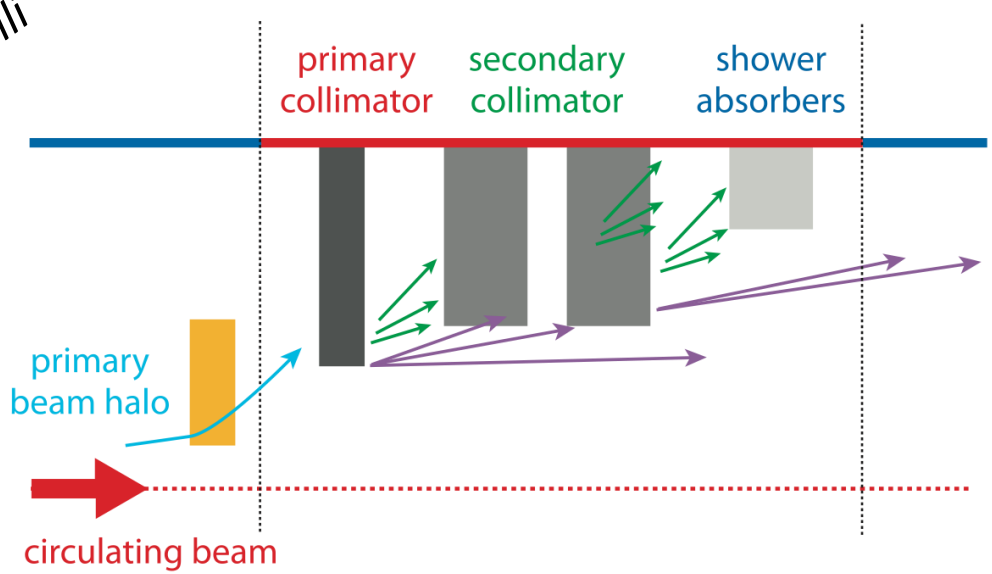
HEL program and planning

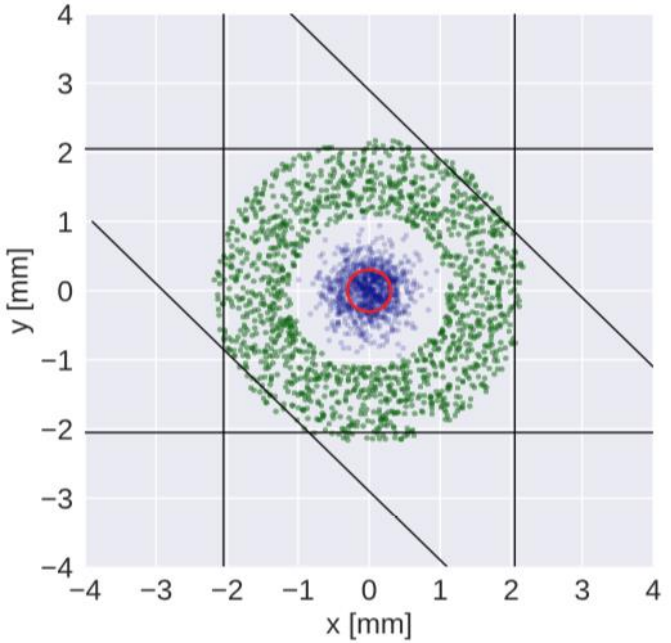
A. Rossi on behalf of the HEL project

CERN – October 19th to 21st 2021

The HEL-based collimation concept

Courtesy of S. Redaelli





- Active halo depletion: control diffusion speed, selective by amplitude.
  - Electron beam equivalent to non-material scraper; small kick per turn → safe device
  - Does not need to be in IR7: enhanced diffusion brings losses in IR7
  - Constraints from tight transverse aperture determine the requirement on the small electron beam size.

Hollow Electron Lens in HL-LHC baseline after C&SR 2019, as in-kind contribution

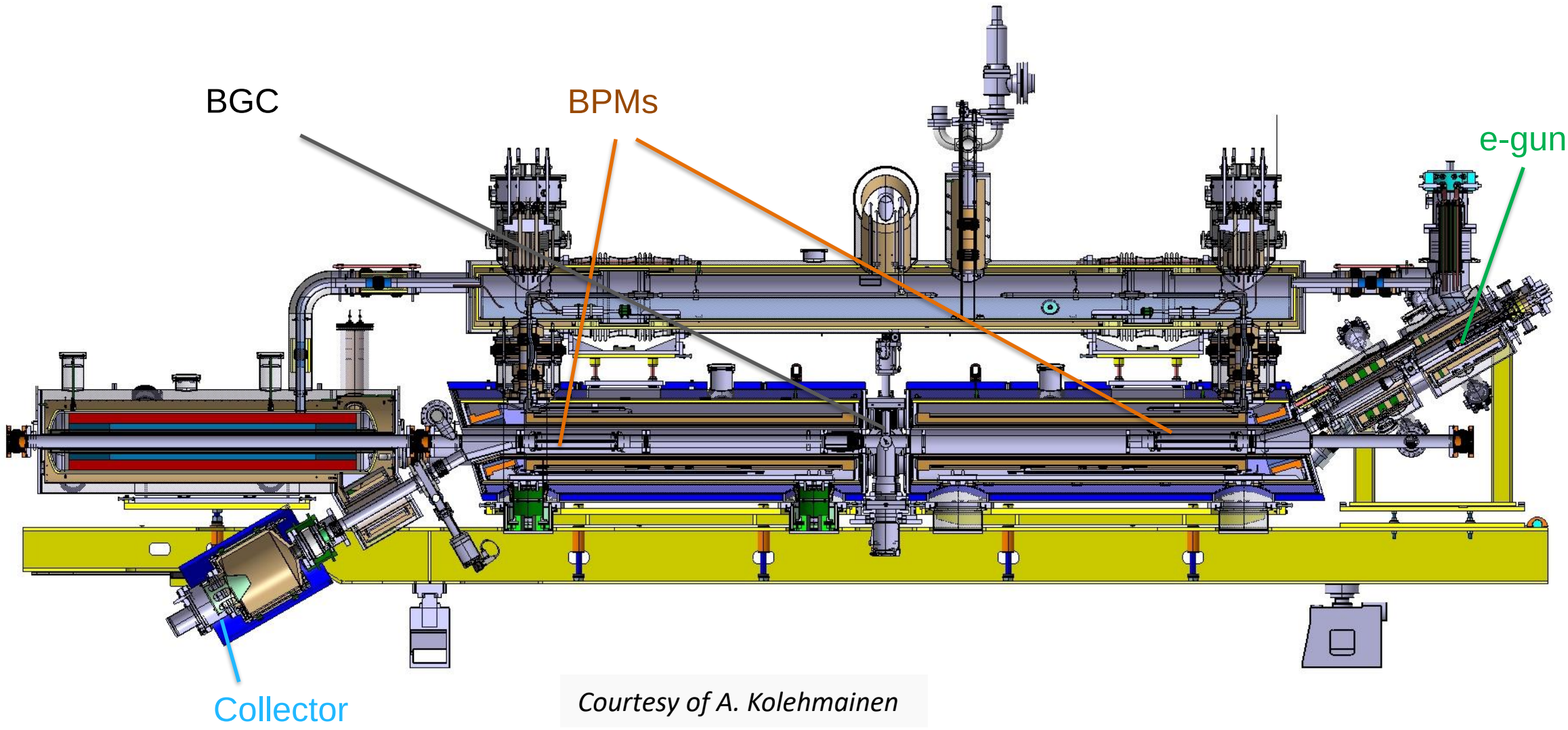
WP5.3 Scope

- 2 Hollow Electron Lens units to be installed in IR4 during LS3 plus spares components for a full 3rd unit
- Main deliverables from BINP
  - Electron gun and collector
  - Beam instrumentation
  - Vacuum system
  - Magnetic system (solenoids, correctors, compensation dipole)
- Main deliverables from UK-CI: BGC
- Main deliverables from CERN
  - Magnet detection/protection and powering
  - Cryogenics
  - HV powering and anode pulse generator
  - Design of BPM, gun and collector
  - Ancillaries (cables, water cooling, controls – including vacuum – …)
- Final tests and installation in collaboration

WP5.3 WBS

WP5.3.1	Magnet System	TE-MCS A. Foussat
WP5.3.2	Magnet Protection	TE-MPE M. Wozniak
to go to WP9	Cryogenics	TE-CRG G. Ferlin
WP5.3.3	Vacuum	TE-VSC G. Bregliozzi
WP5.3.4	Powering	SY-EPC M. Martino
WP5.3.5	Modulator	SY-ABT E. Carlier
WP5.3.6	Electron Gun & Collector	SY-BI A. Rossi
WP5.3.7	Instrumentation (BPM, BGC, BLM)	SY-BI M. Wendt, R. Veness, C. Zamantzas
WP5.3.8	Electron Beam Test Stand	SY-BI A. Rossi
WP5.3.9	Survey & Alignment	BE-GM J-F. Fuchs
WP.5.3.10	Utilities & facilities	SY-BI A. Rossi
to go to WP15	Integration & Tunnel infrastructure modification & Installation	J. Oliveira (EN-ACE)
	Design by D. Perini & A. Kolehmainen EN-MME	

HEL design 2021



Courtesy of A. Kolehmainen

HEL main specifications

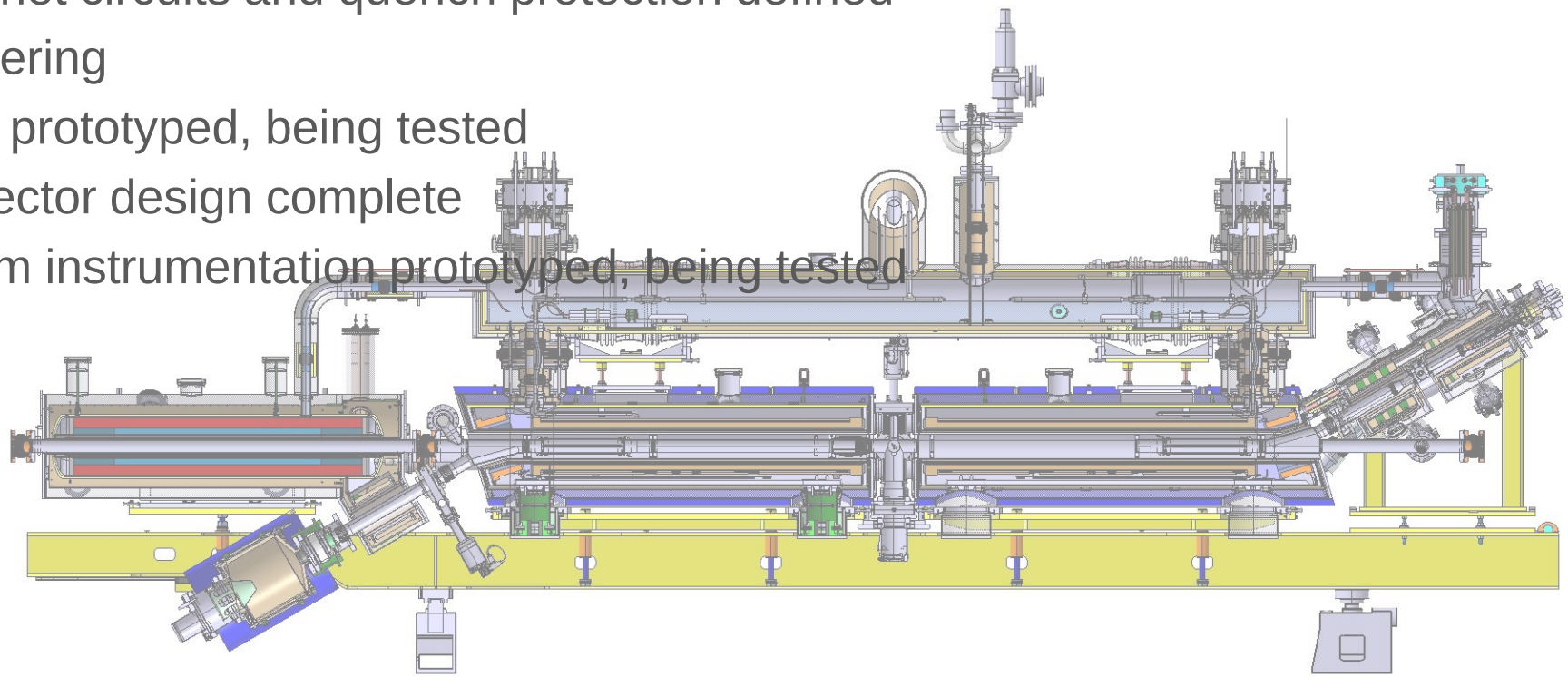
Property	Specification	
Design current (cathode 4/8 mm radii)	**5.0 A ± 0.5 A**	Stability over a pulse and from pulse to pulse 0.5%
Interaction region length (at min. inner beam radius)	**3 m**	90% halo depletion in 5 min
Min/max inner radius at 7 TeV	**1.1/2.2 mm ± 0.01 mm**	3.6/7.2 LHC beam sigma (280 m β) ± 1%
Electron beam position range	**± 4 mm**	± 2 mm for LHC orbit variations, misalignment + 2 mm for set up purposes
Electron beam angle range	**± 2 mm / 3 m**	For LHC orbit variations
Position stability fill to fill and pulse to pulse	**0.03 mm**	1% of LHC beam sigma at 7 TeV
Rate of position change	**0.1 mm / s**	-
Electron pulse length	**1.2-86 μs**	To leave witness batches
Maximum number of pulses for LHC turn	**3**	
Electron beam rise time	**< 200 ns**	To inject between SPS batches
Tolerated integrated dipole kick in the core	**1 nrad**	➔ Tight requirements on e-beam : • symmetry entrance / exit of e-beam trajectory • Electron density distribution • Smooth trajectory

WP5.3 Main achievements

- Functional specifications of overall HEL device (EDMS No 2514085)
  - Missing more detailed study on e-beam optics and magnetic layout/map
- Functional specifications of HEL Magnets (EDMS No 2515452) drafted
  - Interfaces specifications almost complete (drawings missing)
  - In review (Hollow E-Lens Magnet System Review https://indico.cern.ch/event/1061478/)
- Functional specifications of HEL High Voltage System (EDMS No 2265586) in eng. check
  - Technical specifications already on going. Safety will be included in each of the HEL TS documents
- Functional specification of HEL Pulse Generator (EDMS No 2265592) in eng. check.
  - Technical feasibility analysis completed → internal to CERN

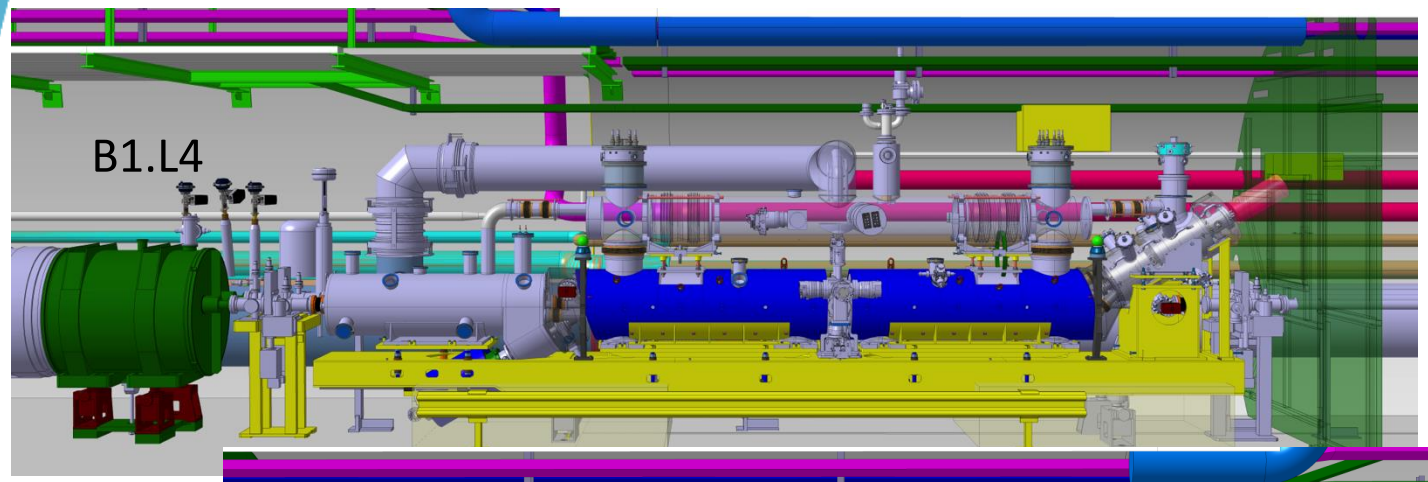
WP5.3 Main achievements

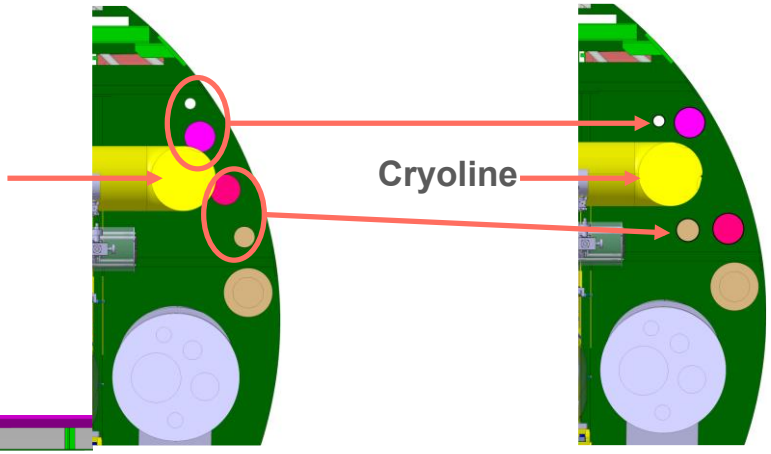
- Overall design well advanced
  - Integration and installation
  - Cryogenics
  - Magnets specs reviewed
  - Magnet circuits and quench protection defined
  - Powering
  - Gun prototyped, being tested
  - Collector design complete
  - Beam instrumentation prototyped, being tested

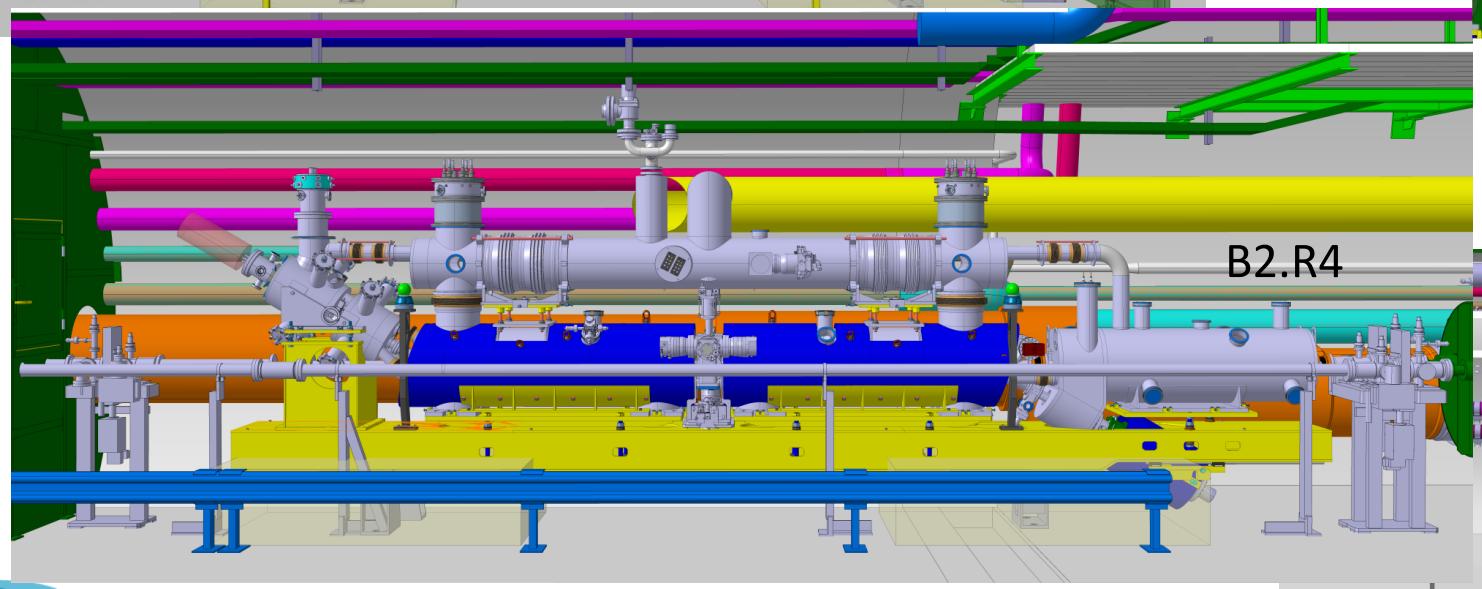


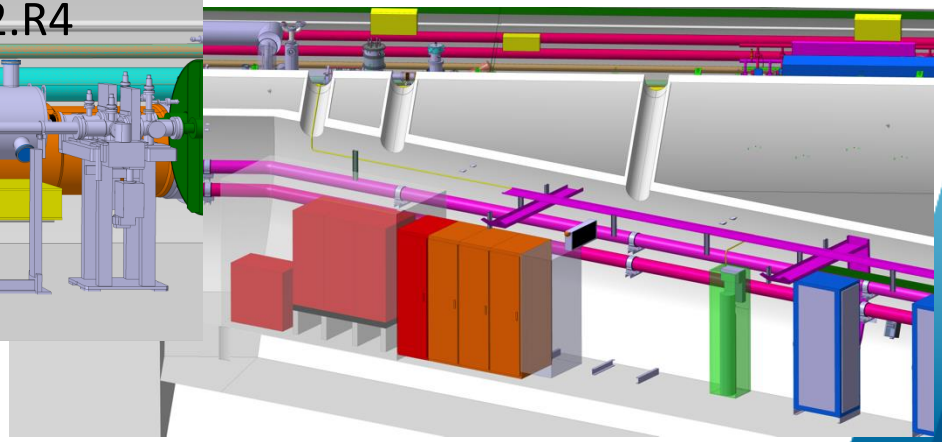
WP5.3 Main achievements

Integration and installation





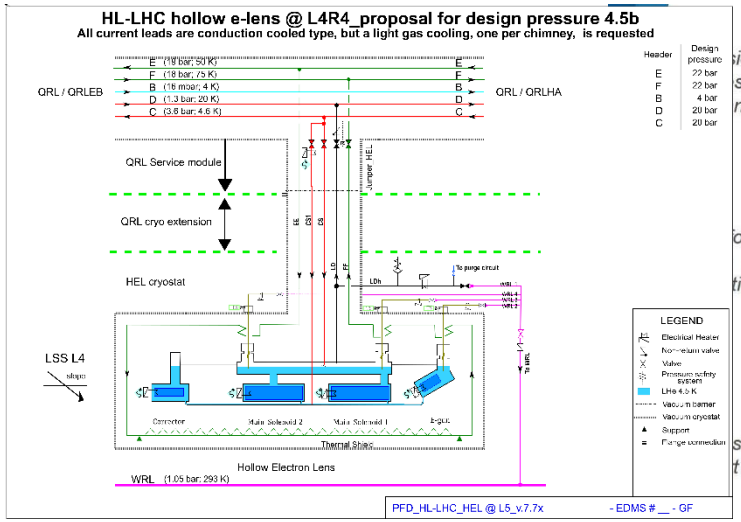


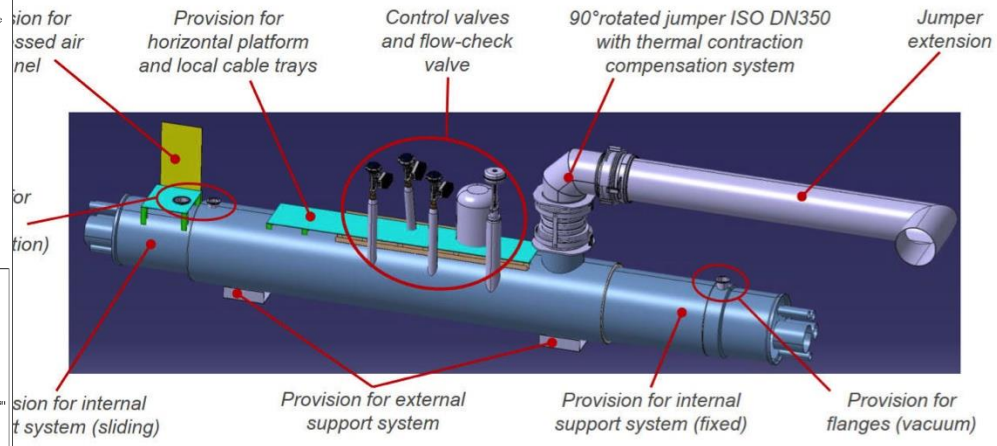


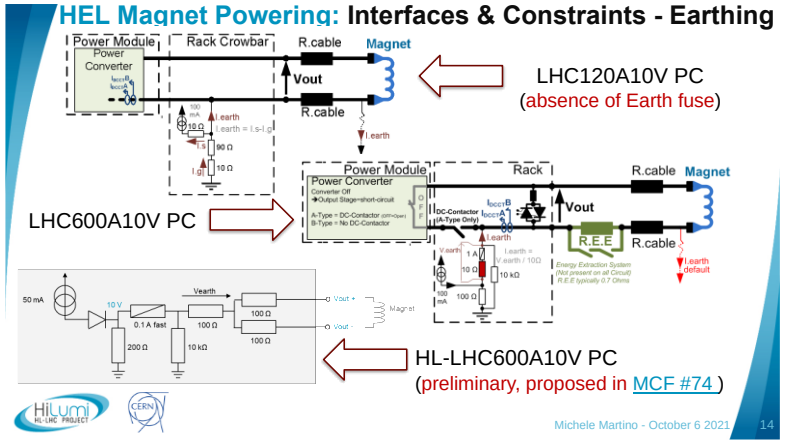
WP5.3 Main achievements

Cryogenics

- Service module designed
- Pressure analysis for magnet system complete (4.5barA)

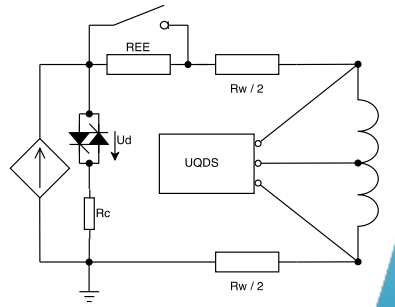






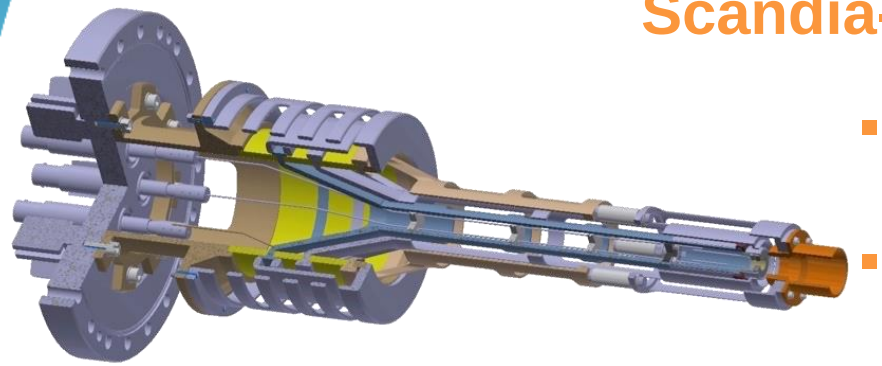
Circuits and quench protection

- Recovering 120A&600A PC from LHC – circuit analysis completed
- Energy extraction required for main solenoids only, full study complete

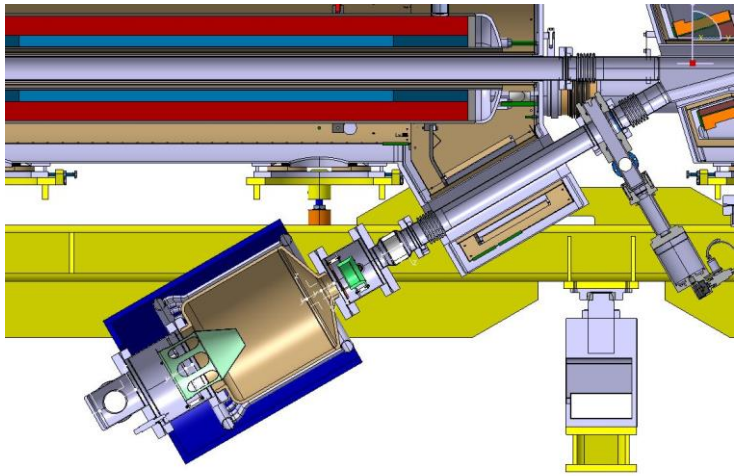


WP5.3 Main achievements (key technology demonstration)

Scandia-doped W cathode electron gun

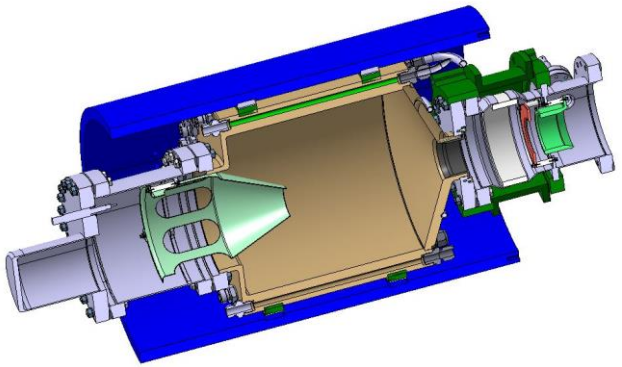


- Scandia-W cathode produced 5A at FNAL (G. Stancari)
- HEL e-gun prototype CHG-16-sc-e BIS validated electrically at e-beam test stand (no HV break-down)
- Current extracted at E-Lens Test Stand



Collector

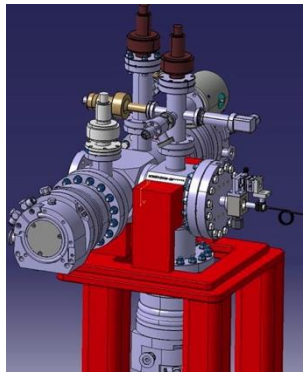
- Collector design completed
- Waiting for validation from e-beam transport simulations before production is launched

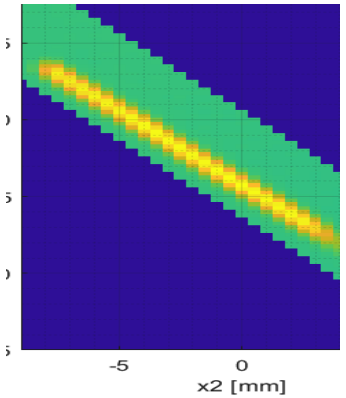


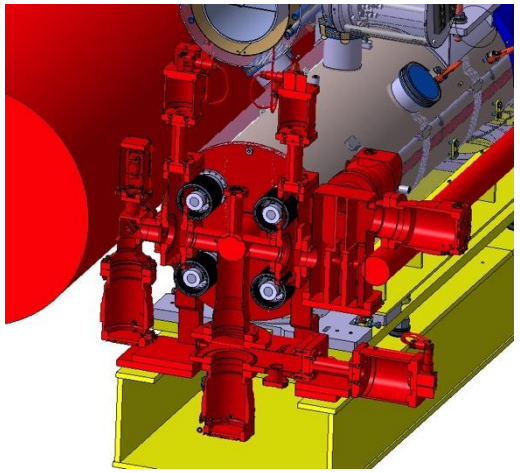
WP5.3 Main achievements (key technology demonstration)

- Version for LHC measurements to be tested at EBTS – Q1/2 ’22, at LHC in 2023.
- Gas curtain 9x0.3mm at 10^{16} N_2/m^3
- Design to fit in tight HEL space in progress

BGC (e- and hadron beams)

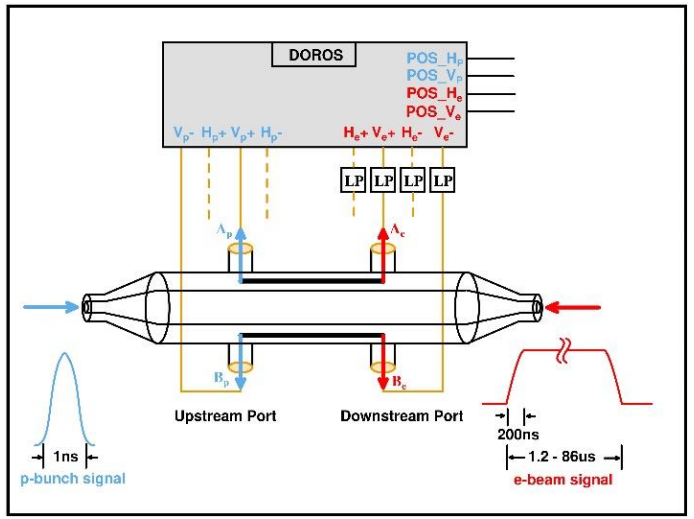


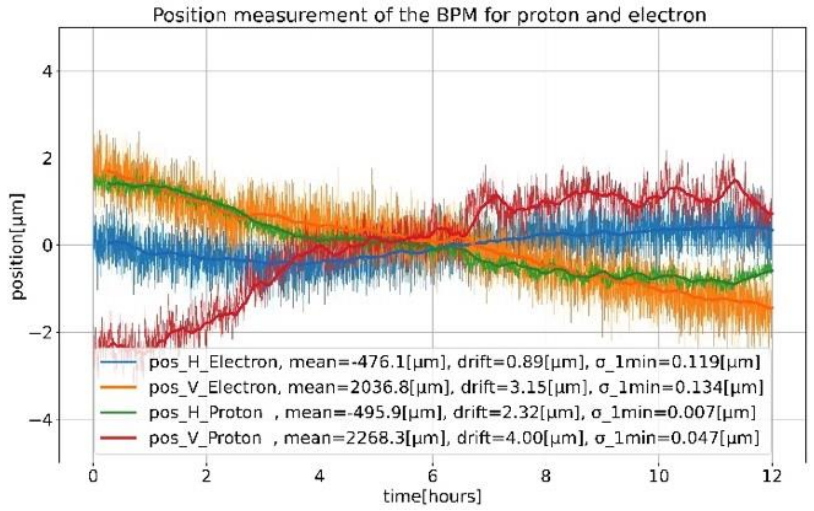




Stripline BPM (e- and hadron beams)

- Numerical simulations and laboratory measurements demonstrate the feasibility of measuring both ~ DC e-beam and bunched LHC beam, with < 2um difference

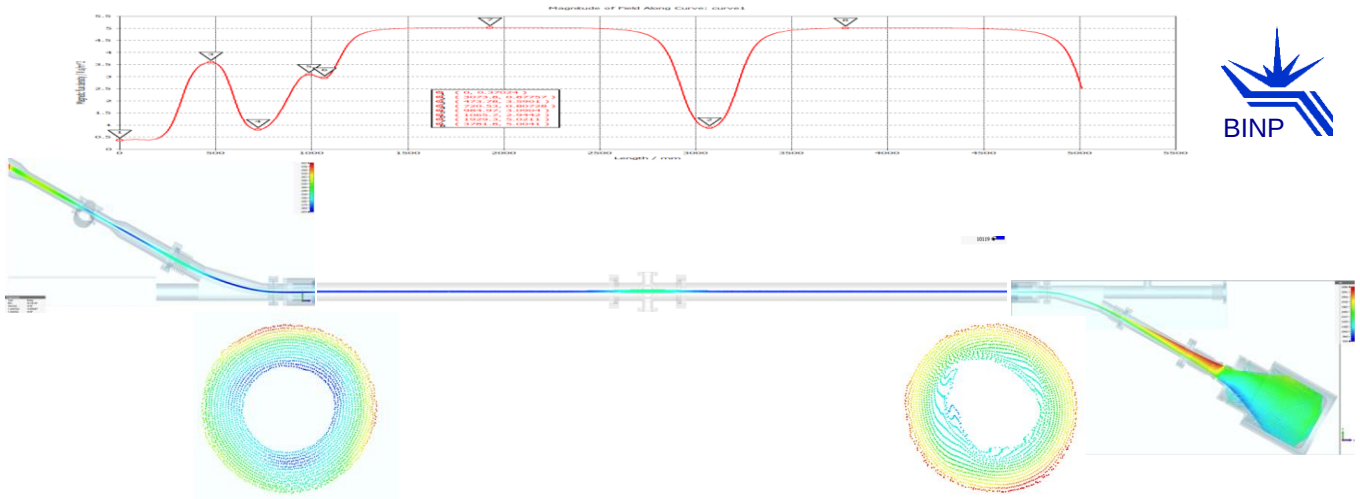


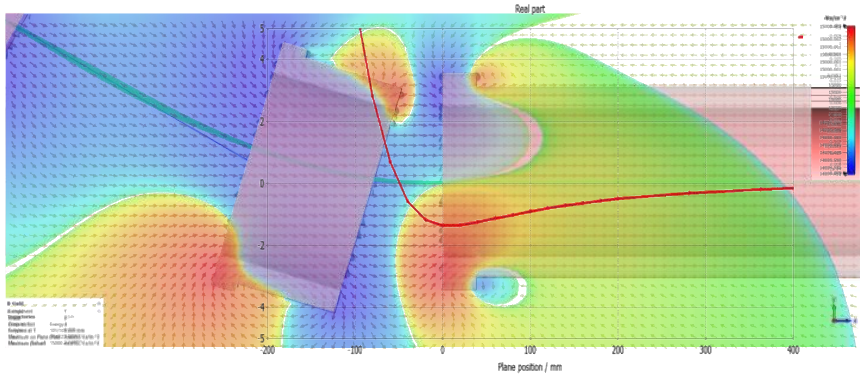


WP5.3 Open points: e-beam optics and magnet layout

- Electron beam optics
  - 0.1nrad residual kick

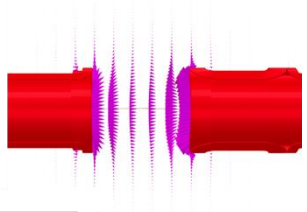
Courtesy of D. Nikiforov and BINP team

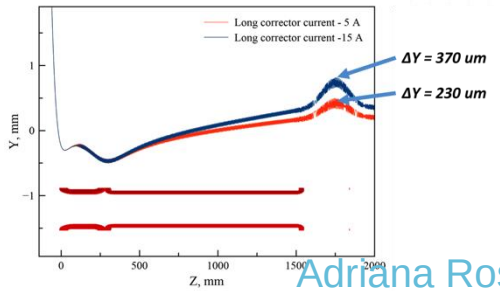




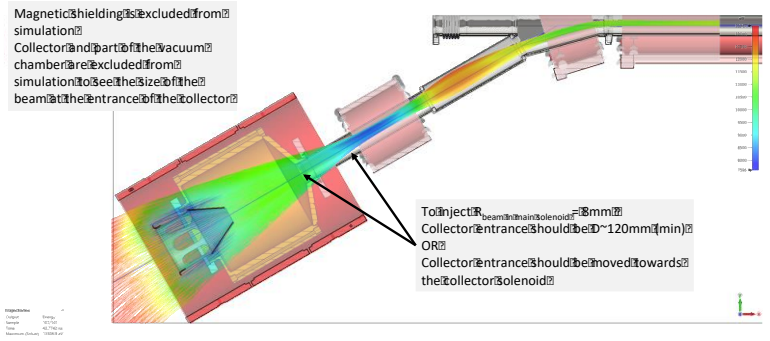
- Magnetic model required for specs work done in collaboration with BINP

Due to magnetic field lines distortion in the middle gap, the full uncentered beam deflection was observed



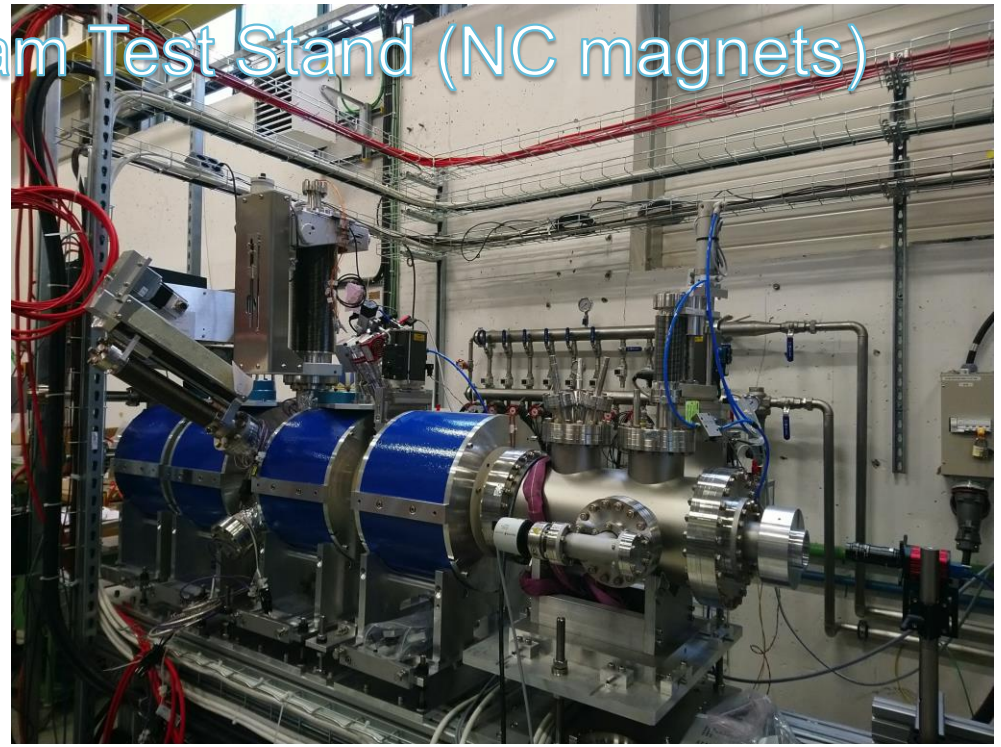


EBeam trajectories, initial R_b=8mm

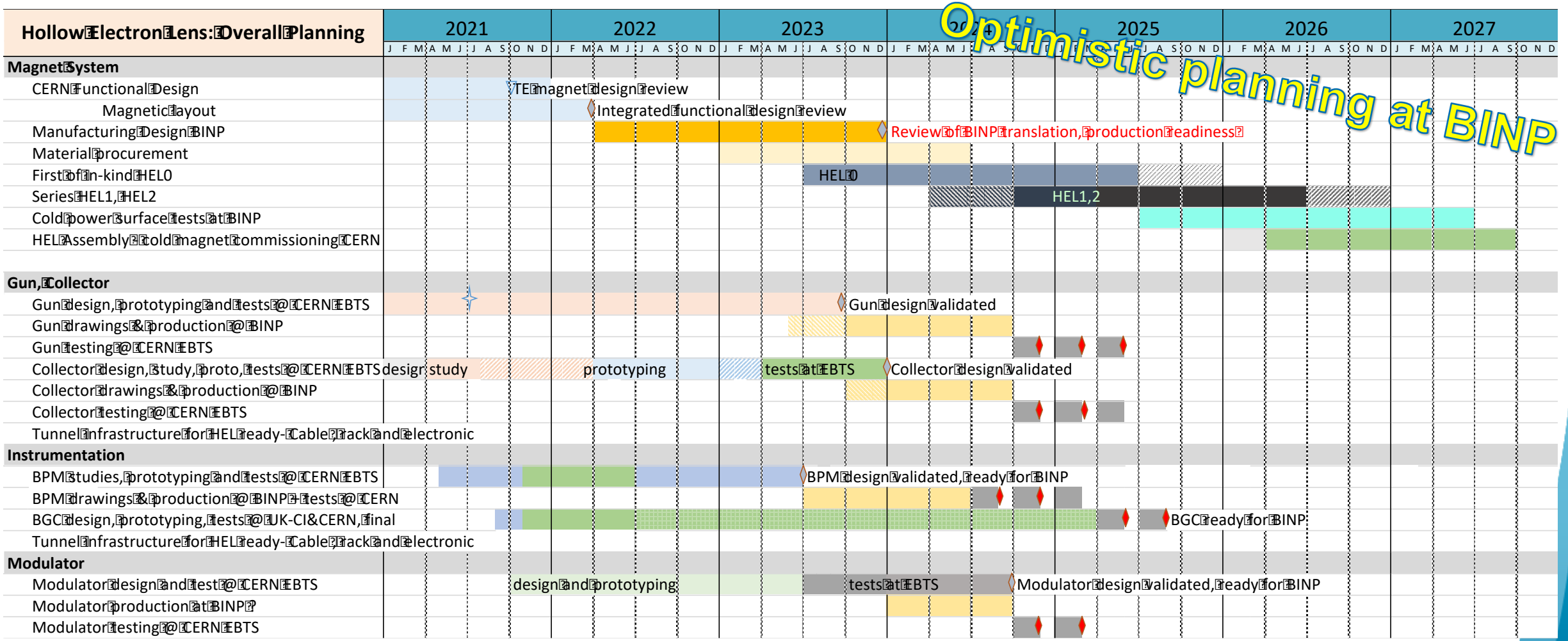


WP5.3 Roadmap

- Complete studies to define magnetic layout in collaboration with BINP
- Finalise magnet functional specifications and interfaces technical specifications
- Complete all procurement documentation to pass the baton to BINP . . .
- Continue tests at CERN Electron Beam Test Stand (NC magnets)
  - Electron gun
  - Collector (prototype still to be built)
  - BPM
  - BGC
  - Pulse Generator
  - HV system (powering and controls)



In-kind status and effect of planning



Assumptions for production schedule at BINP based on capabilities estimated by CERN experts!

Thank you for your attention