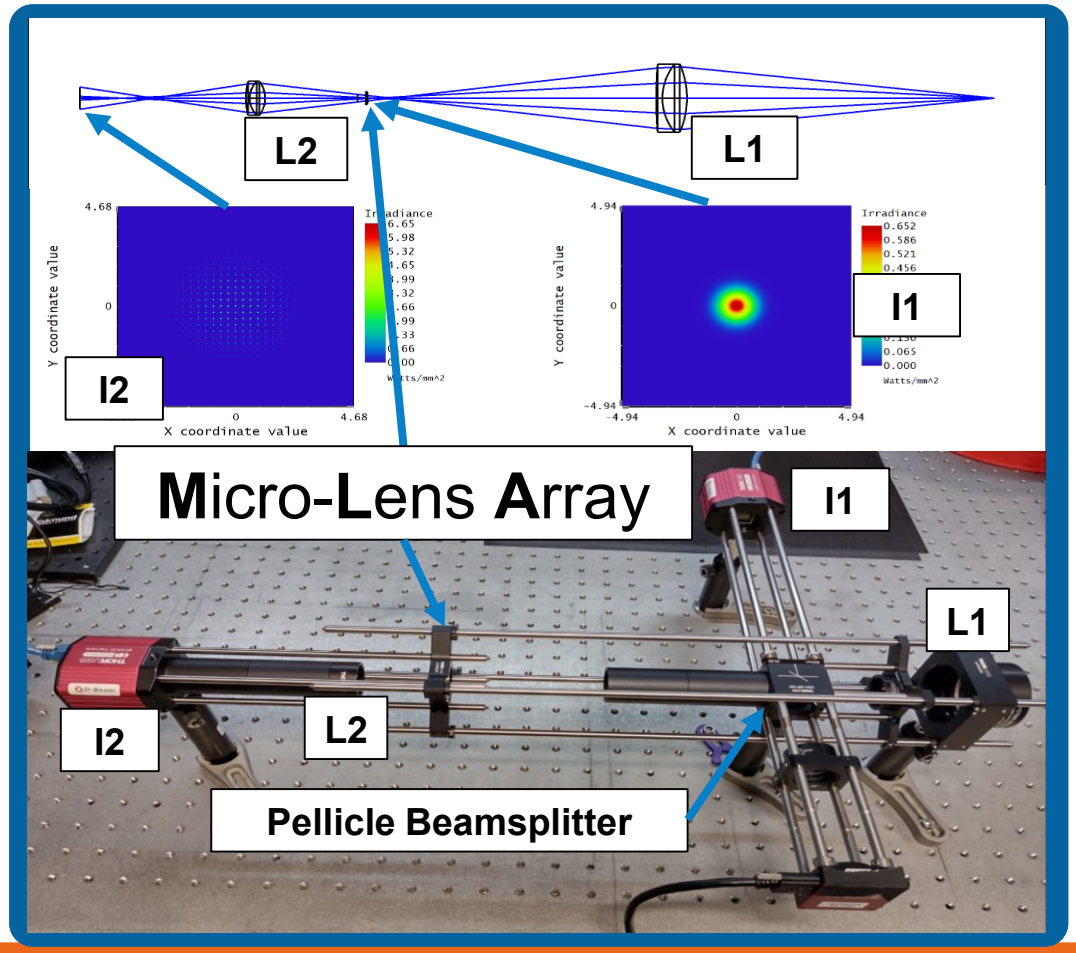
- Techniques:
  - Pin diodes
  - PMT+Scintillating fiber

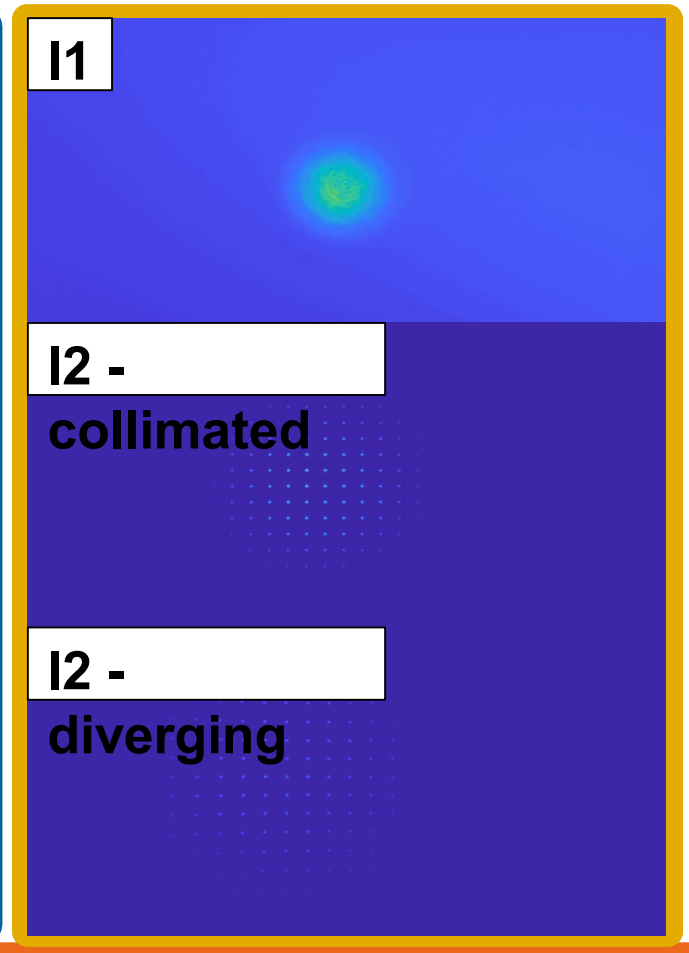
- BLM electronics to be provided



PIN Diode, dual incidence detector, by Bergoz Instr.

Single Shot Emittance with MLA (MicroLens Array)

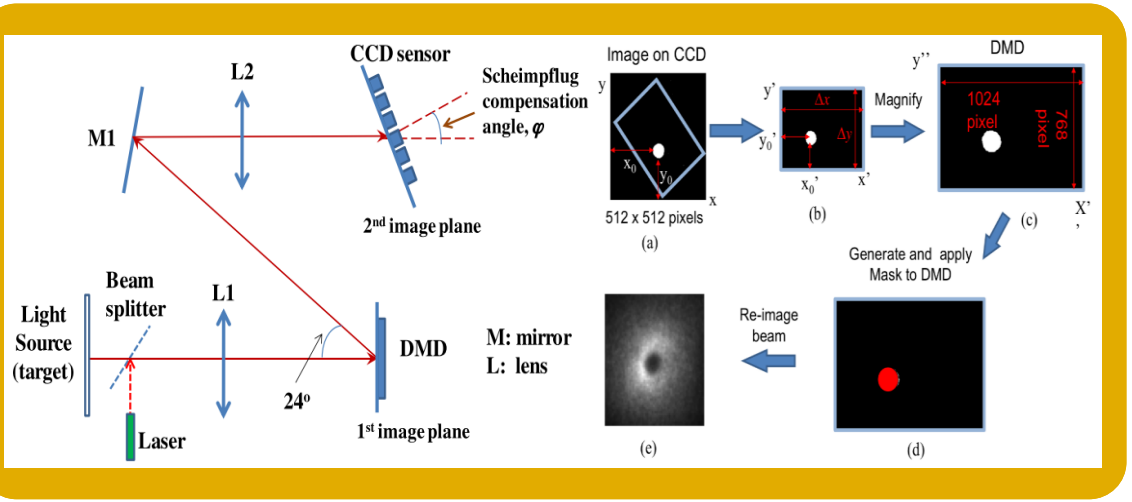


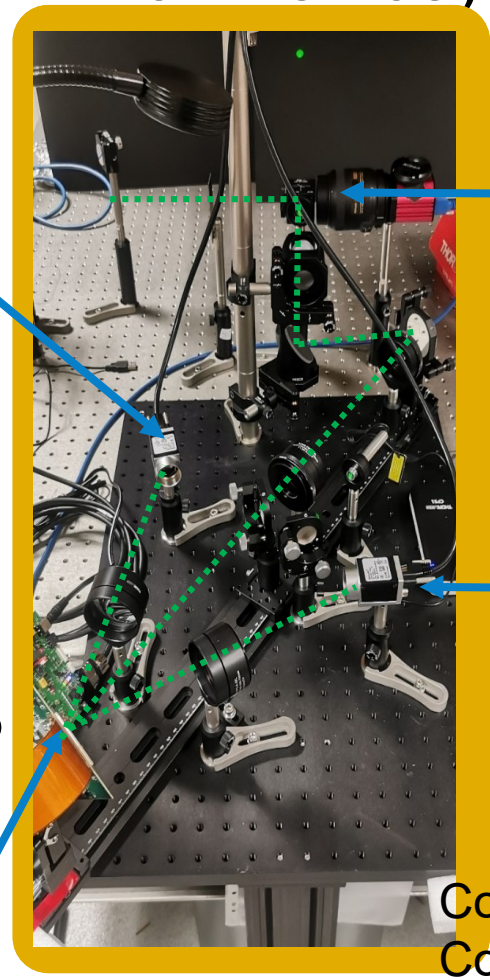


Operates for energies over 100MeV
Resolution degrades with ↓energy

Courtesy:
Cockcroft institute

Halo imaging with DMD (Digital Micromirror Device)





- Core of beam selected and binary mask is defined
- Mask is displayed on DMD
- Two cameras for **simultaneous imaging of core & halo**
- **Dynamic range achieved for AWAKE ~10^6**
- Operates for energies over 100MeV
- Resolution degrades with ↓energy

Courtesy:
Cockcroft institute

Task force and partners

Needs: Task force for many diagnostics yet to be studied

Summary

- **PERLE@Orsay is a key ERL project for HEP and Nuclear Physics communities**
- **Diagnostics** are crucial devices for PERLE success.
- **PERLE diagnostics quite challenging**: commissioning schemes, large dynamic ranges, broad range diagnostics, beam dynamics...
- **Collaborations on diagnostics under construction** and still opened to new comers
  - Many studies to be performed: benchmarking, designs, ...
  - Decisions upon these studies for “over the shelf” purchase or custom realization
  - In kind contributions, partial or complete funding to be discussed on a further stage

Thank you for your attention!