Report on the senior fellowship activities

98th ISOLDE Collaboration Committee meeting

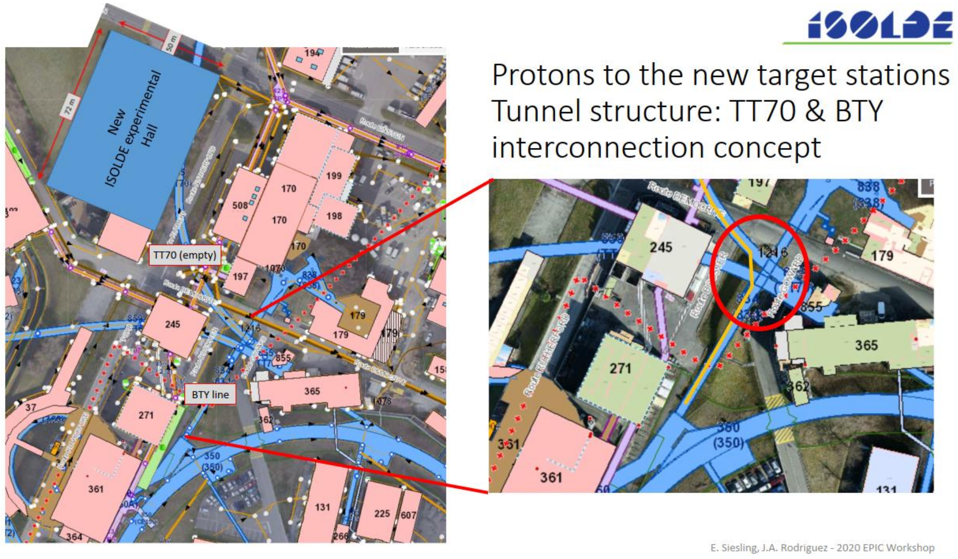
Niels Bidault (BE-OP-ISO)
CERN, 1211 Geneva 23, Switzerland

November 17th, 2023

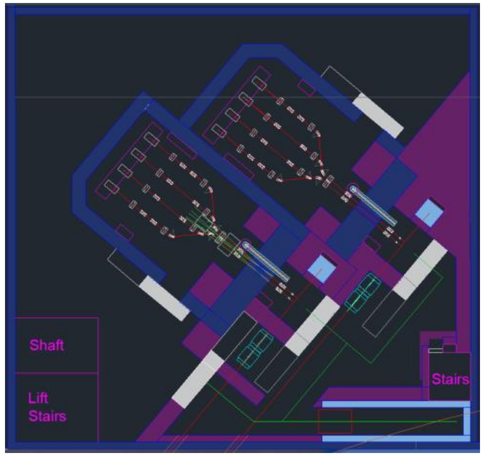
Report on the senior fellowship activities

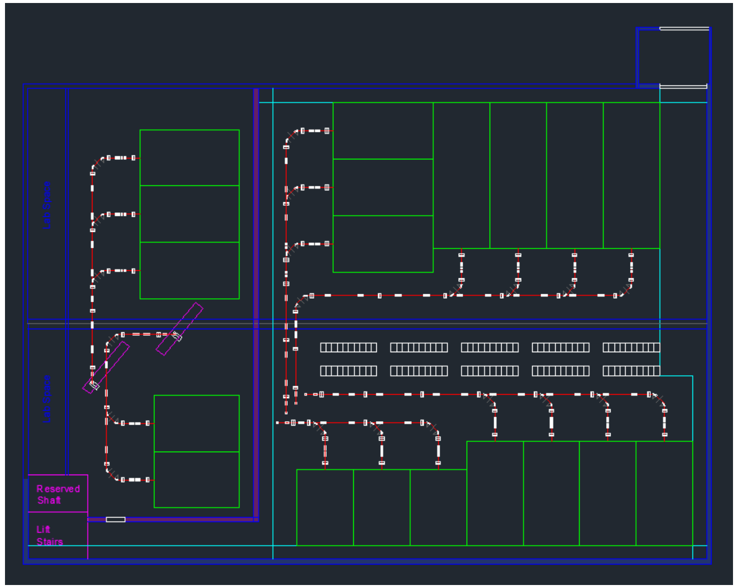
- Beam transport elements for future ISOLDE low-energy upgrades
- Beam dynamics simulations
- Emittance measurements at ISOLDE and OFFLINE2
- Other projects and conclusion

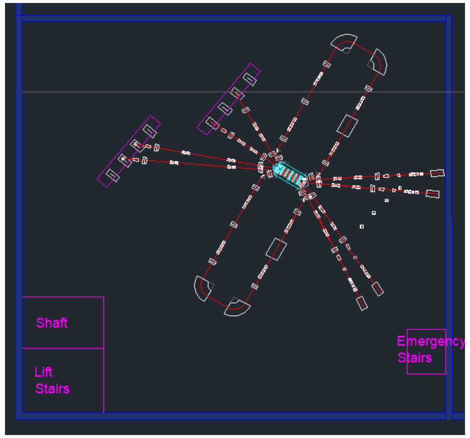
Preliminary concepts



EPIC Workshop 2020, *J. A. Rodriguez* & *E. Siesling*







First layouts of the beamlines in the experimental area, the frontends and separator zone, and of the compact beam switchyard.
Switching between the fast and slow release for collections.
Work by *J. A. Rodriguez*.

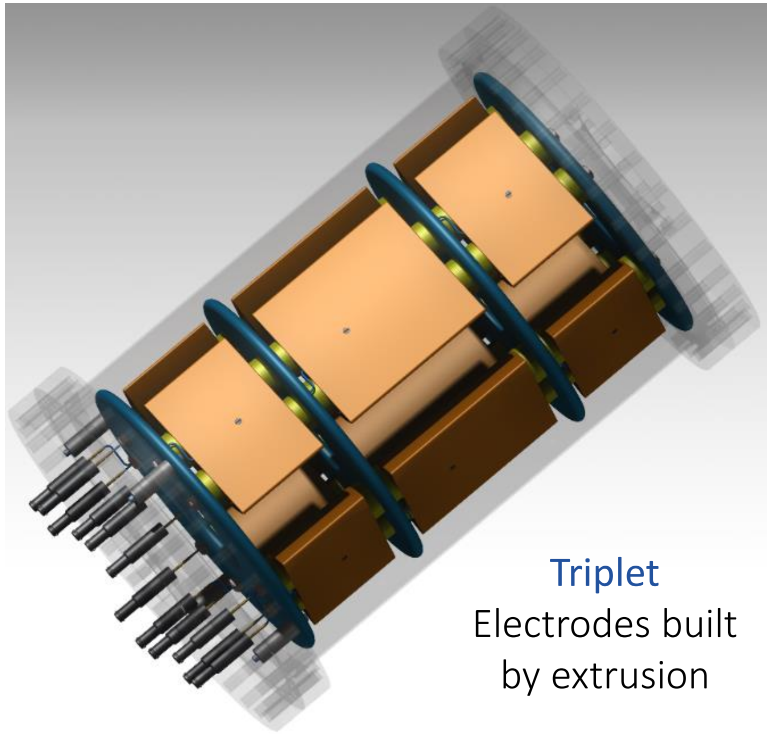
Objectives

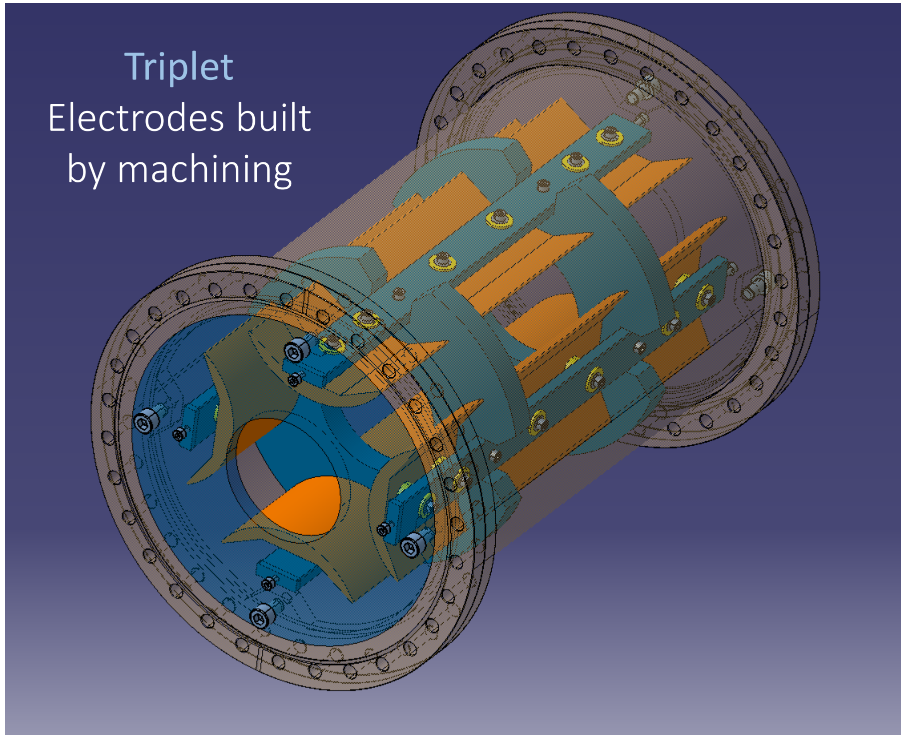
- Parallel experiments and maximize the use of protons
- Assure maximum beam transport from the target ion sources
- Maximize the repeatability of FODO lattices
- Minimize the amount of specific transport elements
- Beam matching optimized for the separators and switchyards
- Control over the waist for injection into the experimental stations

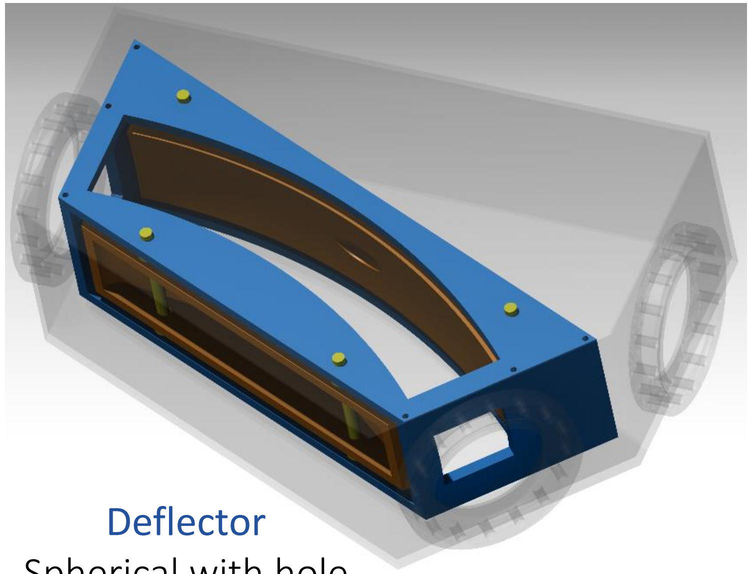
Mechanical design of electrostatic elements

Design rules

- Cost effective technological solutions
- Guarantee the field quality with respect to the beam dynamics constrains
- Vacuum compatible and respecting electrical standards preventing sparking or creepage
- Practical assembly, alignment and disassembly

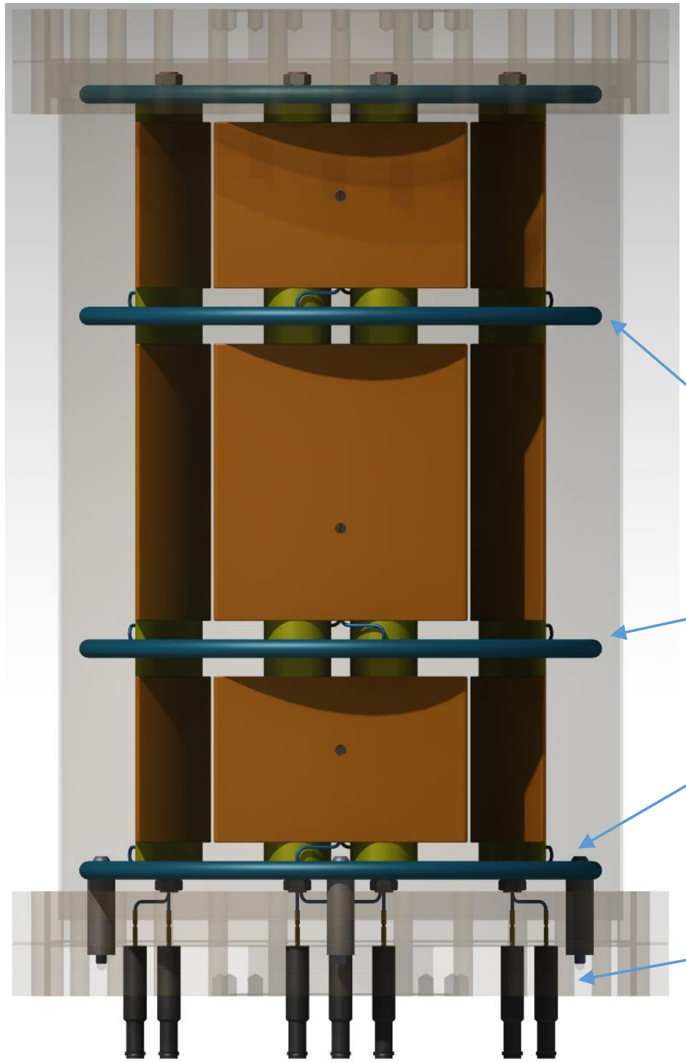


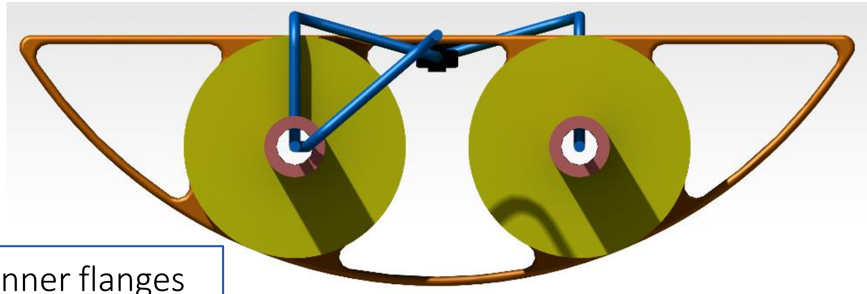




Acknowledgements to Thomas Marroux (summer student), EN-MME-FS, EN-MME-EDS, BE-GM-ESA, TE-VSC-BVO and SY-ABT-SE.

CAD models of quadrupoles





Advantages Low cost of fabrication, high repeatability, control over the geometry, low rugosity.

Disadvantages Potential need of end caps to prevent sparking, prototyping may be costly.

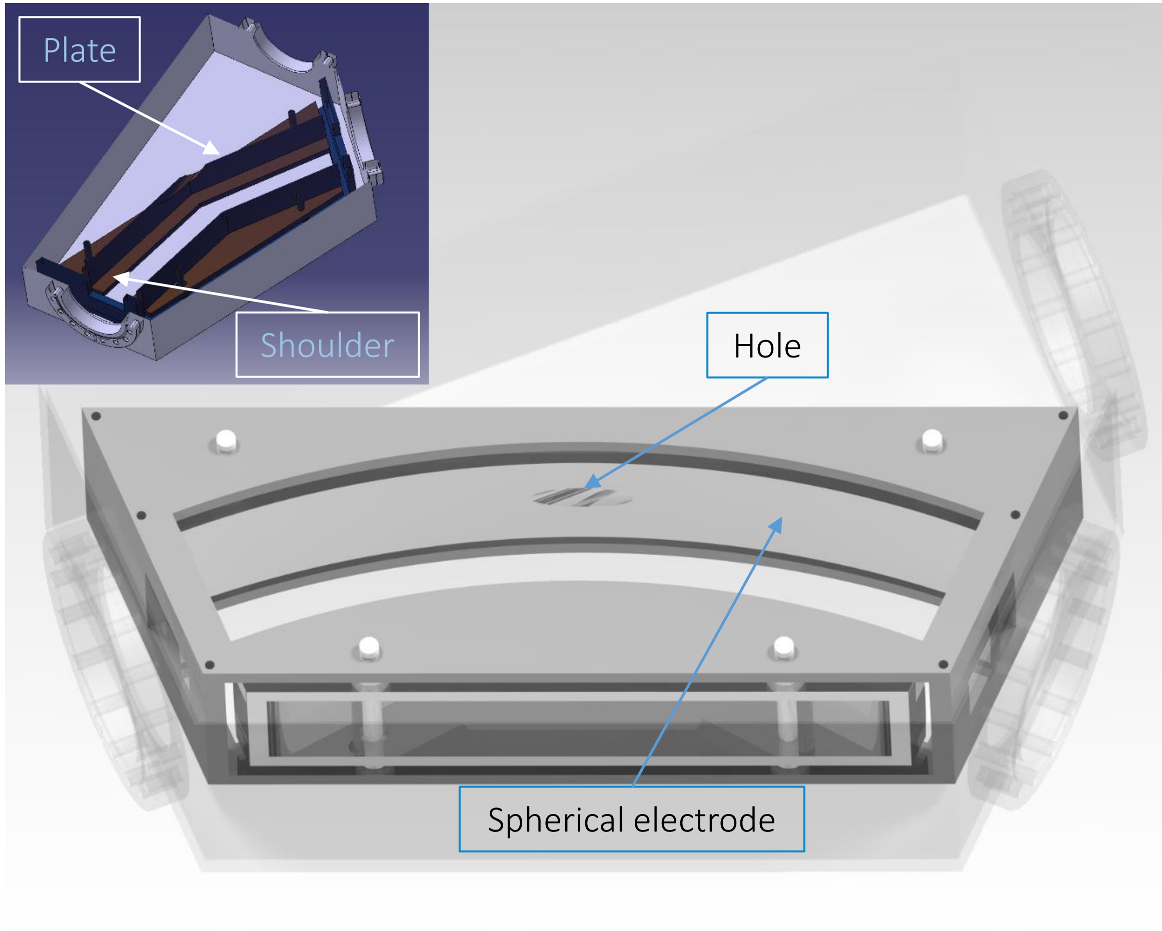
Models of triplets, doublets and single quadrupole were designed, with the characteristic dimensions as free parameters:

- Electrode gap
- Lengths of the electrodes and in between them
- Radius of the electrodes

Technological solutions:

- Standard CF fixed and rotatable flanges to the vacuum chamber and standard CF zero length flanges.
- Commercial alumina insulators with standard geometry
- Commercial feedthroughs (10 kV), connectors and coaxial cables to the electrodes

CAD models of deflectors



Models of spherical deflectors were designed, with the characteristic dimensions:

- Bending radius and angle: 0.4 m and 45 deg.
- Gap between electrodes: 4 cm.
- Hole size for straight transport:

For different electrode geometries:

- Perfectly spherical
- Emulating the spherical electrode fields with flat electrodes

Technological solutions

- Inner assembly frame inspired by the deflector designs for ELENA
- Chamber manufactured from metal sheets
- Commercial alumina insulators with standard geometry, feedthroughs (15 kV) and connectors

Remaining questions

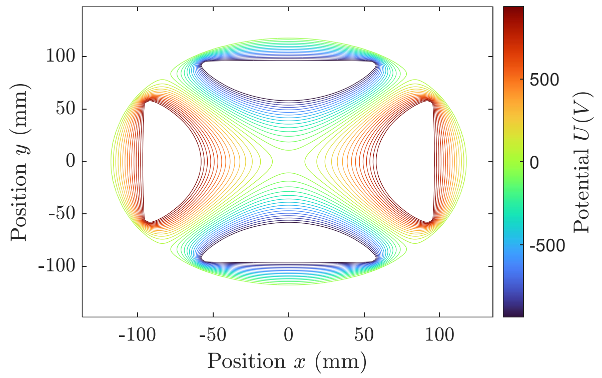
- Another iteration on the fabrication processes and possible plate geometries would be beneficial.

Report on the senior fellowship activities

Simulations with CST: quadrupoles

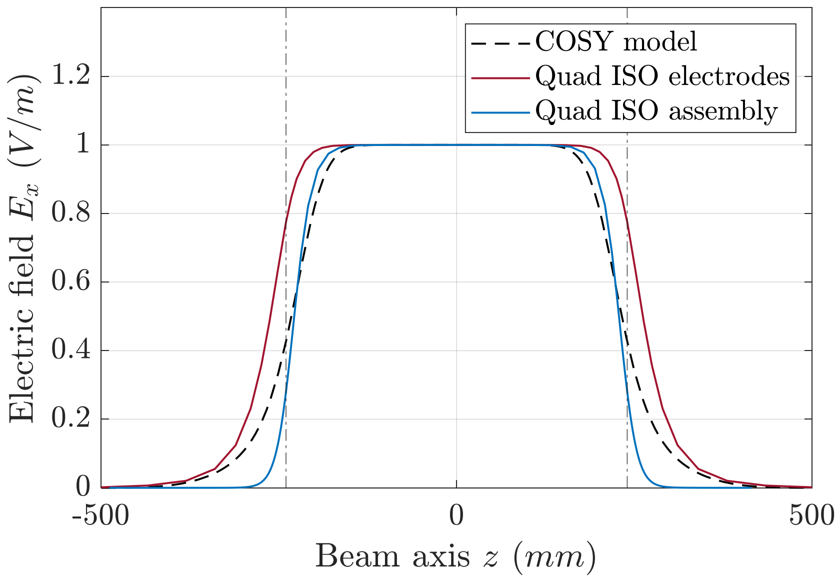
Studies on the electrode gap, radius and shape:

- The cylindrical shape present no significant difference compared with hyperbolic shape
- Pole to pole diameter of 140 mm, so electrode radius if 80.28 mm - ratio from H. Wollnik Optics of Charged Particles

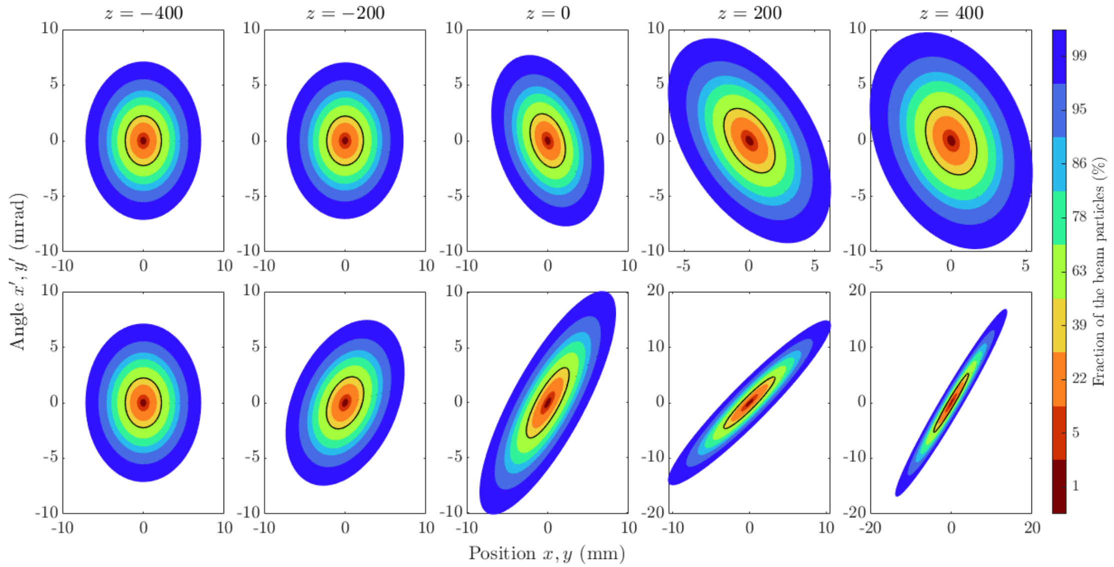


Studies on the fringe field:

- Optimization on the inner grounded flanges
- Approach theoretical transfer matrix
- Determination of the effective voltage or the effective focusing strength

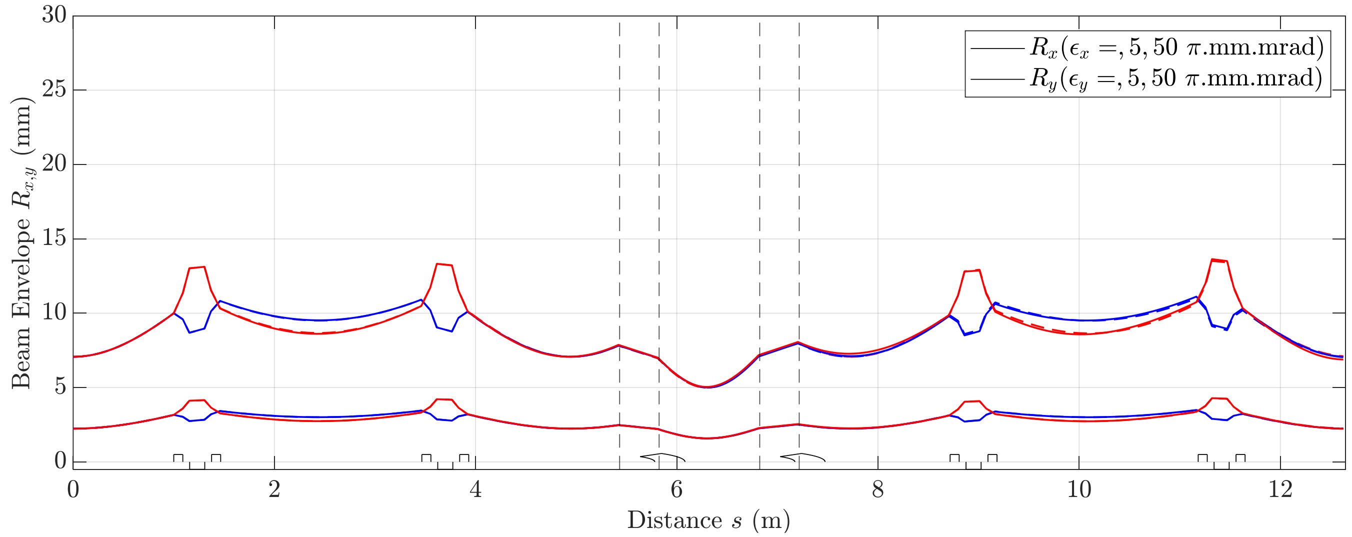


Example of ellipse tracking through a quadrupole with CST:

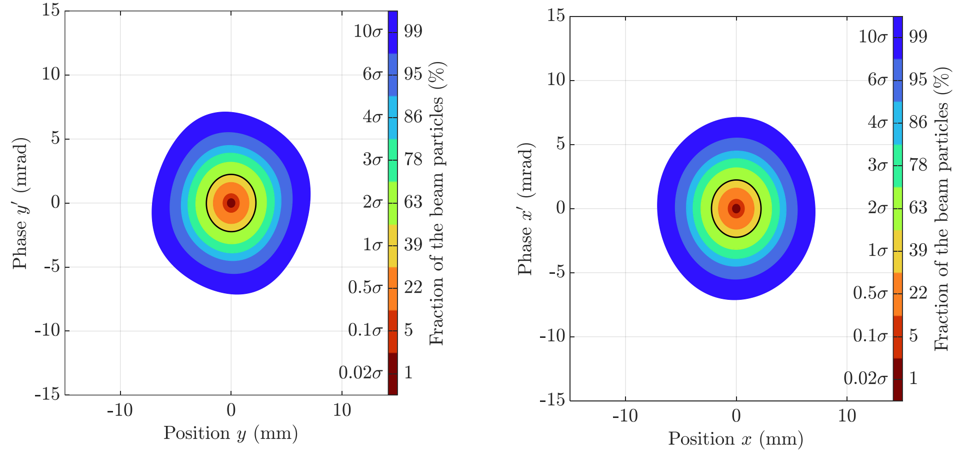


Beam dynamics with COSY Infinity

Separator zone Source -> Triplet -> Concrete wall -> Triplet -> Two 45 deg. Deflections -> Triplets to Separator magnets

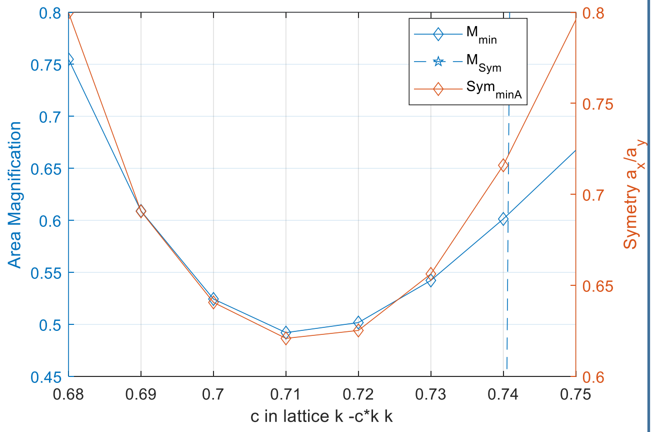


Output phase space for symmetric beam



Beam **matching** to the separator magnets:

- Triplet L_{QP} = 0.09 m / 0.15 m / 0.09 m
- Last Distance to the magnets of 1 m
- Control the waist of the beam in x or y planes



High-level Matlab application to model with COSY Infinity any beam transport line with modulable characteristic lengths, comprised of:

- FODO: doublet lattices.
- Triplet lattices
- 45-deg. deflectors

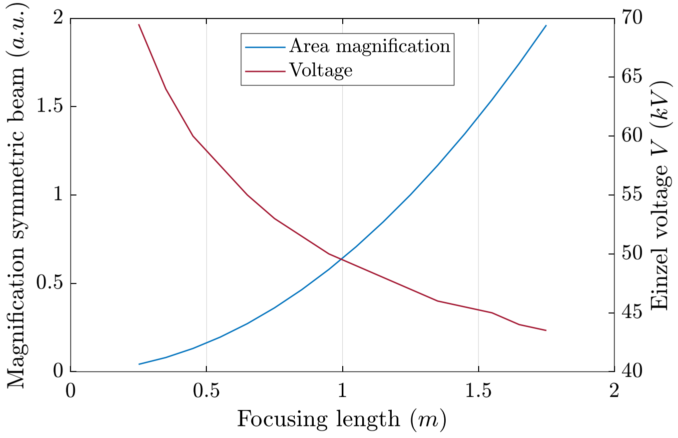
Conclusion

- Voltages < 10 kV for quadrupoles / 20 kV for deflectors
- Focusing distance to the magnet < 2 m
- Control the waist of the beam in x or y planes
- Matching into the separator magnets

Injection into experimental stations

Einzel lens

- Compact element to provide strong focusing
- High voltage required
- Einzel focusing power is dependent on the geometry and the voltage ratio
- Decelerating mode requires lower voltage
- Less spherical aberrations with accelerating mode



Gridded Einzel lens

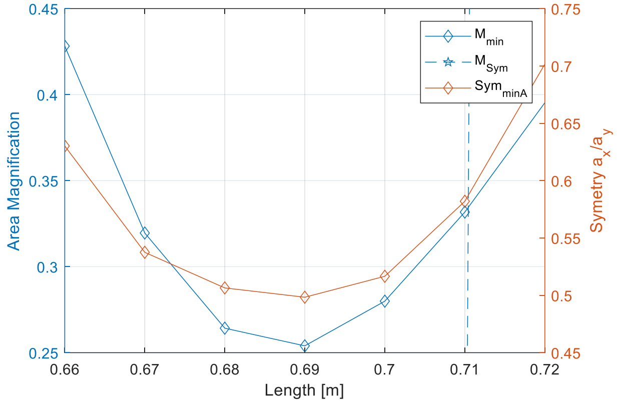
Spherical Aberration Corrections for an Electrostatic Gridded Lens, 2008, A. Pikin

Numerical simulation of gridded electrostatic lens Rev. Sci. Instrum. 83, 02B907 (2012) G. N. Kropachev, N. N. Alexeev, A. I. Balabin, et al

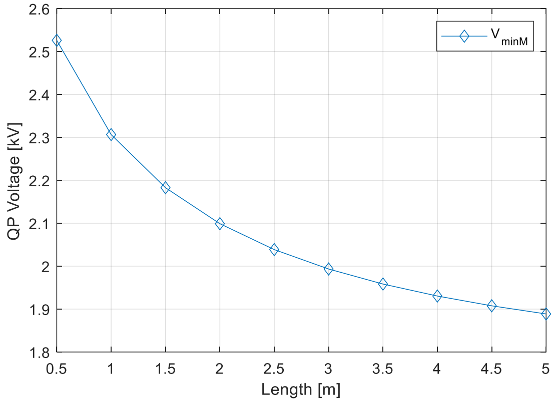
Triplet

- Single triplet will not necessarily preserve the beam symmetry
- Not a lot of margin on the focusing distance
- Voltages can be kept < 10kV

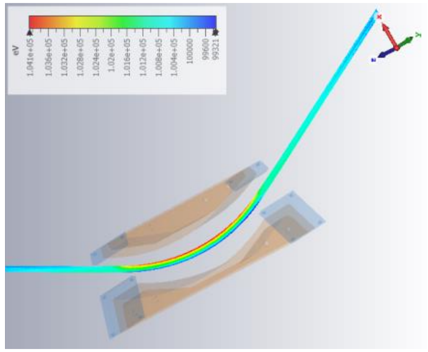
Focusing for a Triplet L_{QP} = 0.25 / 0.4 / 0.25 m



Maximum voltage required for a 60 keV beam

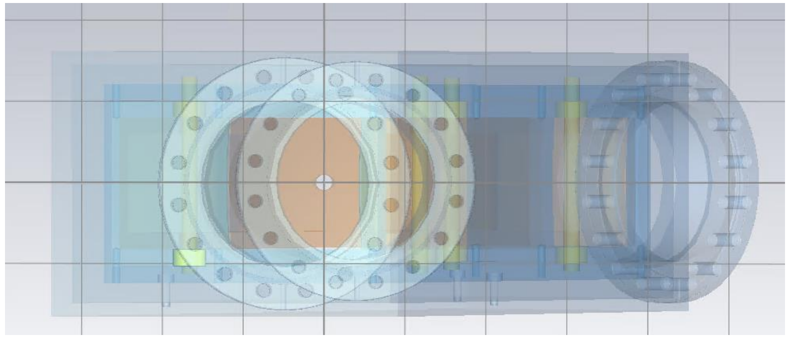


Simulations with CST: deflectors



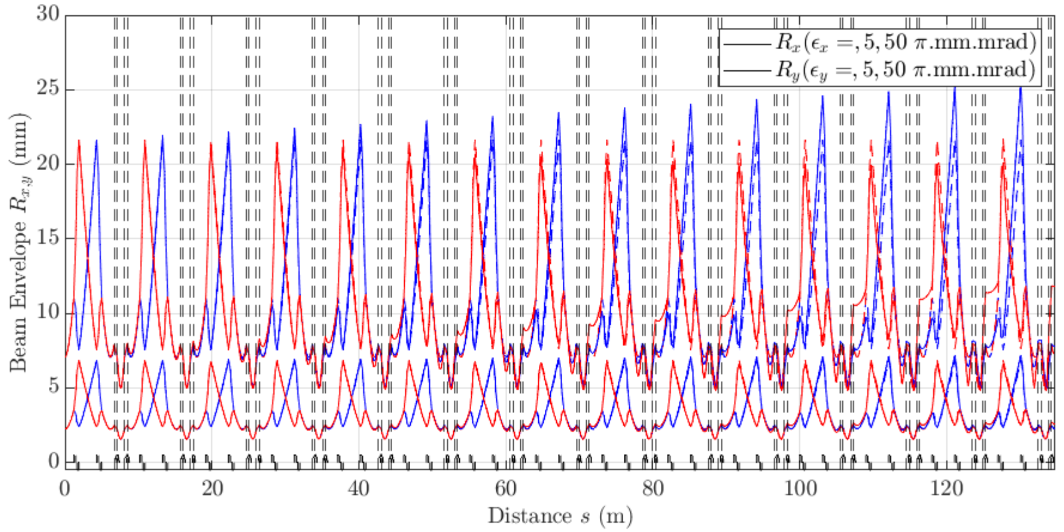
Deflector studies on the electrode gap, radius

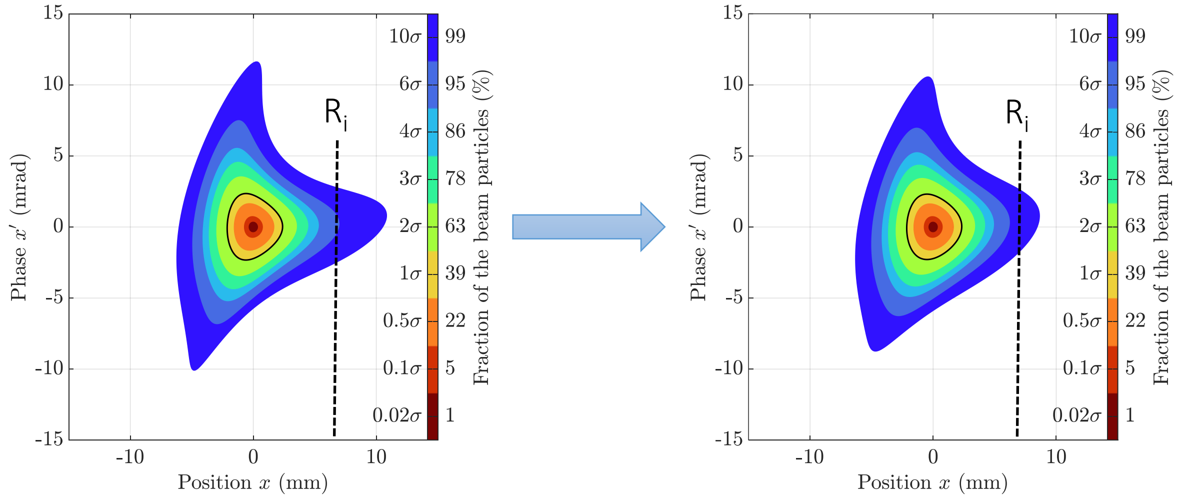
- Gap values of a minimum 4 cm
- Radius 0.4 – 0.7 m. Ideal 0.5 m
- Voltages < 20 kV



Hole in deflector with a radius 5 mm (< envelope for 50 pi.mm.mrad)

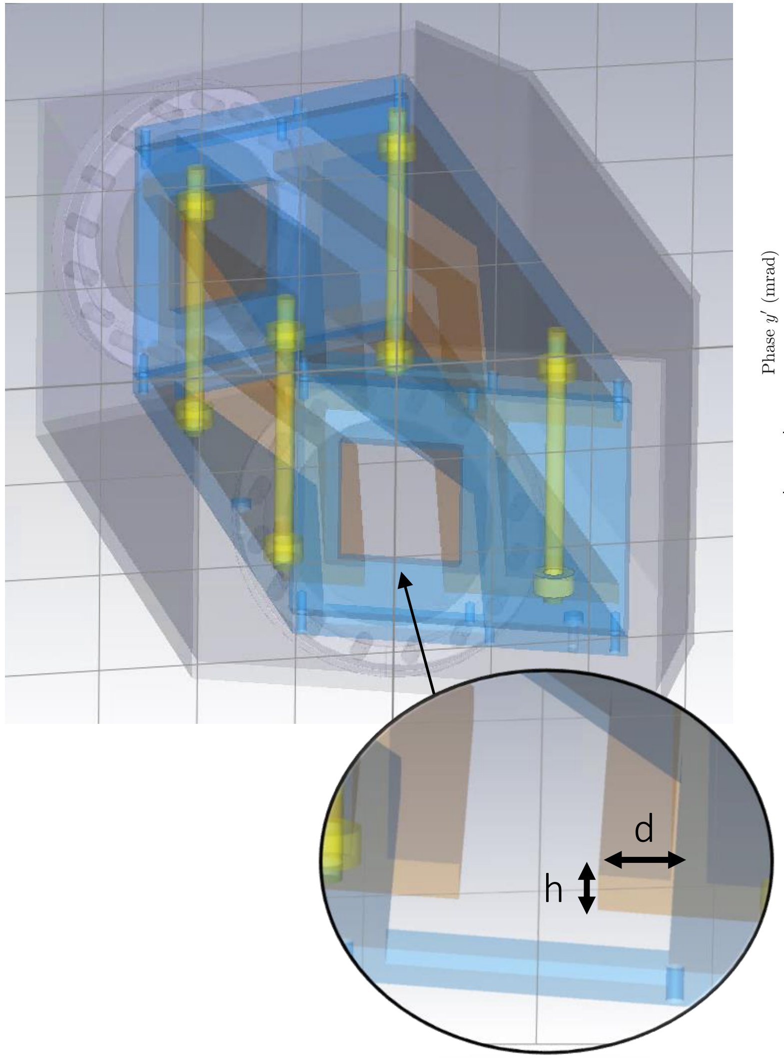
Example of beam tracking through multiple 45 deg.-spherical benders to illustrate the effect of the bending radius





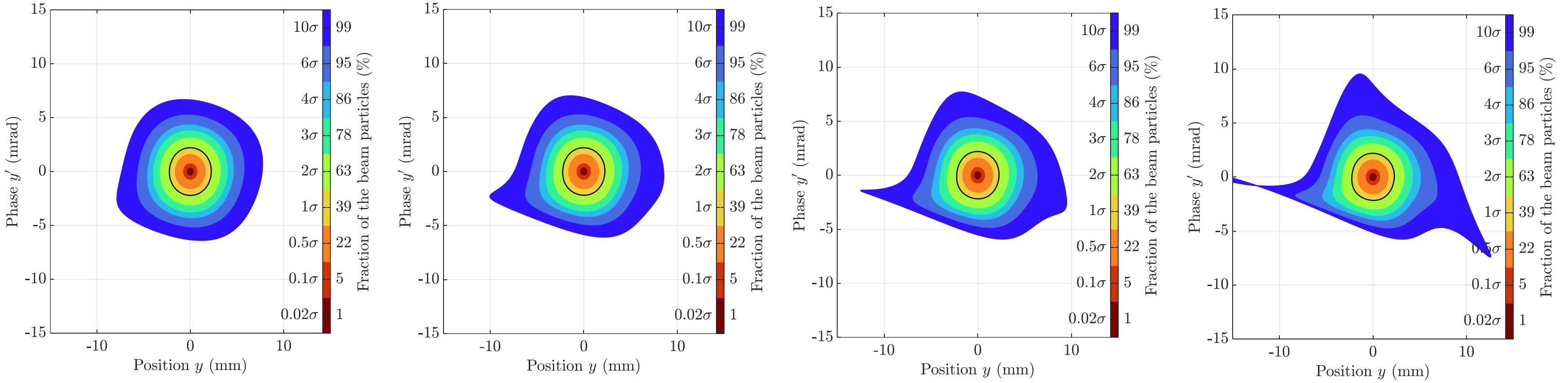
Horizontal phase space after tracking for bending radii 0.5 and 0.7 m

Simulations with CST: deflectors



Deflector studies on the electrode shape

Vertical phase space tracking for different deflectors: spherical, cylindrical and two different sizes h



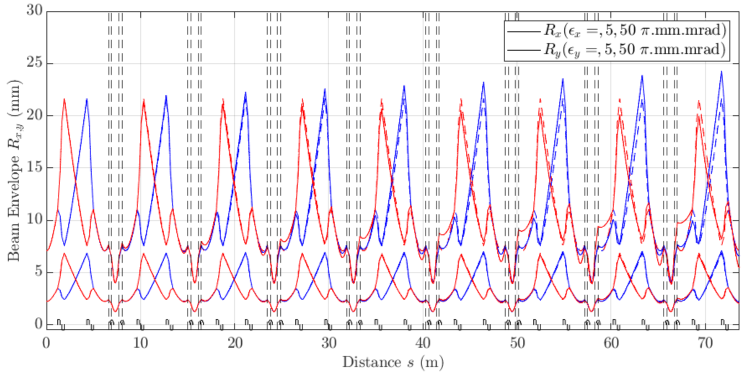
Spherical

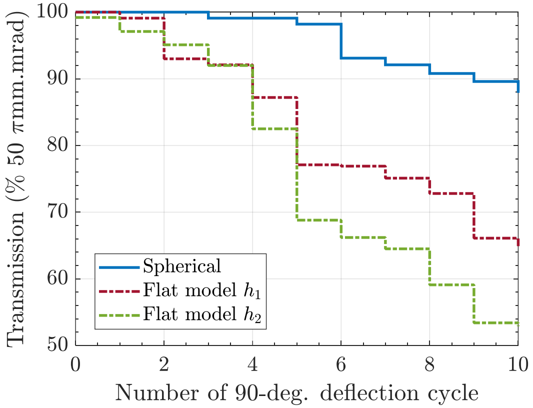
Cylindrical

Flat with shoulder h_1

Flat with shoulder h_2

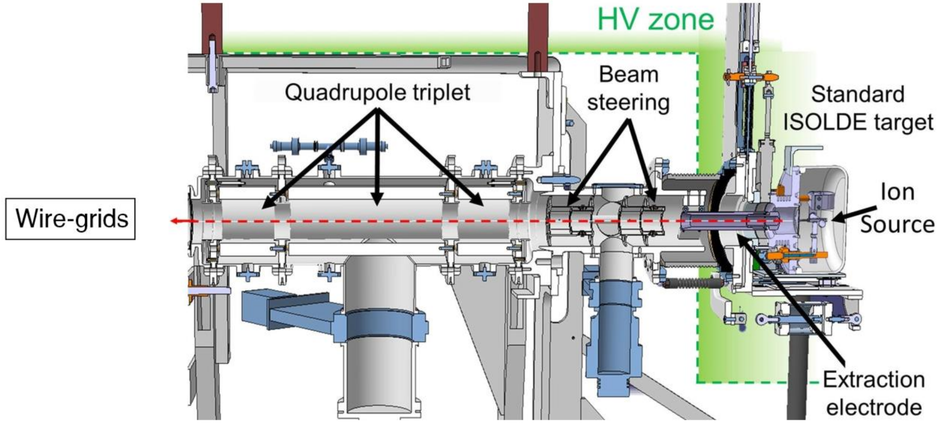
Transmission with a virtual aperture the size of the initial beam's envelope R_i





Report on the senior fellowship activities

Emittance from the target ion sources



Setup and results

Use the wire grids at ISOLDE, with a spacing of 0.5 mm.

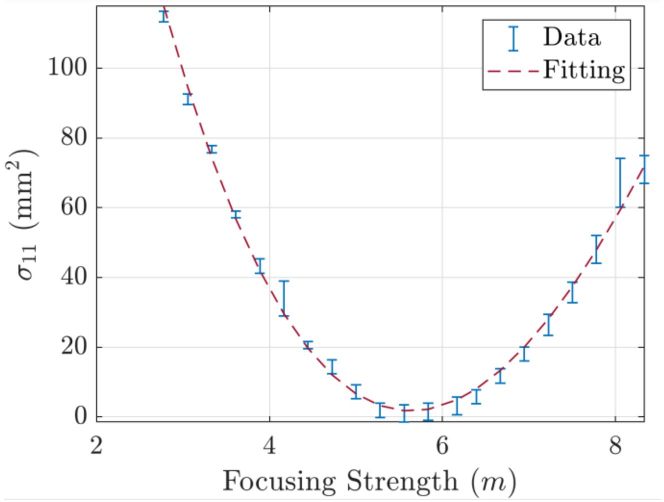
Quadrupole-scan emittances are larger than historical measurements, and Allison scans:

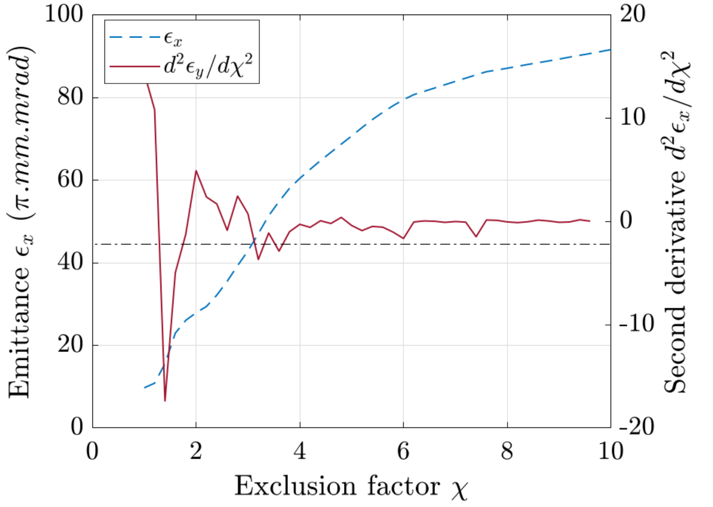
Transverse emittance investigation of the ISOLDE target-ion sources
F. Wenander, NIM Phy. Res. B, Vol. 204, May 2003, Pages 261-266.

After integration in CST to determine a realistic transfer matrix:

- The focusing strength relative uncertainty is about 10 %
- The discrepancy with other methods cannot be fully explained

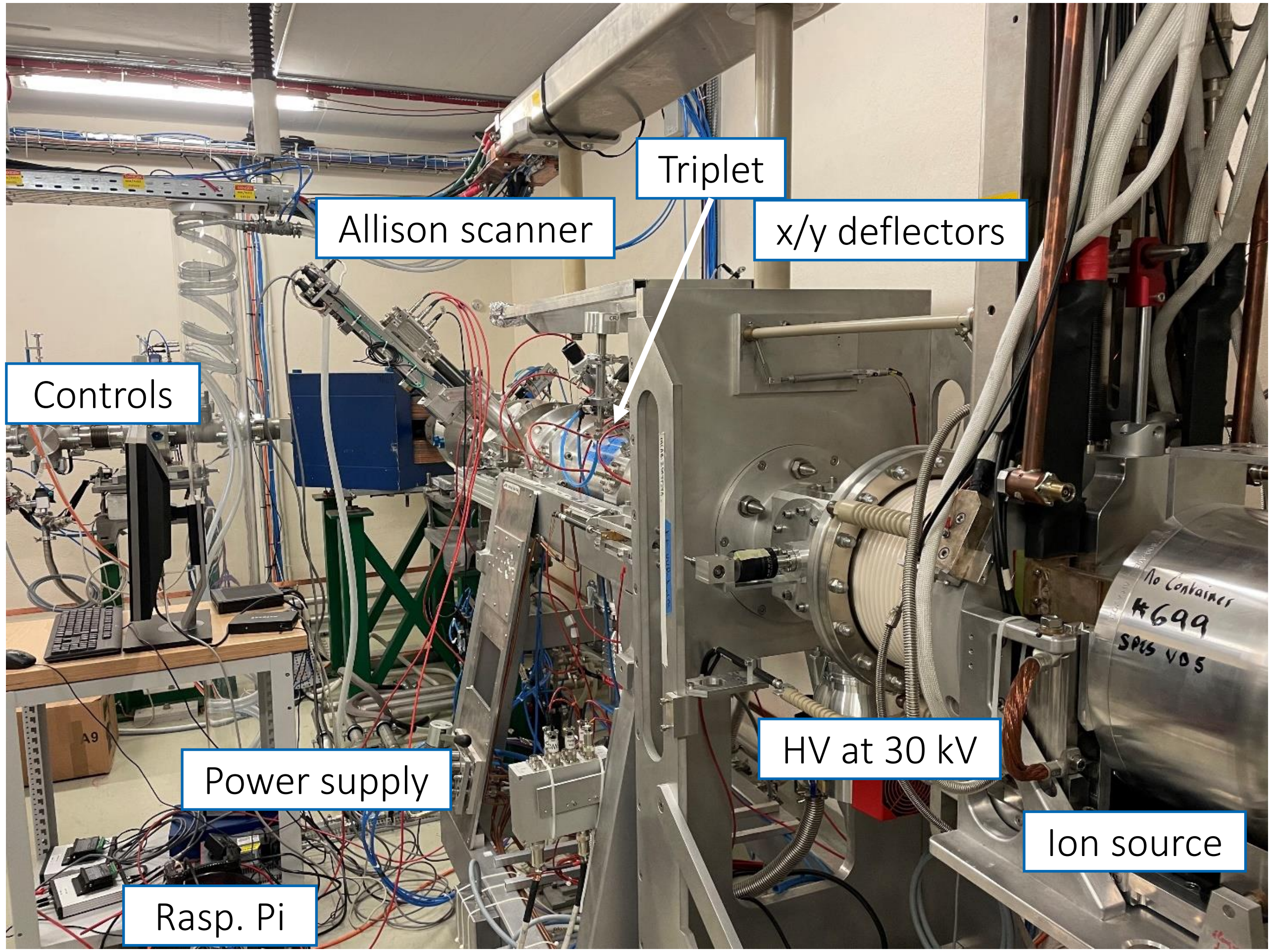
Type	Parameter	Value
Surface	$\epsilon_{x,y}$ (π.mm.mrad)	12 , 15 ±4
	$\beta_{x,y}$ (mm.mrad^{-1})	2.5 , 3.4 ±2.1
	$\gamma_{x,y}$ (mrad.mm^{-1}))	13 , 10 ±4.0
	I_{total} (nA)	0.6
	E (keV/u)	30
Plasma	$\epsilon_{x,y}$ (π.mm.mrad)	39 , 36 ±4
	$\beta_{x,y}$ (mm.mrad^{-1})	1.7 , 2.4 ±1.1
	$\gamma_{x,y}$ (mrad.mm^{-1})	8.6 , 5.5 ±2.5
	I_{total} (nA)	100
	E (keV/u)	30
LIST	$\epsilon_{x,y}$ (π.mm.mrad)	60 , 52 ±4
	$\beta_{x,y}$ (mm.mrad^{-1})	3.0 , 1.5 ±1.5
	$\gamma_{x,y}$ (mrad.mm^{-1})	2.9 , 4.6 ±1.9
	I_{total} (nA)	0.5
	E (keV/u)	50

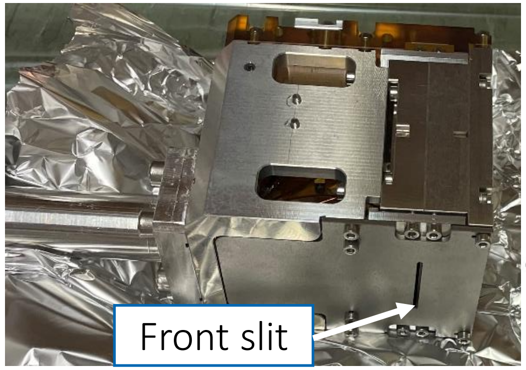


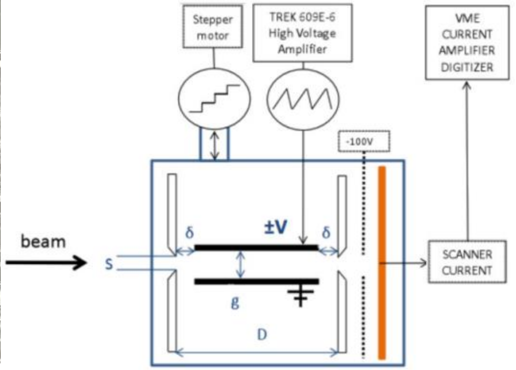


Transverse Emittance Measurements of the Beams Produced by the ISOLDE Target Ion Sources, N. Bidault, Proceedings of IPAC2022, Bangkok, Thailand.

Allison scanners from TRIUMF







Specifications

Can be used for beams up 100 keV

Geometrical resolution of 0.03 mm-mrad

Faraday cup for beams > 1 nA or a channeltron for lower intensities

Schedule

2022: Received from TRIUMF, troubleshooting, installation at ISOLDE

2023: Troubleshooting and installation at OFFLINE2

Documentation

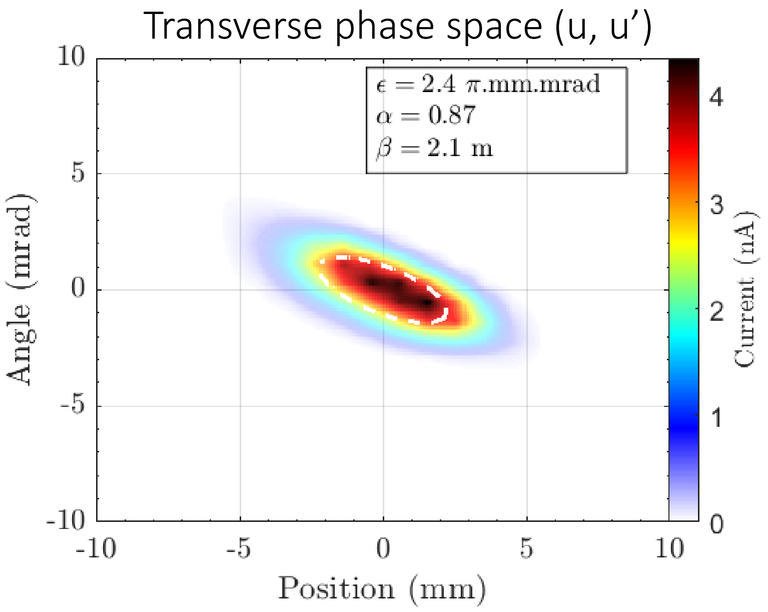
CERN-wiki procedure on how to use the scanners and on the data treatment associated (link).

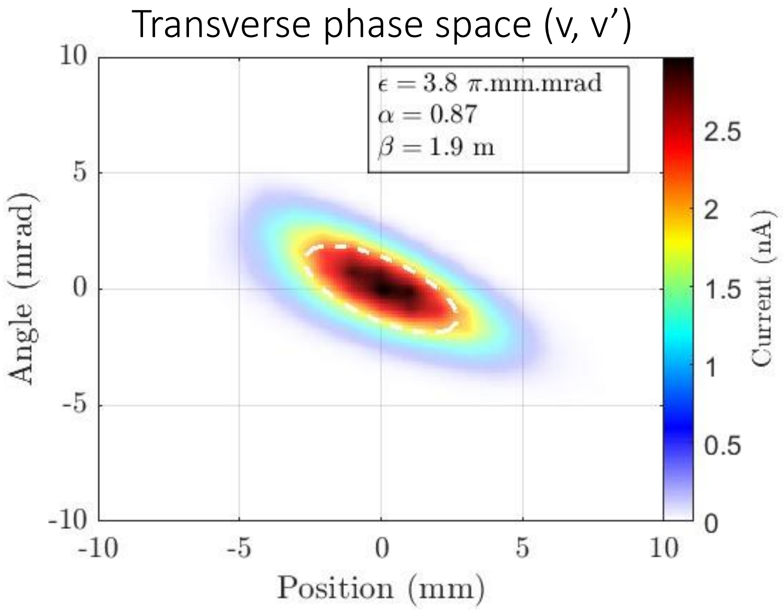
Allison Scanner Emittance Diagnostic Development At TRIUMF, A. Laxdal et al., Proceedings of LINAC2014, Geneva, Switzerland.

Emittance measurements at ISOLDE - RC6 Beamline

Results from the Allison scanners

$^{39}K^{+}$ at 30 keV from a surface ion source. 80 nA beam intensity with 95% transmission from CA0 to RC6.





Conclusion and Perspectives

- Documentation in https://edms.cern.ch/document/2995924/1. Phase space data shared with Lukas Nies and Pablo Arrutia (SY-ABT-BTP).
- The measurements can serve as estimates for choosing the focusing systems required by the Penning trap in the PUMA project.
- More systematic characterization of the beam parameters in ISOLDE low-energy lines compared with simulations would be beneficial.

Emittance measurements at OFFLINE2

Plasma Ion Source

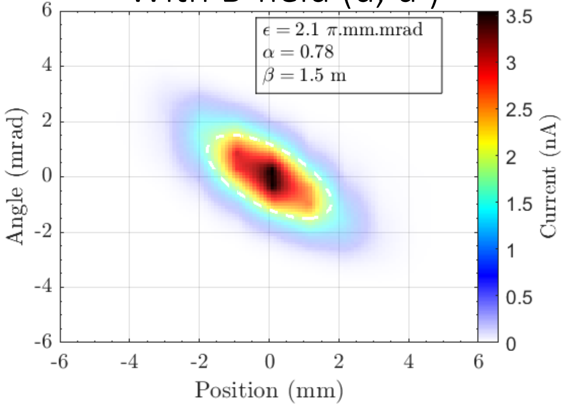
Target #794 VD7 Prismap, with 30 nA beam intensity, mainly Ar with constant gas injection.

Transverse phase space scans for different operational parameters

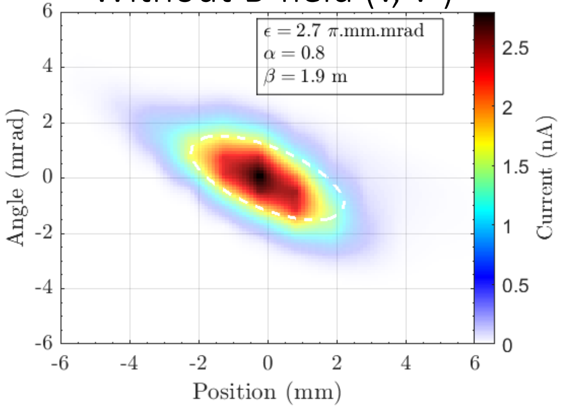
- Source B-field
- Anode voltage
- Line heating
- Beam energy
- Beam focusing

Example Variation of the extracted beam emittance as a function of the plasma B-field by changing the coil current.

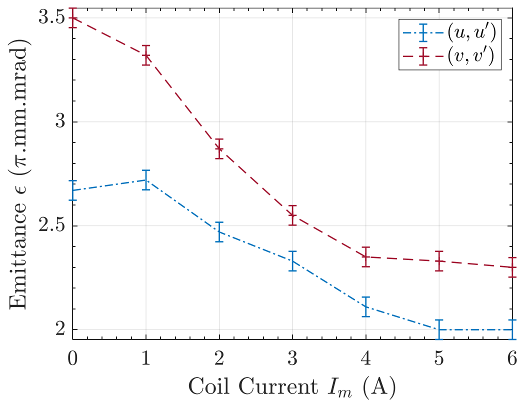
With B-field (u, u')



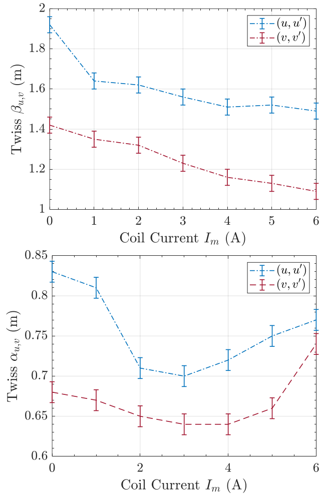
Without B-field (v, v')



Evolution of the emittance



Evolution Twiss parameters

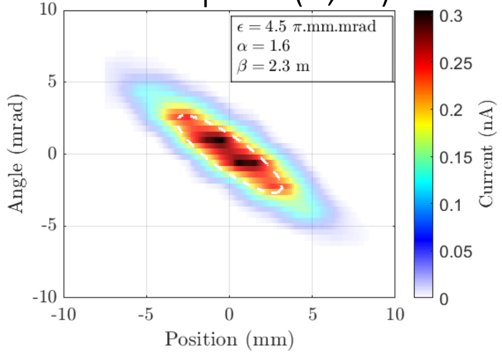


Emittance measurements at OFFLINE2

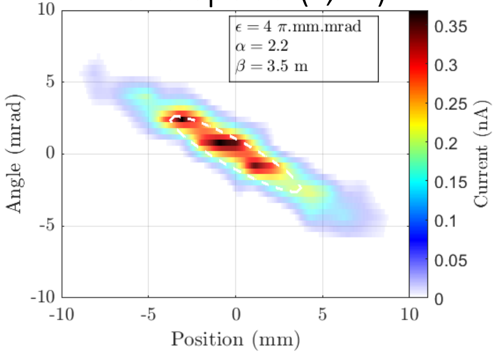
Surface Ion Source

Target #719, with CF4 injection. With 10 nA of beam intensity, mainly BaF. Fixed line heating (270 A).

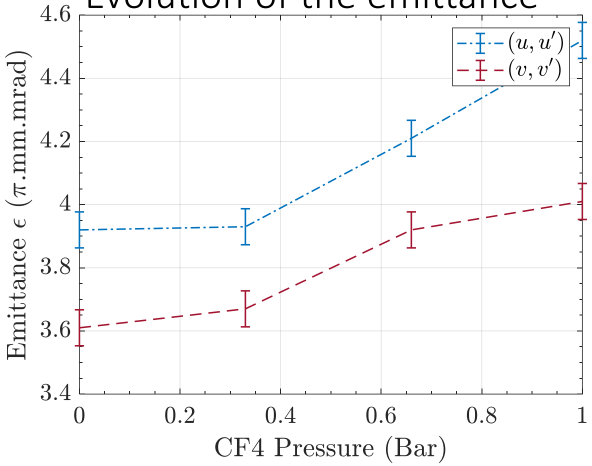
Phase space (u, u’)



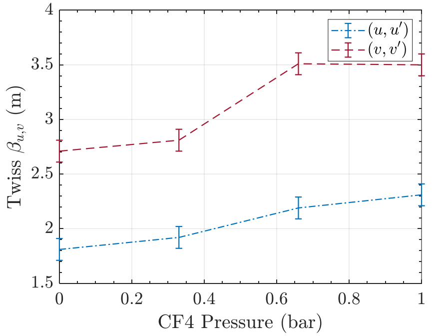
Phase space (v, v’)

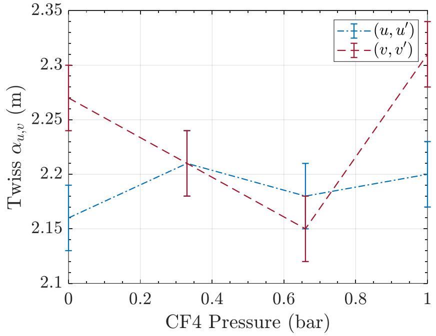


Evolution of the emittance



Evolution Twiss parameters





Laser Ion Source and Trap (LIST)

Measurements will occur next week.

Unfortunately, the current setup does not allow the combination of lasers on target with the Allison scanners.

Conclusion and Perspectives

- SY-STI can use the Allison scanners: L. Le is trained, and the documentation is available.
- Thorough characterisation of VD7 Plasma Ion Source for different operational parameters. Less information on LIST.
- Need to evaluate whether the current results can be published or wait until more measurements on LIST with lasers are done.

Report on the senior fellowship activities

- Beam transport elements for future ISOLDE low-energy upgrades
- Beam dynamics simulations
- Emittance measurements at ISOLDE and OFFLINE2
- Other projects and conclusion

Other projects: GeOFF Optimizer

GeOFF developed by BE-CSS-DSB

Implementation at ISOLDE

- Communication with pjlsa
- All optics of REX/HIE-ISOLDE
- OFFLINE and OFFLINE2
- Pulsed devices (functions)

Detectors

- Faraday-cup
- Wire-scanners
- Wire-grids

Objective functions

- Max Intensity
- Symmetric beam
- Find waist
- Beam positioning

Wiki: https://wikis.cern.ch/pages/viewpage.action?spaceKey=RBS&title=GeOFF+manual+ISOLDE+and+Offline

Other projects: OP-TM and Hardware Commissioning

OP-Technical Meeting co-chair, representing ISOLDE

- UCAP
- References
- SIS, FESA snap, announcer, etc.

Hardware Commissioning

- Orchestration with AccTesting (TE-MPE)
- Sequencers
- Reporting tools

Objectives

- Extend the use of AccTesting across the accelerators
- Facilitate the test completion, analysis, and reporting
- Better follow-up on the equipment performance

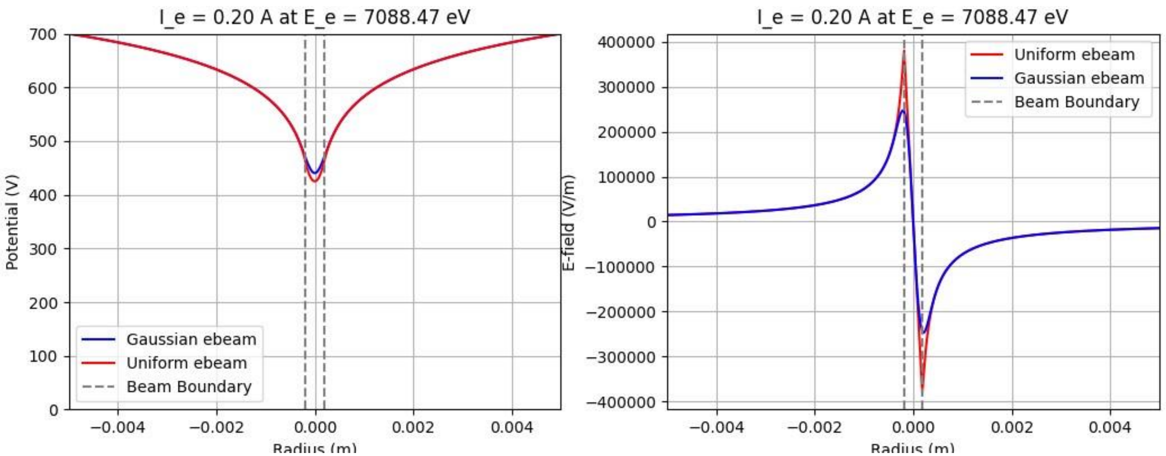
At ISOLDE

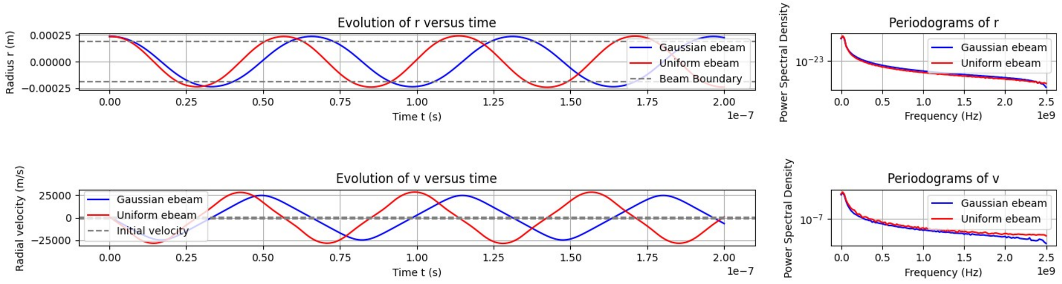
- Start familiarising with AccTesting during the 2024 HWC
- Establish a consolidated wish list of devices to integrate
- Be ready to use the new AccTesting version after LS3

https://mpe-cb.web.cern.ch/projects/acctesting/

Other activities

EBIS studies with Fredrik Wenander (BE-ABP-HSL)





- Python code the ion dynamics inside an arbitrary electron beam
- Python code to study plasma instabilities using the dispersion relation
- Characterization of the REXEBIS electron gun performance and residual gas composition
- Review of the diagnostic tools for charge-breeders: Rev. of Sci. Instrum. 93, 021101 (2022)

Facilities Operation Meeting former scientific secretary and new PS-CSAP secretary

Documentations and wikis for GLM/GHM beam sweeping application, the Scripting tools, GeOFF optimiser and the Allison scanners

Conclusion

Beam optics elements for future ISOLDE upgrades

- CAD models of multiple elements - and beam transfer matrix equivalents using CST
- Beam dynamics simulations with COSY infinity to optimise key design factors
- More accurate modelling of the dipole magnets requires CAD models
- Different options of arrangement inside the building

Emittance measurements

- Measurement at the end of the RC6 line
- Characterization of plasma and surface ion sources with varying operational parameters
- More insights into beams produced with lasers require moving the Allison scanners

Thank you for your attention

…and thank you for 8 wonderful years
at IS♡LDE