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WP16: Intense, RF Modulated E-Beams

for Application in Pulsed Electron Lenses

1st Annual Meeting / Riga / 23.05.2018

David Ondreka / GSI

Outline

- WP16 Overview
- Electron Lenses
  - Principle
  - Applications at CERN and GSI
- Task Report
  - System Integration
  - Gun and Modulator
  - Test Stand
- Summary

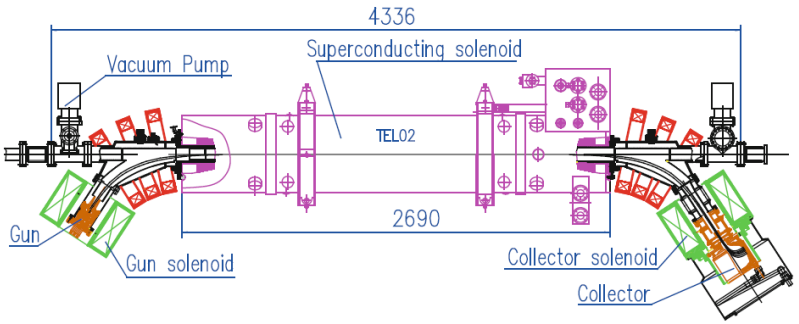
WP16: Objectives

- JRA activity among four beneficiaries (CERN, GSI, IAP, RTU)
- Manufacturing of an RF modulated electron gun for application in electron lenses
  - High electron currents ~10A
  - RF modulated at ~5MHz
  - Variable transverse beam profiles
  - Different cathode shapes
- Operation of a test stand for the RF modulated electron gun
  - Normal conducting solenoids for beam transport
  - Capabilities for testing different vacuum chamber geometries
  - Instrumentation for probing transverse and longitudinal electron beam profiles

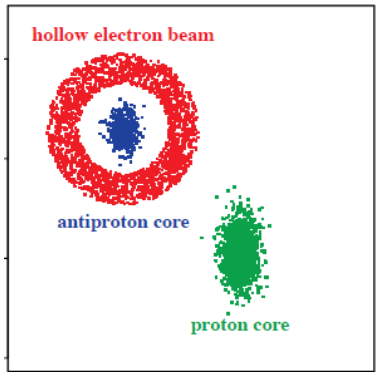
Principle and Applications of Electron Lenses

- Collinear low-energy electron beam
  - Co- or counter-moving with hadron beam
  - Magnetically confined in solenoids
  - Circulating hadron beam affected by electromagnetic fields of electron beam
  - DC or pulsed operation possible
- Applications so far at colliders only
  - Tevatron
    - Long range beam-beam tune shift comp.
    - Abort-gap cleaning
    - Halo cleaning with hollow electron beams
  - RHIC
    - Head-on beam-beam comp.
- Active research field
  - LHC LRBB compensation
  - Non-linear integrable lattices (IOTA)
  - SC compensation in low-energy hadron rings

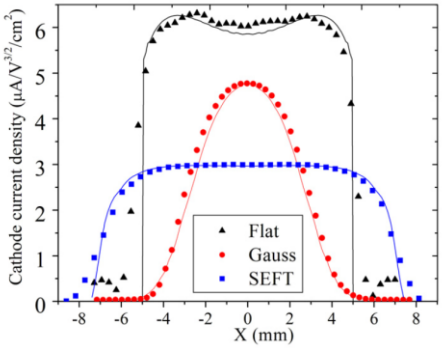
Layout of TEL-2 at Fermilab



Tevatron: p^- halo cleaning with hollow e-lens



TEL transverse profiles

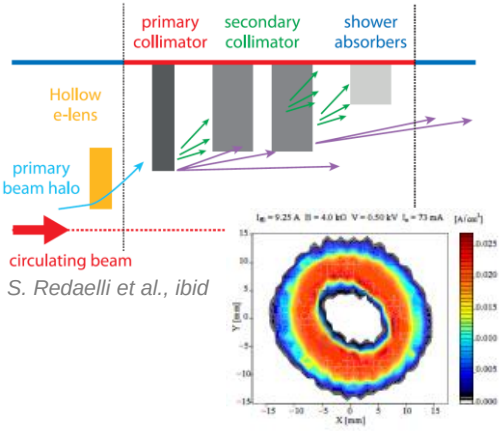


G. Stancari, "Electron Lenses in Beam Physics", 2016

Electron Lenses at CERN and GSI

- CERN:
  Hollow Electron Lens (HEL)
  for enhanced halo diffusion in LHC
  - Upgrade of collimation system for HL-LHC
  - Increased diffusion speed in non-linear field
  - Electron current about 5 A
  - DC and pulsed mode with 200ns rise time

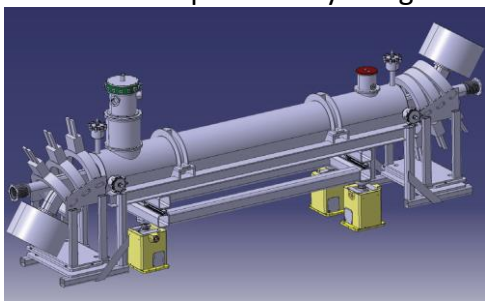
Principle of collimation with HEL



S. Redaelli et al., ibid

V. Moens, Thesis, 2013

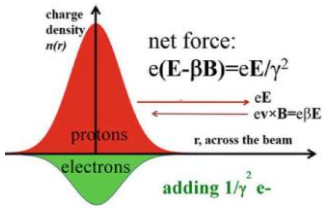
LHC HEL: preliminary design



S. Redaelli et. al., IPAC'15, WEBB1

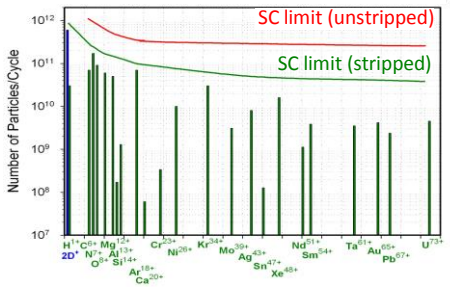
- GSI:
  Electron Lens for
  Space Charge Compensation (SCC)
  - Upgrade of SIS18 to increase intensity
  - Partial compensation of space charge tune spread
  - Bunched ion beams requiring e-beam modulation
  - Matching of transverse profile to flat ion beam
  - Electron currents about 10 A
  - Modulation bandwidth about 5 MHz

Transverse profile matching

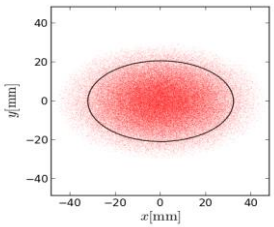


Shiltsev, 2016

SIS18: Present ion intensities



SIS18: Flat beam

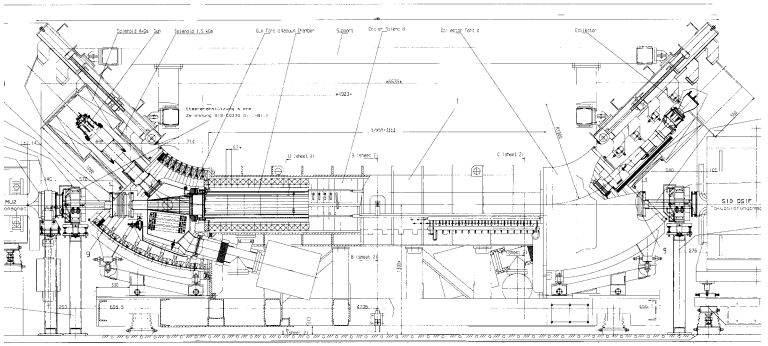


SIS18: Bunches during cycle

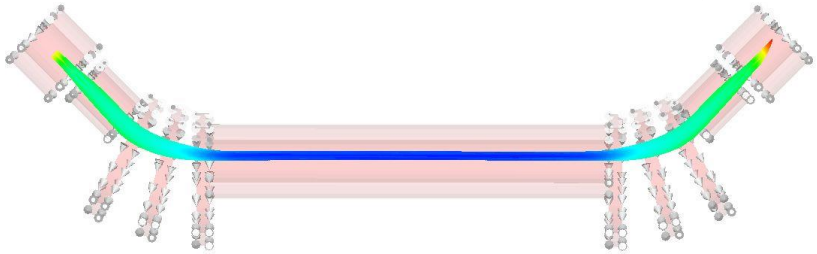
System Integration: Status

- Goals
  - Layout of a full electron lens for space charge compensation (SCC) in SIS18
  - Definition of requirements and constraints for SCC gun to be built within ARIES
  - Design of the magnetic system, vacuum system, HV system, diagnostics, support structure, infrastructure
  - Consideration of ion beam dynamics in presence of SCC electron beam
- Work done in Y1 (GSI)
  - Magnetic layout of lens based on preliminary electron beam parameters
  - Geometry similar to existing SIS18 electron cooler
  - Electron beam transport simulations performed
  - Magnet aperture and field requirements derived
- Work done by associated partner TUD
  - Simulation of ion beam dynamics with SCC lenses
  - Preliminary results (to be published)
    - Min. three lenses required for SIS18 (symmetry)
    - Pulsed homogeneous beam promising for partial compensation

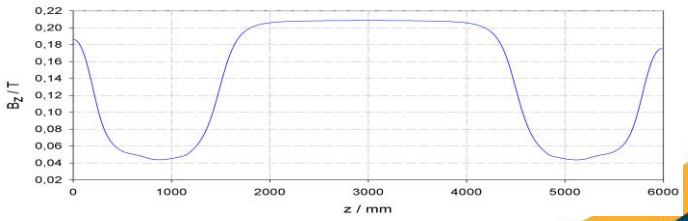
SIS18 electron cooler



SIS18 SCC lens layout: electron beam transport



SIS18 SCC lens layout: longitudinal field



System Integration: Plans for Y2

- Refined electron beam transport simulations
  - Consideration of vacuum chamber geometry
  - Incorporation of final gun design
  - Incorporation of results from ion beam simulations
  - Error analysis and robustness
- Layout of magnetic system
  - Acquisition of gun and collector solenoids based on existing design from IAP
    - To be used temporarily for basic gun tests at IAP
  - Magnetic design of main interaction solenoid based on preliminary lens layout
  - Magnetic design of bending solenoids
- Layout of XHV system
  - Choice of chamber geometry based on electron beam dynamics simulations
- Layout of support structure

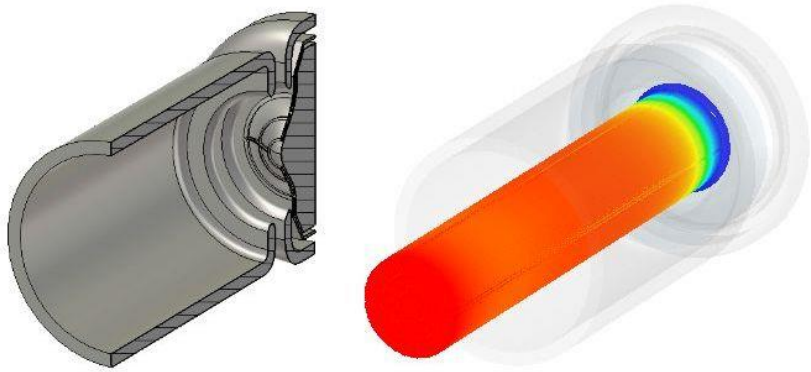
More details in highlight talk by K. Schulte-Urlichs (GSI)

SCC Gun Design: Status

- Goals
  - Design of a gun for the SIS18 SCC lens
    - Peak electron currents up to 10 A
    - Transverse profile matched to elliptical ion beam
    - Full modulation with bandwidth ~ 5 MHz
    - Modulation by grid to reduce power
  - Manufacturing and testing of gun
    - Full gun characterization at CERN test stand
    - Basic powering and performance tests at IAP
- Work done in Y1 (GSI, IAP)
  - Gun design
    - Preliminary design of gun with grid completed
    - Gaussian transverse profiles, preserved under modulation by grid
    - Extraction of round beam, transformation into elliptical beam by quadrupole integrated in gun
  - Preparation of site for basic tests
    - Testing site in concrete bunker cleared
    - Layout of test bench under way
    - Inclusion of gun and collector solenoids of final lens

SCC Gun Requirements (Preliminary)	
Extracted current	10 A
Hor./vert. beam size	35 mm/20 mm
Cathode radius	~30 mm
Gun solenoid field	~0.5 T
Extraction Voltage	>25 kV
Grid voltage	~3 kV
Dissipated power	~3 kW
Modulation bandwidth	5 MHz

SCC gun layout and simulation of extraction



SCC Gun Design: Plans for Y2

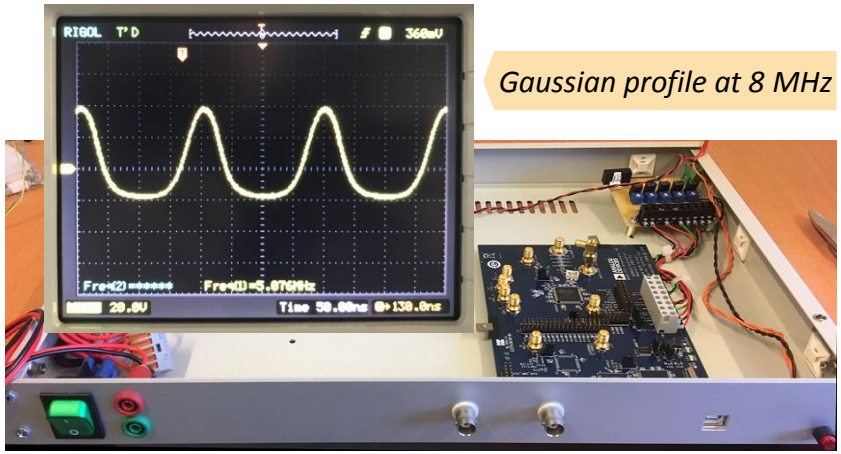
- Finalization of gun design
  - Adaptation of present design to allow for exchange of cathode to deliver homogeneous beam as well
  - Refined simulation of grid modulated extraction including estimation of beam load on grid
  - Technical design for inclusion of quadrupole for modification of aspect ratio into gun
  - Choice of cathode material
- Manufacturing of gun prototype
- Preparation of test site at IAP
  - Finalization of test bench layout
  - Adaptation of existing solenoid design for gun and collector solenoid
  - Purchasing of gun and collector solenoids
  - Preparation of diagnostics and data acquisition

More details in highlight talk by K. Schulte-Urlichs (GSI)

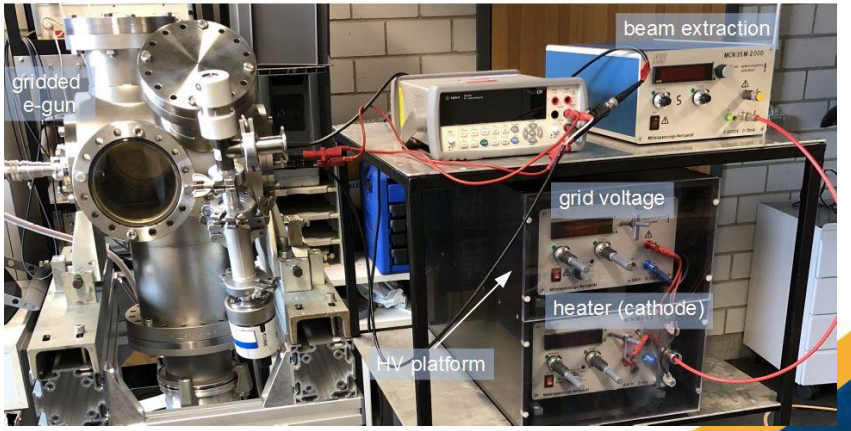
Modulator: Status

- Goals
  - Modulator for grid modulation of SCC gun
    - Full modulation requiring 3 kV at 0.1 A
    - Bandwidth >= 5 MHz
  - Proof-of-concept experiment with mini-gun
- Work done in Y1
  - Modulator (RTU)
    - Driver amplifier built
    - Low-power prototype built for proof-of-concept
    - Concept for final modulator developed
    - Driver amplifier tested
  - Proof-of-concept experiment (IAP)
    - Experiment set up at IAP
    - Mini-gun installed and qualified in DC mode
    - Diagnostics for beam current profile tested
    - Ready for test with low-power modulator prototype

Driver amplifier of modulator and signal output



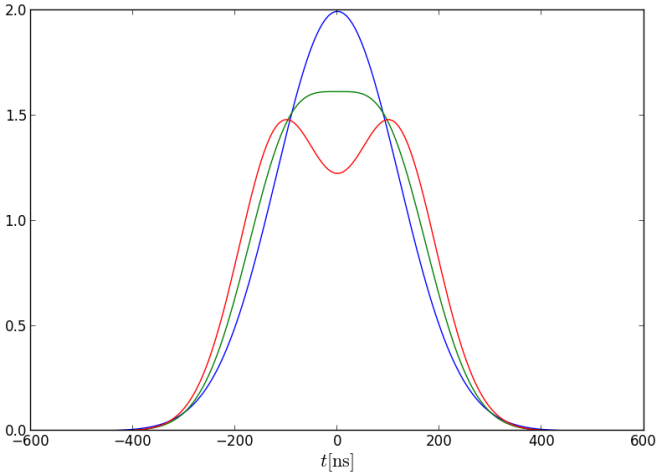
Proof-of-concept experiment at IAP



Modulator: Plans for Y2

- SCC gun modulator
  - Finalization of design
  - Manufacturing
  - Testing with dummy load
- Proof-of-concept experiment at IAP
  - Integration of low-power modulator prototype
  - Commissioning of mini-gun with modulator
  - Characterization of longitudinal profile of modulated electron beam from mini-gun
  - Testing of various longitudinal profile shapes

Possible longitudinal profile shapes

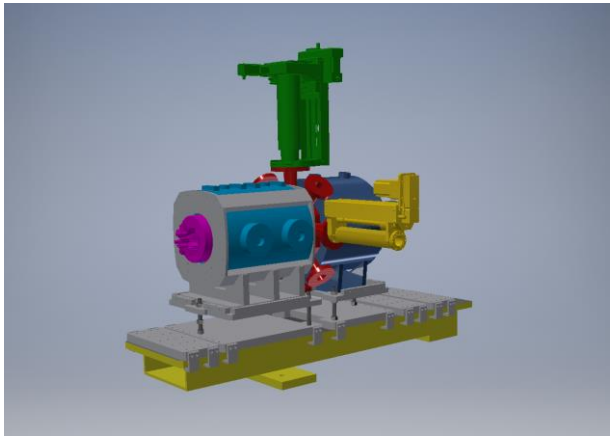


More details in highlight talk by K. Schulte-Urlichs (GSI)

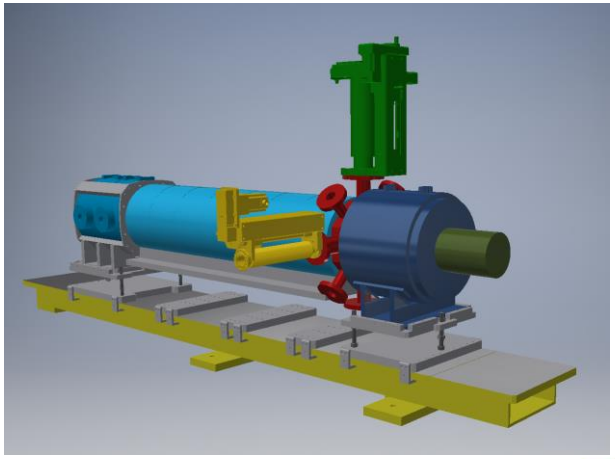
Test Stand: Status

- Goals
  - Common test stand for characterization of both CERN HEL gun and GSI SCC gun
  - Requirements on test stand
    - Characterization of electron beam with respect to longitudinal and transverse beam profiles
    - Investigation of electron beam dynamics including transport through solenoid
- Work done in Y1 (CERN)
  - Collection of requirements for both guns
  - Concept for two-staged test stand
  - Design of first stage completed
    - Layout with two solenoids and diagnostic box
    - Box with pin-hole FC and YAG screen designed
  - First components acquired
    - Gun and collector solenoids refurbished
    - Power converters purchased
  - Layout of second stage developed
    - Includes drift solenoid for studying dynamics of transport and compression

Layout of first stage of test stand



Layout of second stage of test stand



Test Stand: Plans for Y2

- First stage of test stand
  - Complete installation
  - Commissioning of power converters
  - Commissioning of diagnostics tools (HW and data acquisition)
  - Setting up for measurements
  - Characterize HEL gun

More details in highlight talk by S. Sadovich (CERN)

Summary

- WP16 objectives and partners introduced
- Principle and application of electron lenses presented
- Task status and outlook for Y2 given
  - System integration
    - Layout of magnetic system under way
    - First results from ion beam dynamics studies available
  - SCC gun and modulator
    - Preliminary gun design completed
    - Low-power modulator prototype built
    - Proof-of-concept experiment ready for commissioning
  - Electron gun test stand
    - Two-staged test stand concept developed
    - Design of first stage completed
    - First components available

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David Ondreka, Kathrin Schulte-Urlichs (GSI);

Oliver Meusel, Martin Droba (IAP);

Peteris Apse-Apsitis (RTU)

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