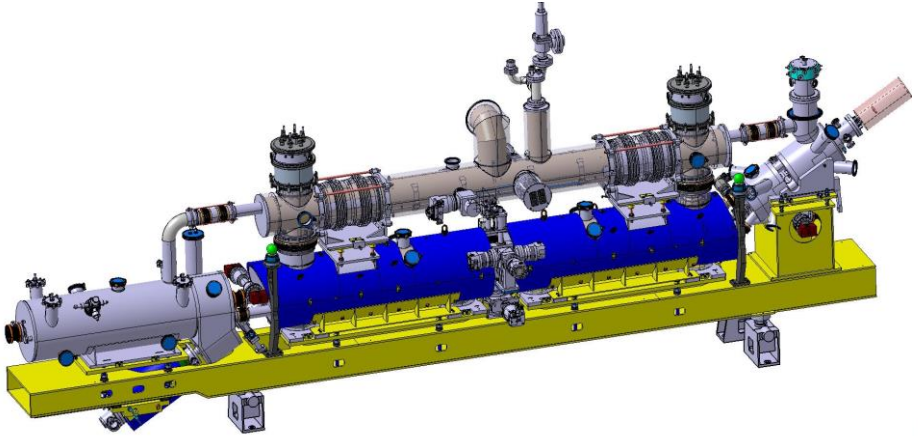
HiLumi
HL-LHC PROJECT

Hollow Electron Lens
HEL



A. Rossi for the HEL team

Acknowledgements along the presentation are not exhaustive

CERN

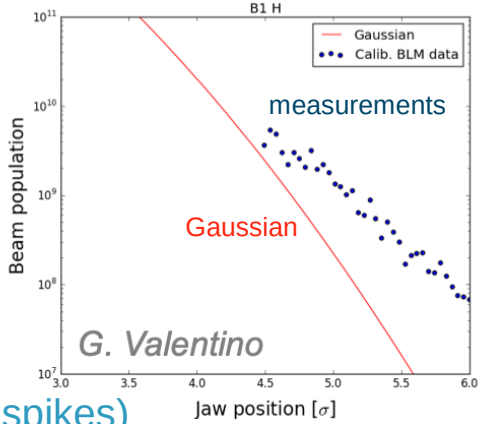
12th HL-LHC Collaboration Meeting, Uppsala (Sweden),19-22 Sept. '22

Outline

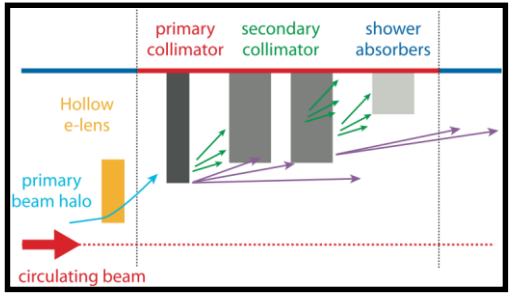
- Motivation for the HEL and integration into the HL-LHC baseline as in-kind from Russia
- Work carried out so far:
  - Mechanical design and documentation
  - Integration, cryogenics, circuit and quench protection
  - Gun and instrumentation design
- Proposal of discoping from HiLumi
- Plan for « soft landing » and deferring the project
- Results obtained recently
- Summary

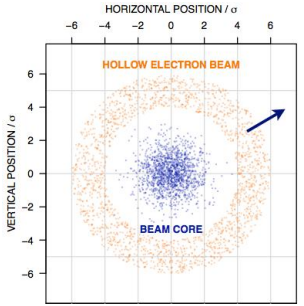
Motivation for the Hollow Electron Lens

- HL-LHC target 700 MJ stored beam energy
- Consistent indications of over-populated tails in the LHC's Run I and Run II (collimator scan measurements).
  Scaling to HL-LHC → up to 30MJ above 3 σ
  - Up to 5% of total beam current statically stored in the tails
  - Obvious concerns for machine availability (dumps from loss spikes)
  - High potential of damage limit for fast failure 1MJ x 10ms in IR7 (C. Hernalsteens @ HL collaboration meeting 2021)



Need for an active tail control at the HL-LHC deemed necessary, assessed through different review panels.



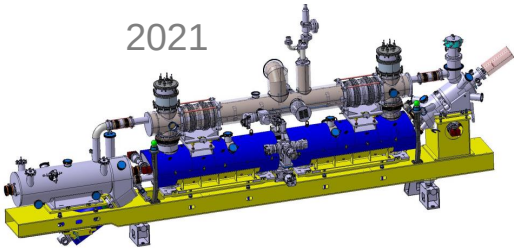


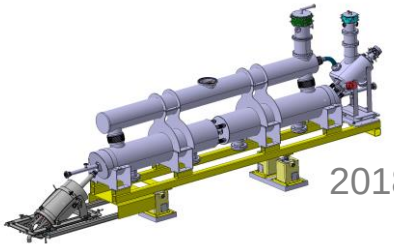
Setting up WP5.3 (2020-21)

- Following integration into HL-LHC baseline after C&SR'19
  - 2 Hollow Electron Lens units installed in IR4 during LS3 plus spares components for a full 3rd unit.
  - In-kind contribution from Russia-BINP and UK-CI.
- Main deliverable's from Russia-BINP
  - Electron gun and collector (build to print)
  - Beam instrumentation (Beam Position Monitors – BPM) (build to print)
  - Vacuum system (build to specs)
  - Magnetic system (solenoids, correctors, compensation dipole) (build to specs)
- Main deliverable's from UK-CI: Beam Gas Curtain (BGC) monitor
- Main deliverable's from CERN
  - Design of BPM, gun and collector
  - HV powering and anode pulse generator
  - Magnet detection/protection and powering
  - Cryogenics
  - Ancillaries (cables, water cooling, controls – including vacuum – …)
- Final tests and installation in collaboration

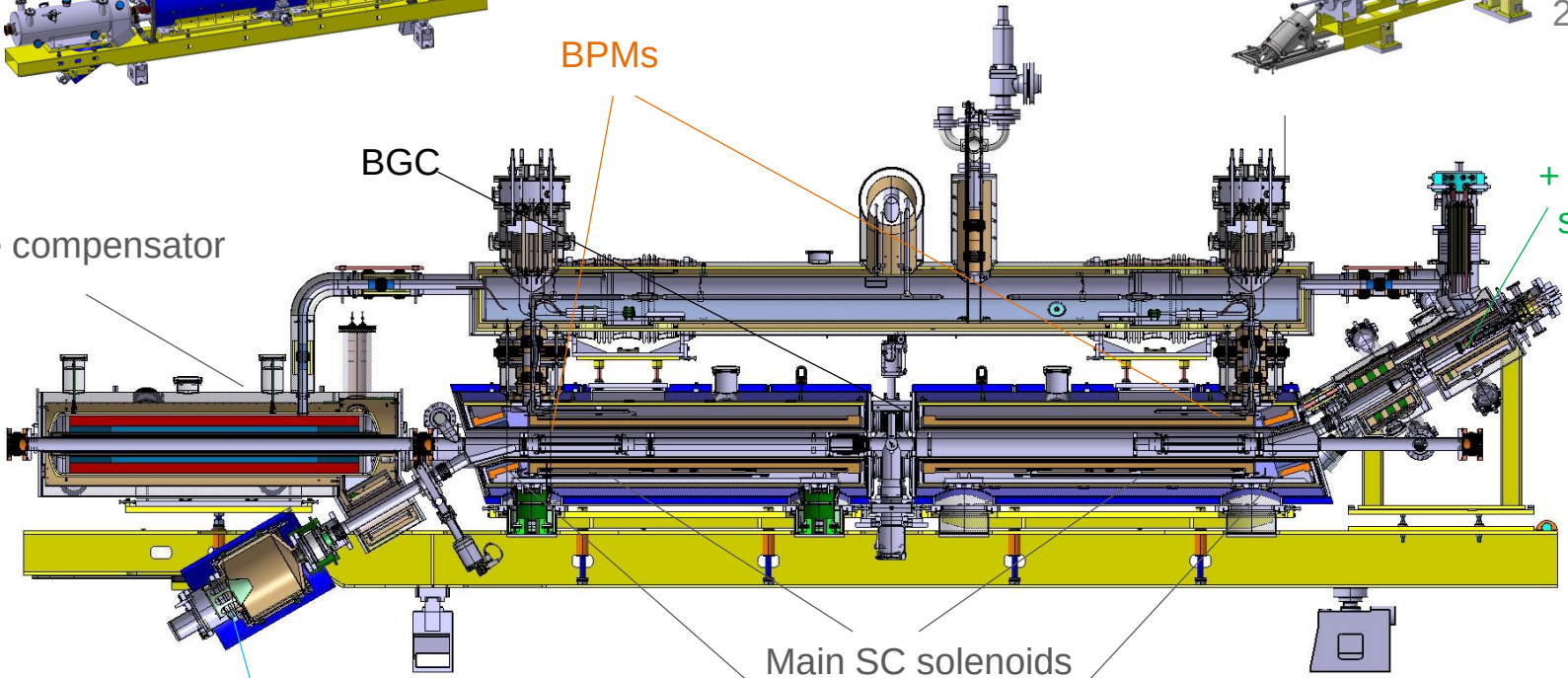
HEL design

2021





2018



D. Nikiforov & BINP team

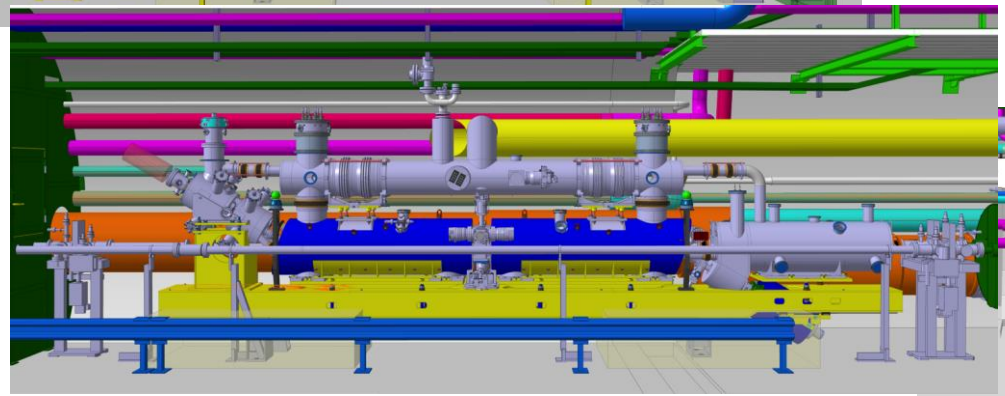
D. Perini, A. Kolehmainen

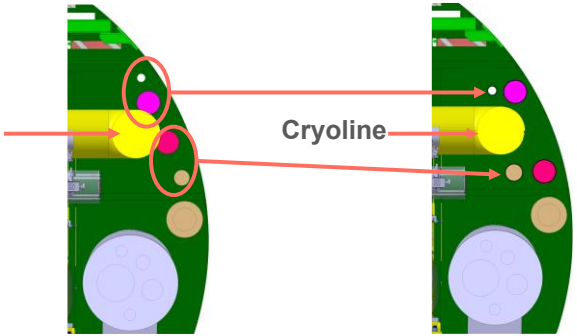
A. Foussat, A. Bragin

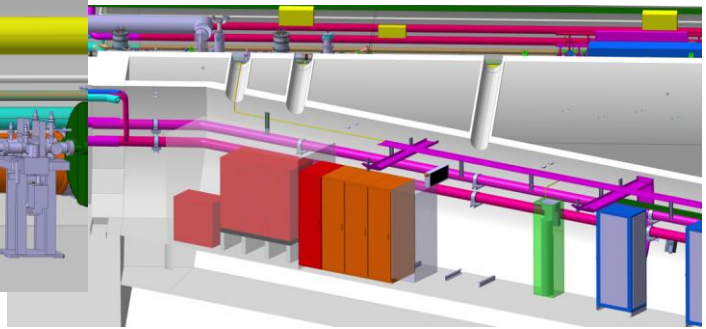
Documentation

- 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 High Voltage System (EDMS No 2265586)
  - 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)
  - Technical feasibility analysis completed internal to CERN

Integration and installation





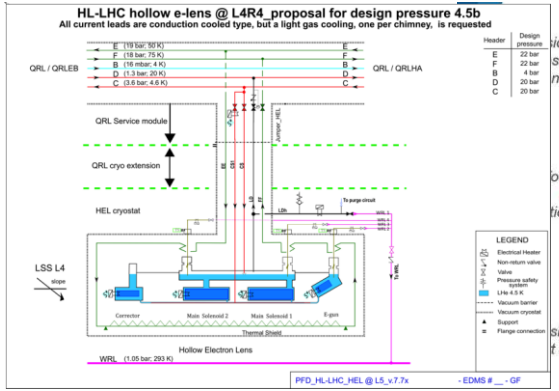


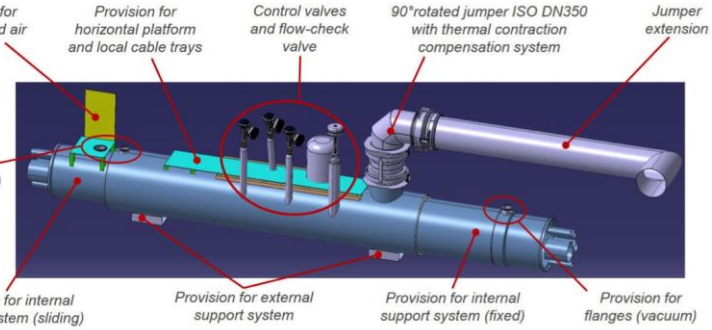
J. Oliveira

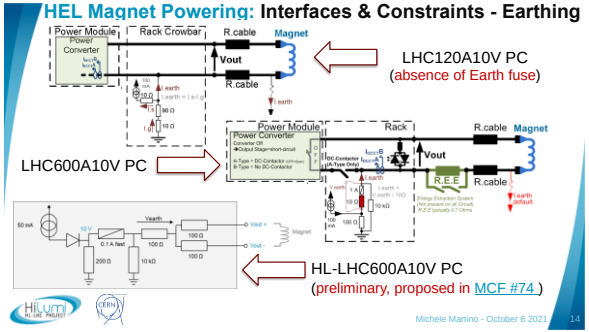
Cryogenics

- Service module designed
- Pressure analysis for magnet system complete

G. Ferlin

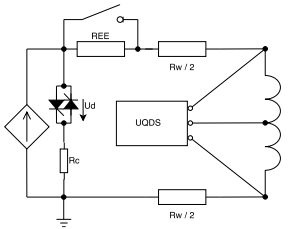






Circuits and quench protection

- Magnet circuit defined
- Quench protection system thoroughly studied
- Energy extraction required for mains only

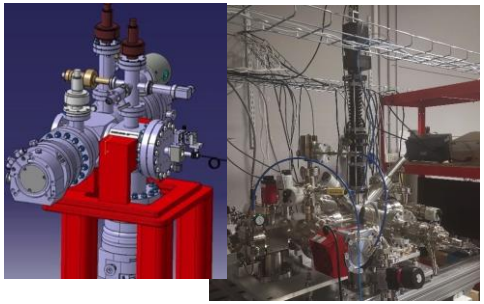


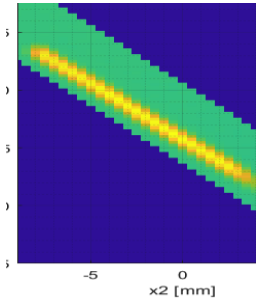
S. Yammine, M. Wozniak

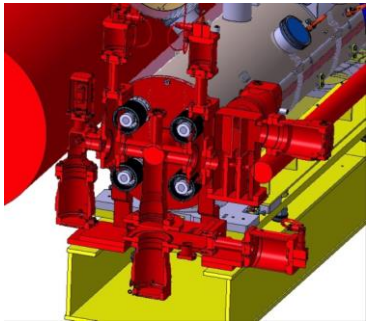
Key technology demonstration

Beam Gas Curtain (e- and hadron beams)

- G. Schneider,
- O. Sedlacek
- WP5/WP13 session Tuesday PM

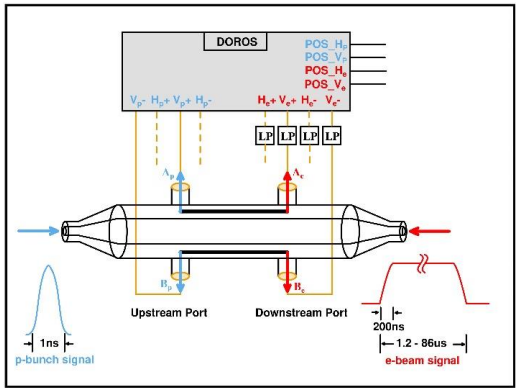


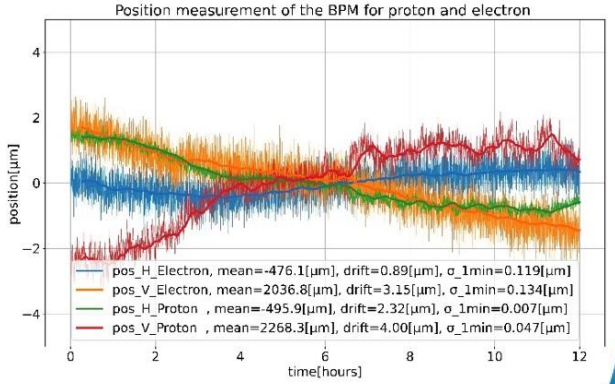




Strip-line BPM (e- and hadron beams)

- Numerical simulations and laboratory measurements demonstrate the feasibility of measuring both ~ DC e-beam and bunched LHC beam, with < 2um difference.
- Measurement at EBTS in 2023

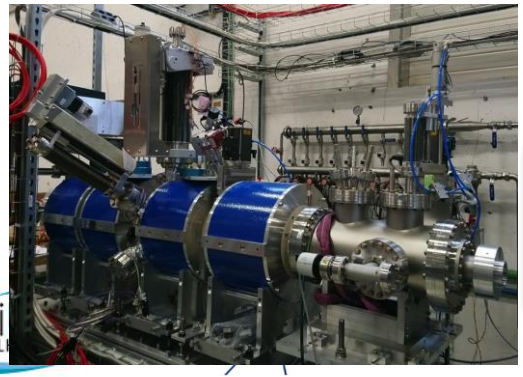




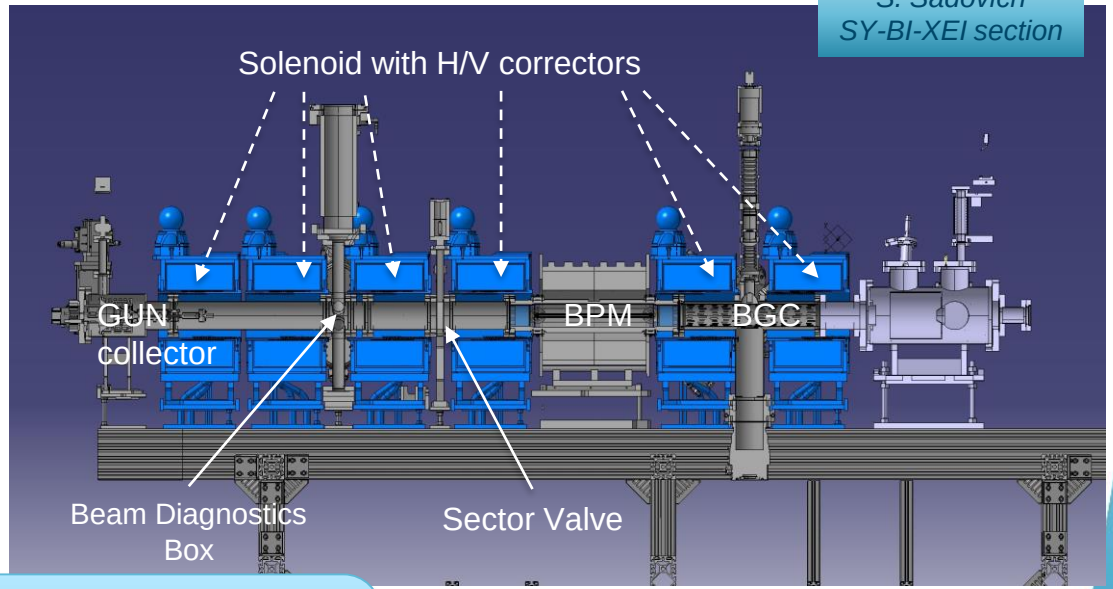
M. Wendt

Electron Beam Test Stand

- Resistive magnets (0.4T max)
- H/V correctors
- Capability of testing:
  - E-gun
  - Collector
  - BPM, BGC
  - Modulator
  - HV power convertor
  - HV control and interlocks



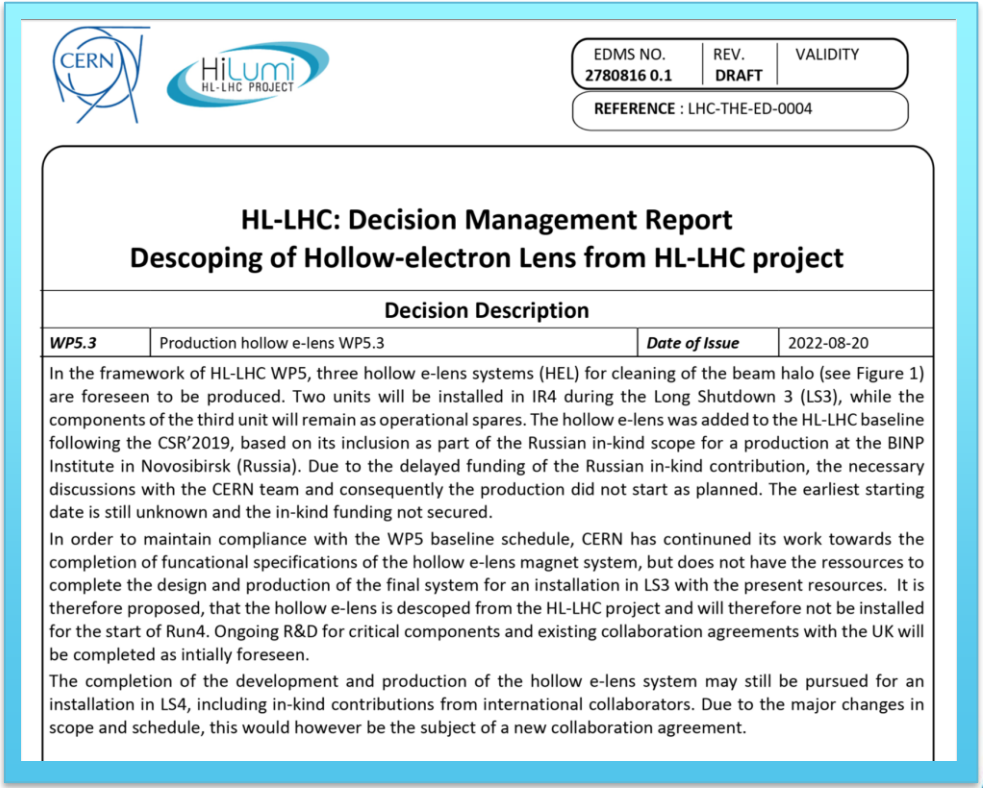
S. Sadovich
SY-BI-XEI section



Sameed M.
WP5/WP13 session
Tuesday PM

HEL after 2022

- DMR to propose a descoping from HiLumi and possible pursuing of the project for installation in LS4



EDMS NO.	REV.	VALIDITY
2780816 0.1	DRAFT	

REFERENCE : LHC-THE-ED-0004

HL-LHC: Decision Management Report
Descoping of Hollow-electron Lens from HL-LHC project

Decision Description

WP5.3	Production hollow e-lens WP5.3	***Date of Issue***	2022-08-20

In the framework of HL-LHC WP5, three hollow e-lens systems (HEL) for cleaning of the beam halo (see Figure 1) are foreseen to be produced. Two units will be installed in IR4 during the Long Shutdown 3 (LS3), while the components of the third unit will remain as operational spares. The hollow e-lens was added to the HL-LHC baseline following the CSR'2019, based on its inclusion as part of the Russian in-kind scope for a production at the BINP Institute in Novosibirsk (Russia). Due to the delayed funding of the Russian in-kind contribution, the necessary discussions with the CERN team and consequently the production did not start as planned. The earliest starting date is still unknown and the in-kind funding not secured.

In order to maintain compliance with the WP5 baseline schedule, CERN has continuned its work towards the completion of funcational specifications of the hollow e-lens magnet system, but does not have the ressources to complete the design and production of the final system for an installation in LS3 with the present resources. It is therefore proposed, that the hollow e-lens is descoped from the HL-LHC project and will therefore not be installed for the start of Run4. Ongoing R&D for critical components and existing collaboration agreements with the UK will be completed as intially foreseen.

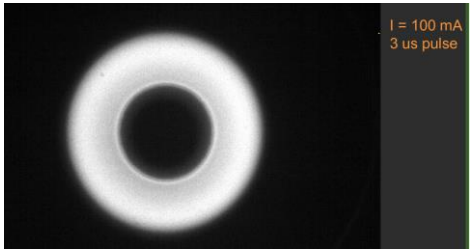
The completion of the development and production of the hollow e-lens system may still be pursued for an installation in LS4, including in-kind contributions from international collaborators. Due to the major changes in scope and schedule, this would however be the subject of a new collaboration agreement.

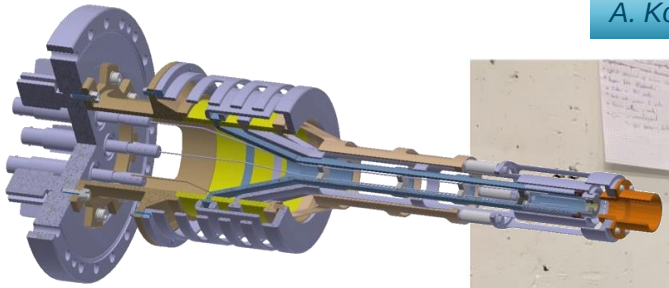
HEL “soft landing” within HiLumi ⟹ 2024-25

- Keep R&D ongoing at CERN and deliver technical design specifications for (WP5)
  - ✓ Gun design and testing to produce 5 A at 10 kV extraction voltage
  - Collector withstanding 5 A x 10 kV, high efficiency and low pressure
  - BPM
- Keep BGC monitor (with UK-CI/Liverpool) (WP13)
- Complete magnetic studies and deliver functional & interface specifications the HEL assembly (as for a transfer line)
  - E-beam transport in solenoid field + correction scheme for magnet functional specs
  - Specification of interfaces (including tunnel integration drawings)
- Propose 2 solutions for QRL (for LS or YETS installation) with associated costs
- Re-assess costs to evaluate the in-kind contribution (new partners)
- Make halo measurements to re-assess needs for the HEL

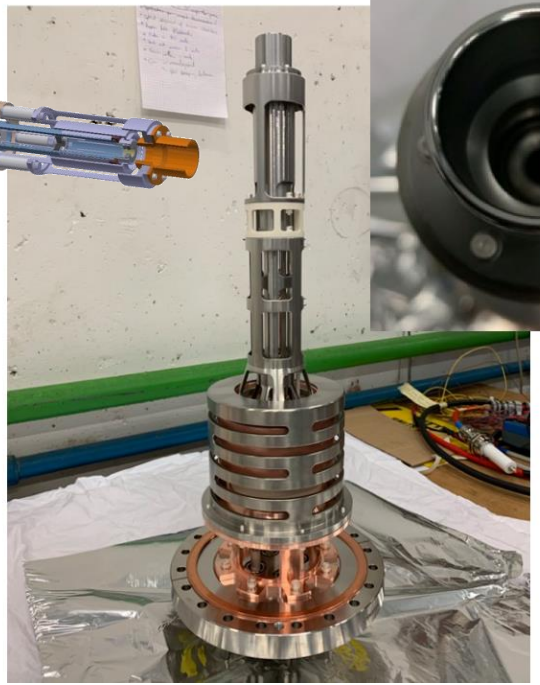
P. Hermes
Wednesday PM
WP5/WP2/WP7/WP14

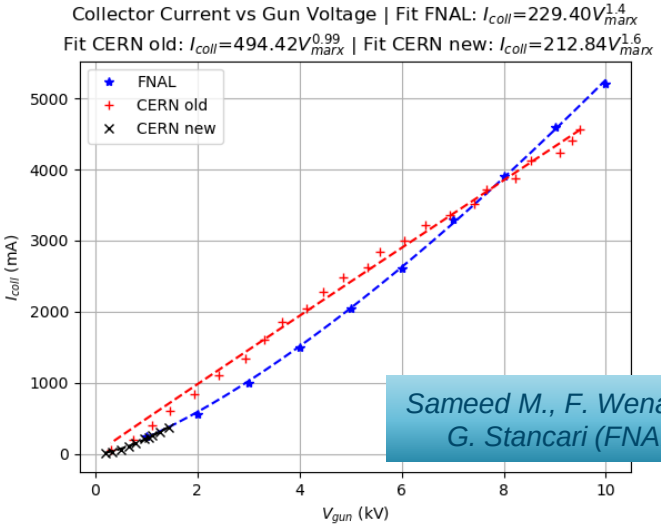
Electron gun





A. Kolehmainen

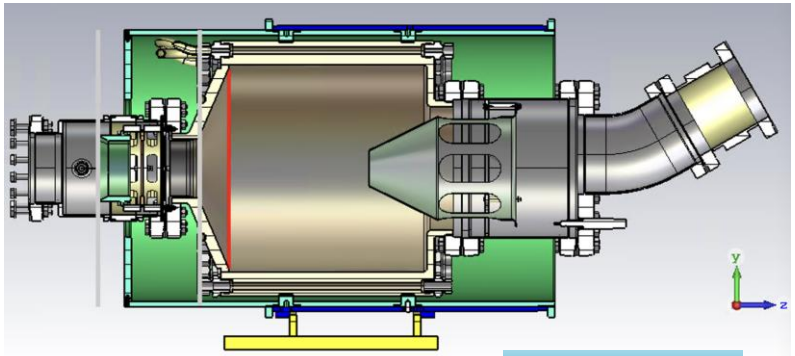




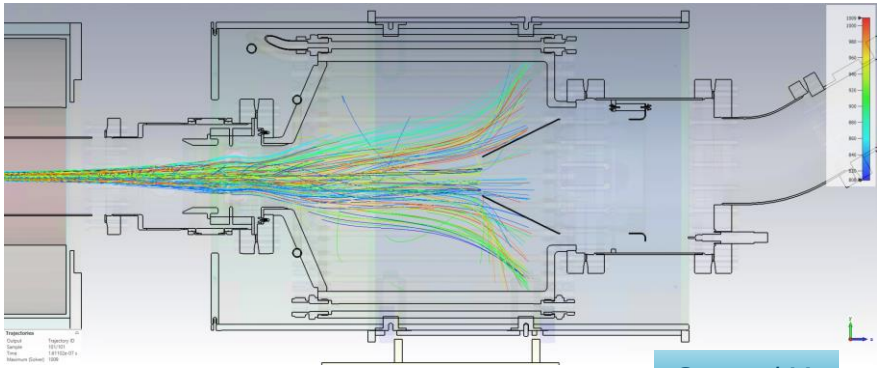
Sameed M., F. Wenander
G. Stancari (FNAL)

HEL Collector

- Mechanics/cooling to withstand max 5 A x 5 to 10 kV power
- Biasing to reduce outgassing and secondary electrons, recover power, improve efficiency
- Collector design completed, ready for prototyping
- To be verified with simulations, before proceeding:
  - Collector efficiency with biasing (retarding and repelling) electrodes
  - Vacuum performance

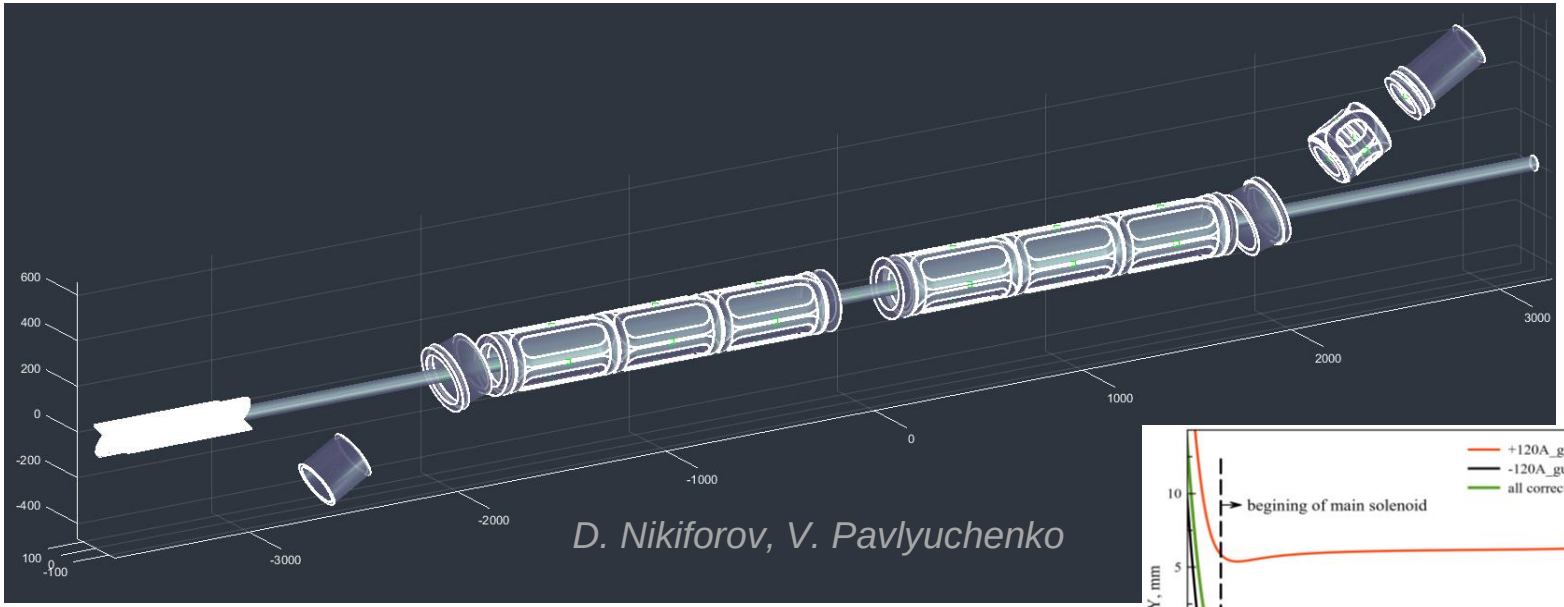


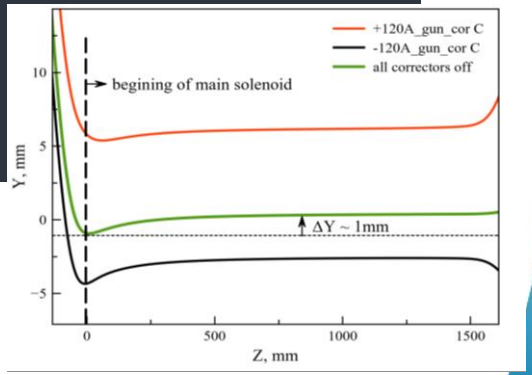
A. Kolehmainen



Sameed M.

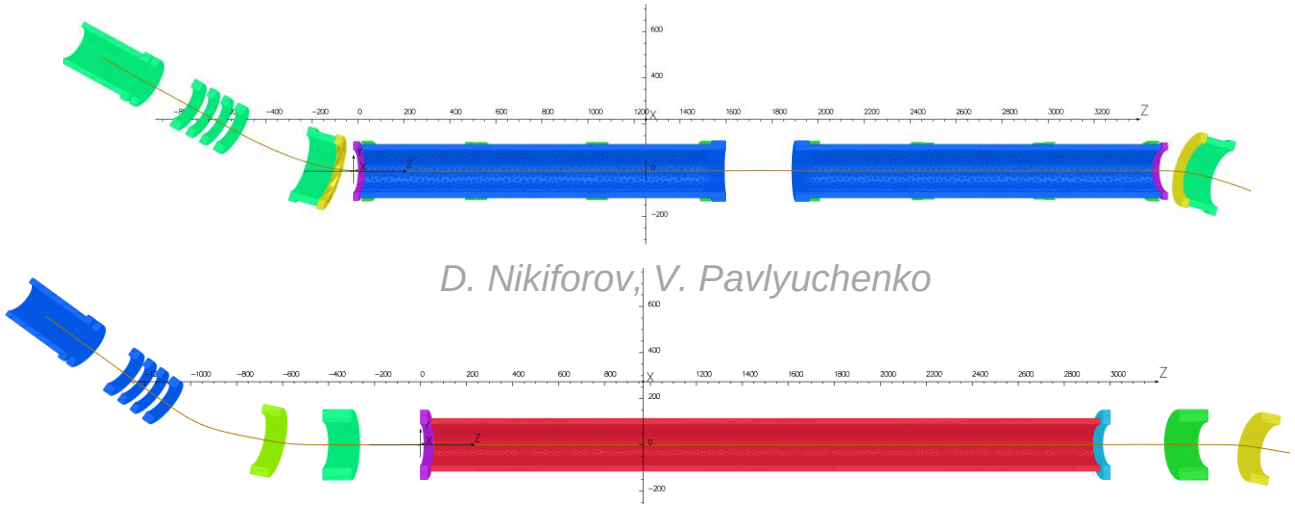
H&V dipole correctors for e-beam





- Max current 120 A to re-use LHC power converters
- Self protected design
- No correction of bump at main extremities

Solenoid magnetic system to compensate bump



D. Nikiforov, V. Pavlyuchenko

- Collaborators from BINP proposed a solution with a ‘counter-field’ solenoid at main extremities.
- Studies ongoing

Summary

- The HEL project was in a very healthy state and awaiting of the Russian contribution.
- Following 2022 world events, the HEL is currently proposed to be descoped from HL-LHC as alternative external funding has not been found.
- The agreed « soft landing » will allow some elements of the project to continue:
  - Completion of R&D at CERN, already well on its way to produce technical specifications of gun, collector and BPM
  - Studies of electron beams to finalise the functional specification of the assembly (as a transfer line)
  - BGC brought to completion

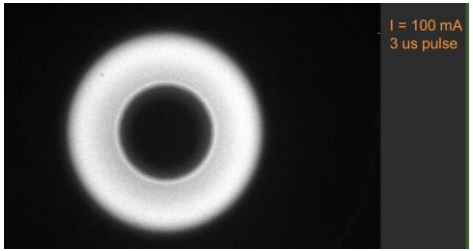
  and the HEL to resume if measurements show the need.

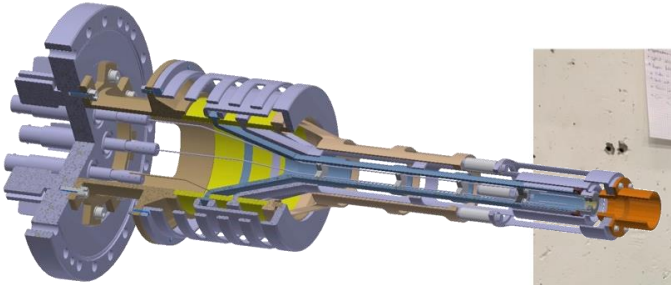
Thank you

Acknowlegments (in no specific order ! and not exhaustive)

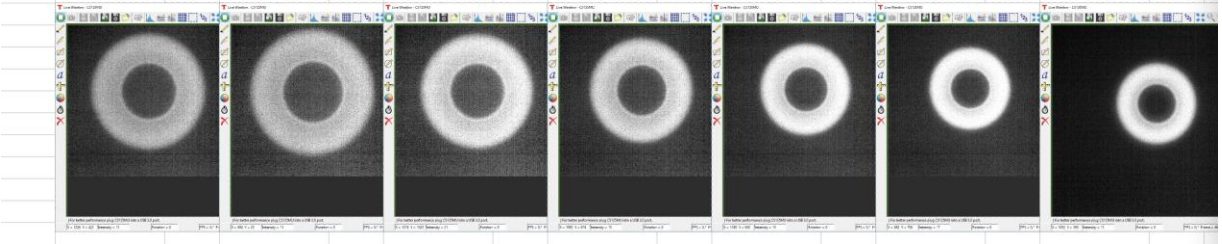
S. Redaelli, G. Stancari, D. Perini, F. Wenander, R. De Maria, A. Kolehmainen, T. Coiffet, M. Toscan Du Plantier, G. Gobbi, C. Zanoni, S. Sadovich, D. Nikiforov, A. Levichev, A. Bragin, A. Barnyakov, M. Arsentyeva, V. Pavlyuchenko, W. Devauchelle, S. Deschamps, J. Cenede, A. Churchmann, S. Muhammed, M. Wendt, L. Soby, R. Veness, G. Schneider, M. Zerlauth, D. Wollman, G. Ferlin, S. Claudet, A. Foussat, S. Yammine, M. Wozniak, J. Oliveira, P. Fessia, E. Carlier, M. Barnes, N. Voumard, M. Martino, J. Parra-Lopez, D. De Luca

Electron gun





Gun Magnet Current (A	100	200	200	200	200	200	100
BDB Magnet Current (A	55	55	100	185	300	420	420
Gun B-Field (T)	0.045	0.091	0.091	0.091	0.091	0.091	0.046
BDB B-Field (T)	0.02	0.033	0.039	0.051	0.066	0.081	0.068
Expansion Factor	1.493	1.646	1.518	1.341	1.178	1.059	0.822
Beam Size (mm)	**24.0**	**26.5**	**24.4**	**21.6**	**19.0**	**17.1**	**13.2**



20mA x 3μs pulse

- 8-16 mm cathode