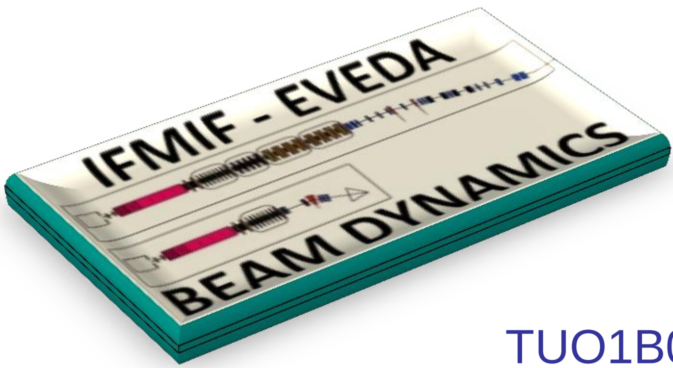
The IFMIF-EVEDA Challenges and their treatment

P.A.P. Nghiem, N. Chauvin, M. Comunian, O. Delferrière,
R. Duperrier, A. Mosnier, C. Oliver Amoros, D. Uriot



TUO1B03

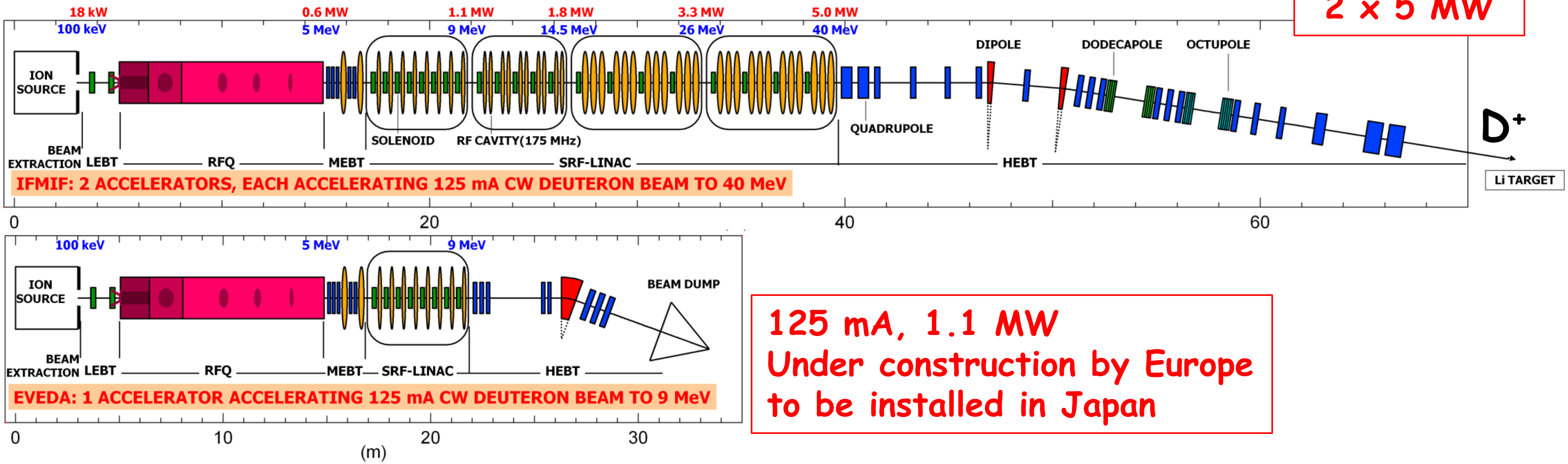
HB2010 Workshop, Sept 28th

Main Features (1)

One of the three projects
Fusion Broader Approach between Japan & Europe

IFMIF: International Fusion Material Irradiation Facility

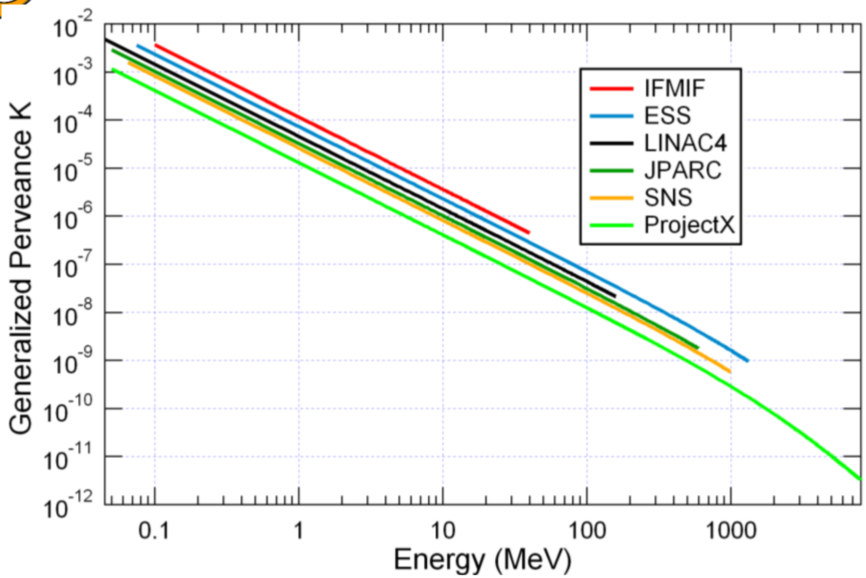
2 x 125 mA
2 x 5 MW

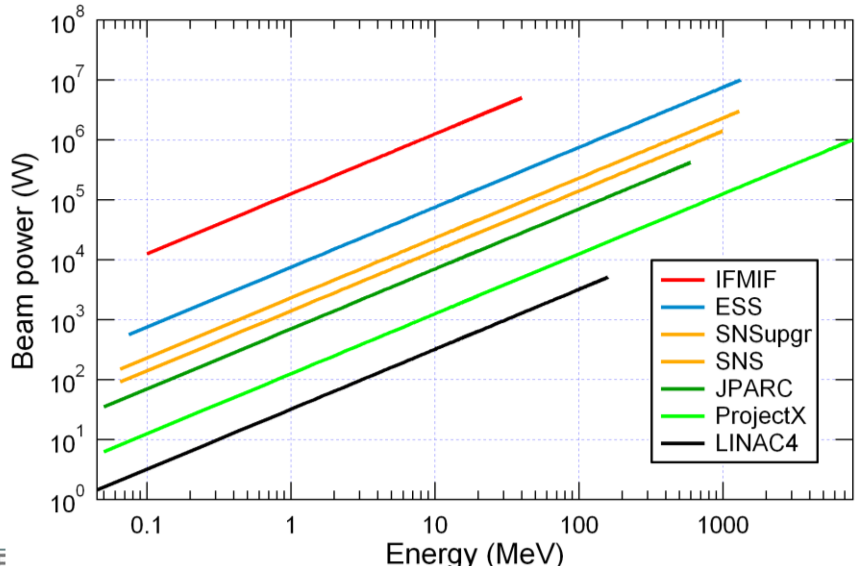


125 mA, 1.1 MW
Under construction by Europe
to be installed in Japan

EVEDA: Engineering Validation Engineering Design Activity

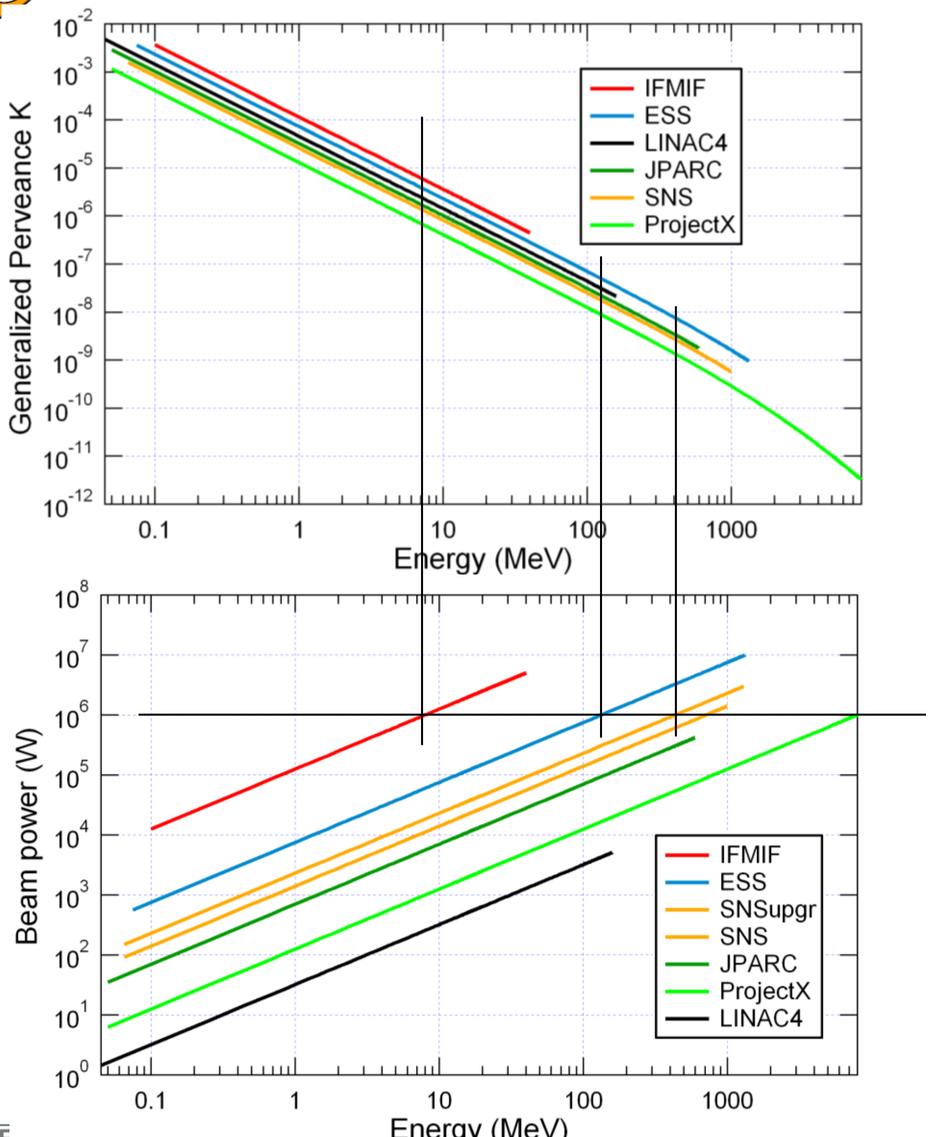
Main Features (2)





The highest intensity
The highest beam power

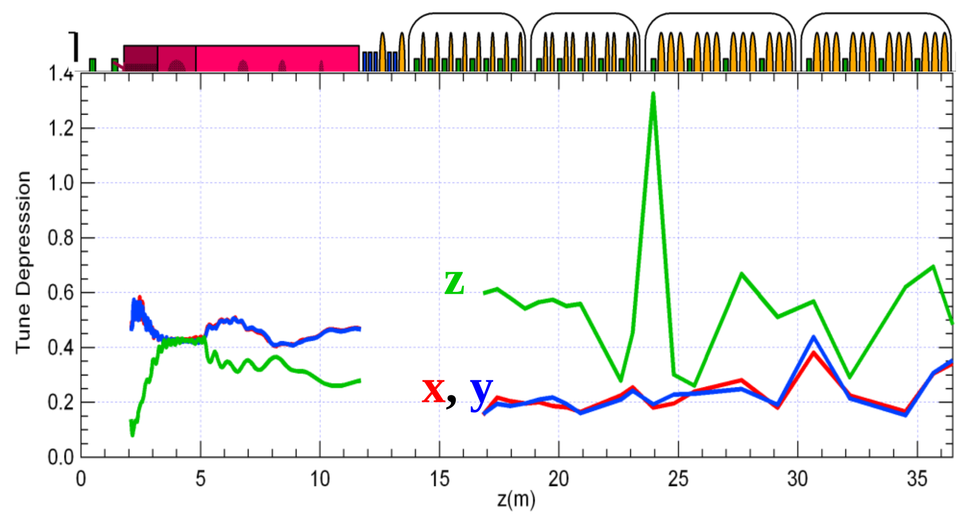
Main Features (2)



Simultaneous combination

The highest intensity
The highest beam power
The highest space charge
The longest RFQ

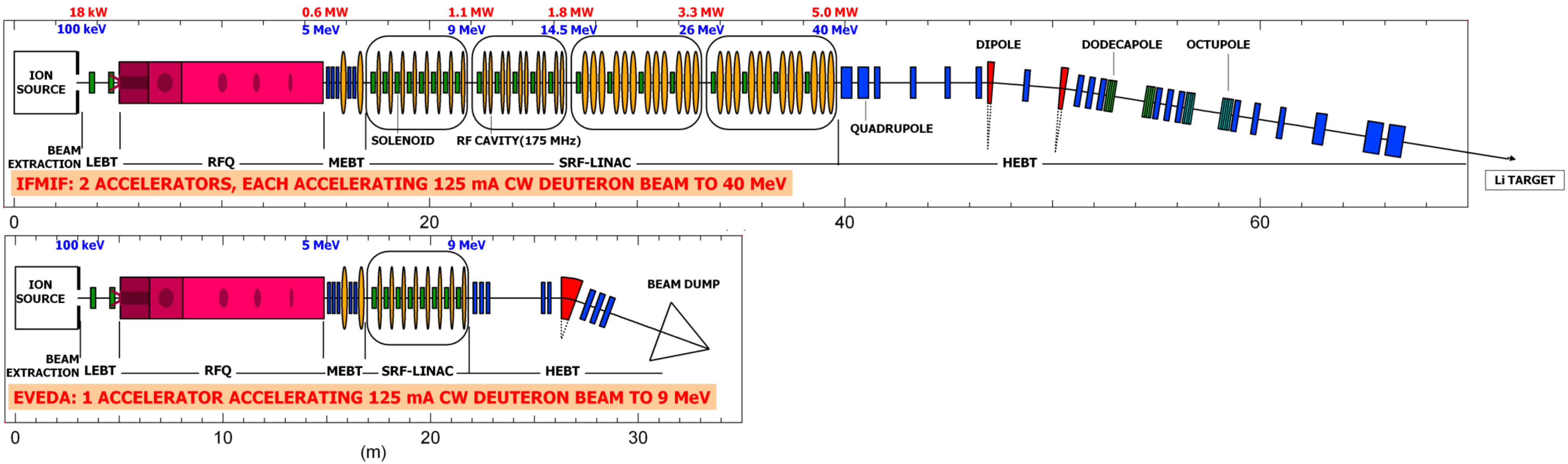
Unprecedented challenges



Main Issues

E < 5 MeV
Losses still significant (%)
→ Issue: To reach the required 125 mA

E > 5 MeV
Harmful loss-induced radiations << 1W/m
→ Issue: To avoid micro-losses $<< 10^{-6}$ of the beam

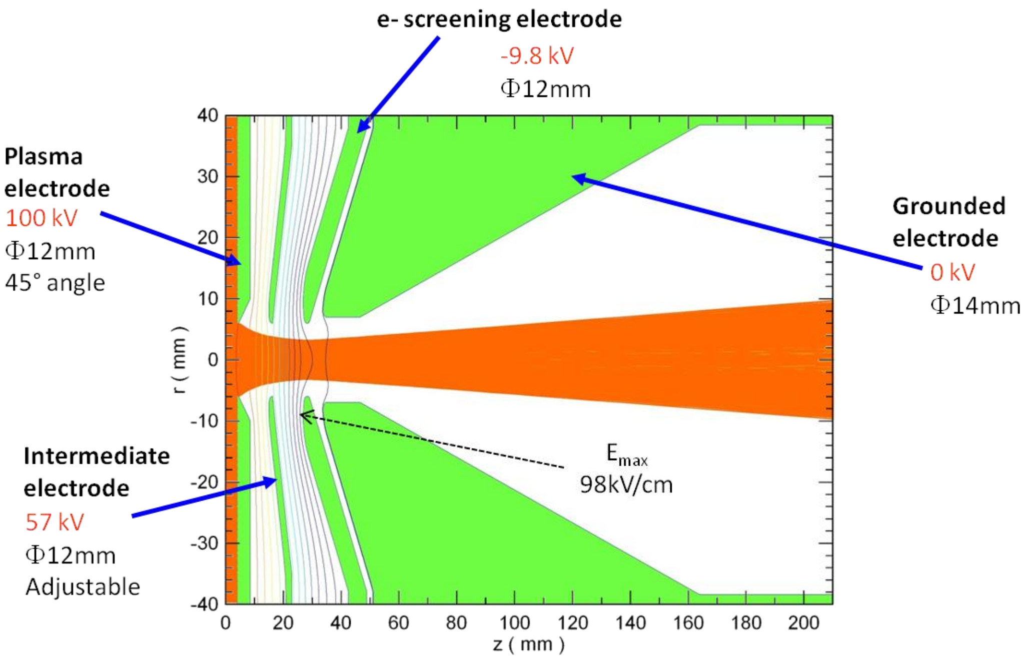


Source Extraction

Total Extracted current: 175 mA
→ Strong SC → Emittance ↗

Optimum injection into RFQ
→ Emittance ↘

Conflicting issues !!



100 KeV, 175 mA total beam current, 1560 A/m² (Φ 12mm)

(80% D^+, 15% D_2^+, 5% D_3^+) = (140 mA D^+, 26 mA D_2^+, 9 mA D_3^+)

Work around SC effects:

- Enlarge extraction aperture
- Increase accelerating field (but < 100 kV/cm)
- shorten extraction length (because no compensation) → reduce number of electrodes

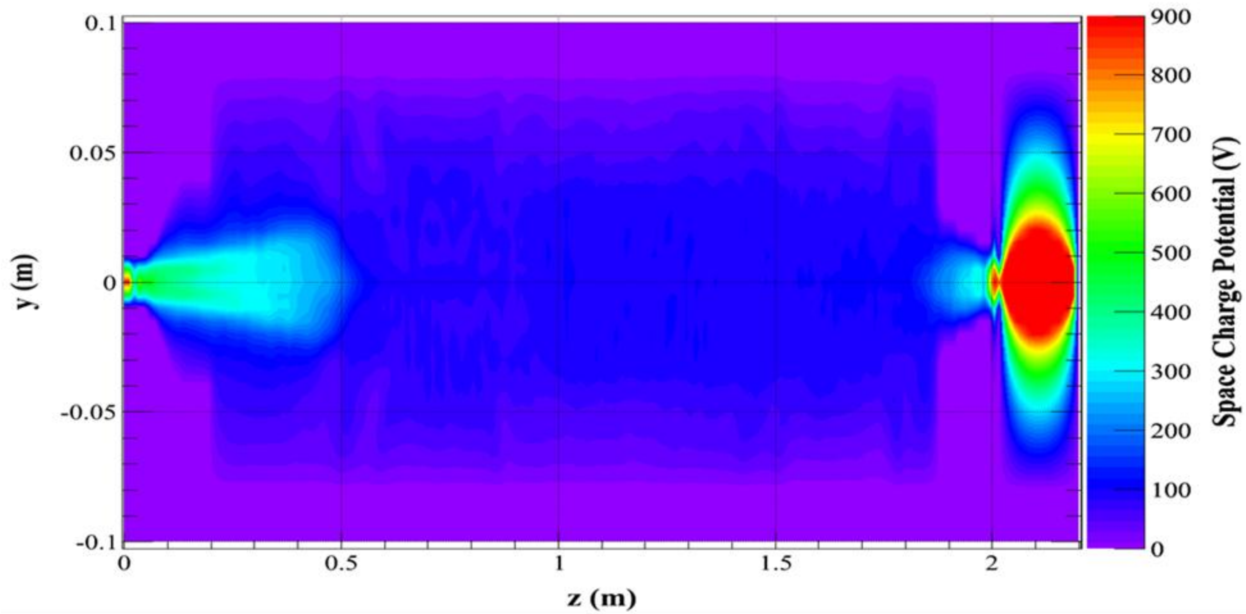
LEBT (1)

High current → strong SC

Large σ_I → strong neutralisation

Competition must be finely studied
Which is the winner ? Where ?

SolMAxP (CEA): SC potential map
Main focusing field, Heavy gas ion(Kr), e^- repellers at entrance at exit



LEBT (2)

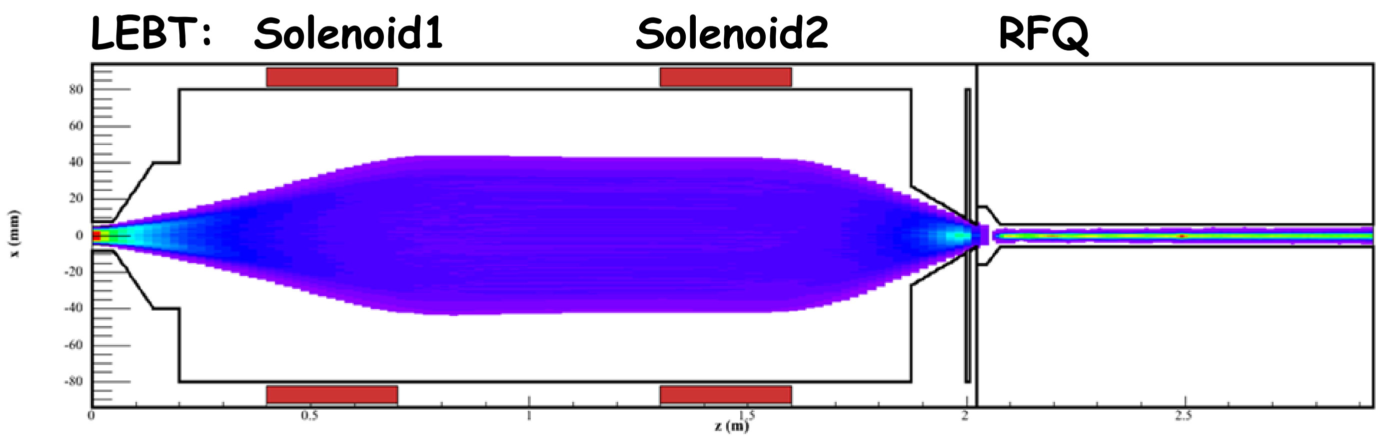
Reach the required current → optimise injection into RFQ

Strong SC

Bad precision of theor.calculation →On-line optimisation mandatory, ... following diagnostics	High compactness →Lack of room at RFQ entrance ... for diagnostics

Conflicting issues !!

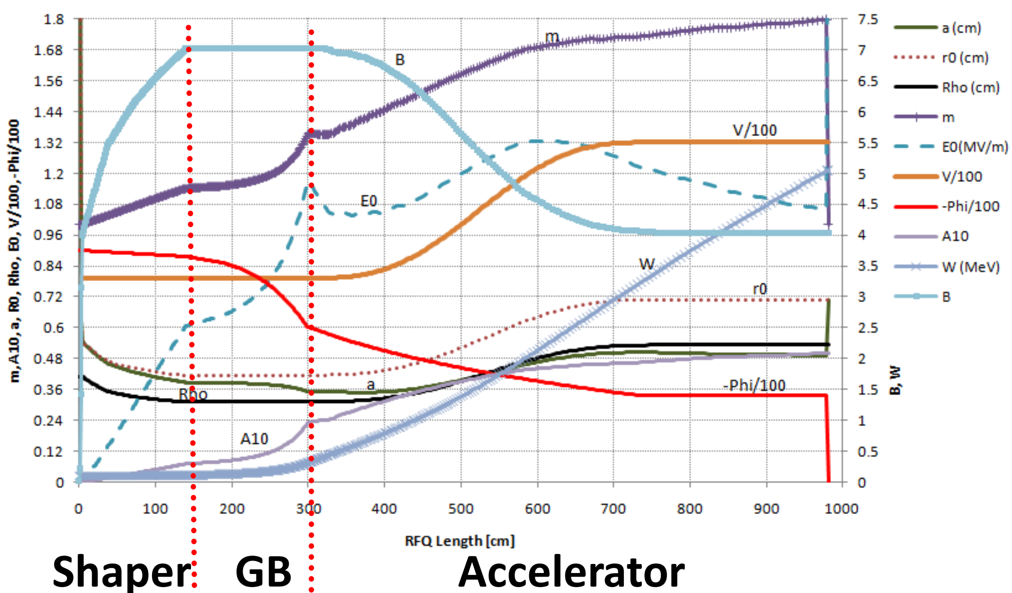
Optimisation method: highest transmission of LEBT-RFQ
On-line: maximise current at RFQ exit



RFQ

Strong SC → accelerate while focusing up to higher energy (5 MeV)
→ longer RFQ
+ higher beam power + harmful loss-induced activation

Optimisation: limit losses
spread losses on a biggest length, but on lower energy part
→longer Gentle Buncher



Linear field
2TERM-geometry type
Strong electric focusing
Strong B
Except at entrance for facilitating injection from LEBT – (LEDA RFQ)

MEBT + SRF-Linac (1)

MEBT: transports and matches the beam into the SRF-Linac
SRF-Linac: channel with its well defined matched beam in terms of RMS
Tuning of MEBT and SRF-Linac are decoupled

- Strong SC →
any change in beam distribution
will change net forces,
will change particle trajectories
→ Distribution dependent

- E>5MeV →
harmful loss-induced activation
→ Loss << 1W/m
- High beam power (~MW)
→ Loss << 10^{-6} of he beam

Multiparticle simulations with more than 10^6 macroparticles
For the MEBT and the SRF-Linac simultaneously
Each of the macroparticle at the external border must be scrutinised
→ Time consuming !

MEBT + SRF-Linac (2)

Num.calc.not precised to 10^{-6}
Machine not reproductible to 10^{-6}
→On-line fine tuning ... w diagnostics is mandatory and frequent.

High compactness
→Lack of room...
for conventional diagnostics

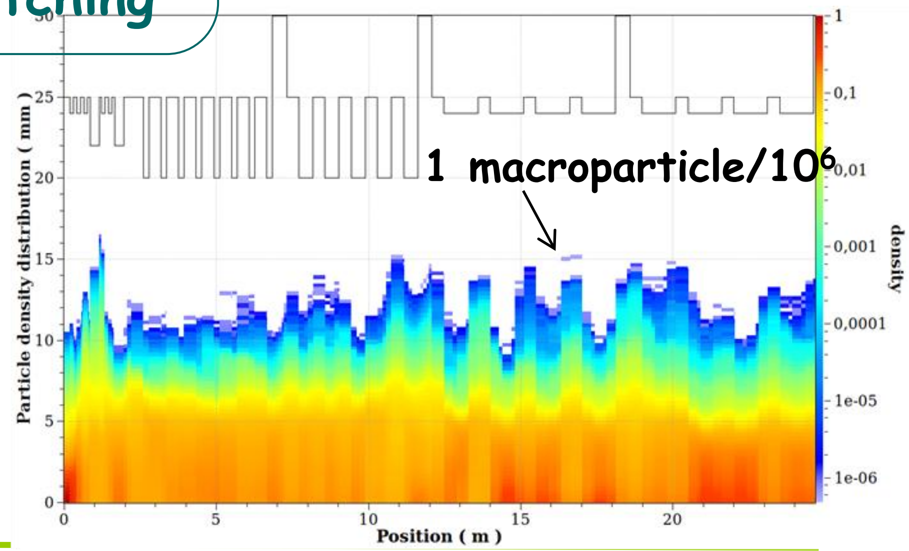
Conflicting issues !!

Uncommon procedure:
- Match beam rms envelope, then
- Minimise extent of particles on the border

→ "Halo matching" instead of "Beam matching"

That procedure can be applied on-line at the condition that microlosses can be measured the closest to the beam pipe, permanently & immediately

MEBT + SRF-Linac



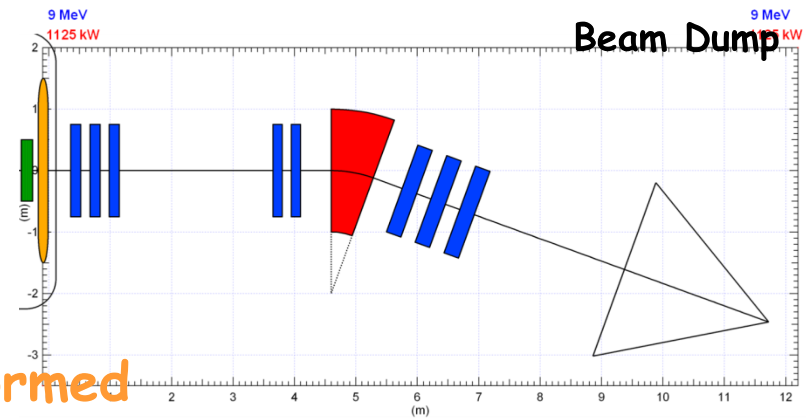
HEBT

EVEDA HEBT:

- Adapt the beam size for measurements (Diag. Plate) → many tunings to foreseen
- Expand the beam at the Beam Dump

→Issues: for each tuning, simultaneously
- avoid micro-losses
- limit power density at the Beam Dump

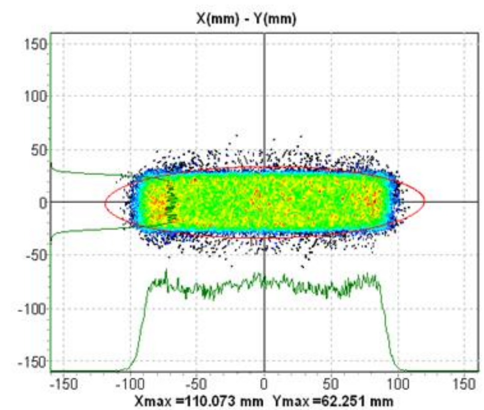
→ Many multiparticle simulations to performed



IFMIF HEBT:

Beam footprint at Lithium Target must be rectangular and uniform

→ Issues: Seen the beam power (2x5 MW)
Pb of reliability, reproducibility and stability
Remain to be studied



Emittance-growth issue (1)

Once the external beam limit is perfectly minimised and regular, sometimes the emittance can literally blow up

→ Compromise between halo and emittance minimisations

Envelope equation: 2 competing terms

$$E_{x,y} = \frac{\varepsilon_{x,y}^2}{\sigma_{x,y}^3}$$ and $$SC = \frac{K}{2(\sigma_x + \sigma_y)}$$

K is generalised perveance, continuous beam independent of particle distribution type

or $$SC_3 = \frac{3K_3(1-f)}{(\sigma_x + \sigma_y)\sigma_z}$$

K_3 is generalised perveance, bunched beam dependent of particle distribution type (coef)

Coef is obtained by equalising SC and SC_3 at one position at MEBT entrance

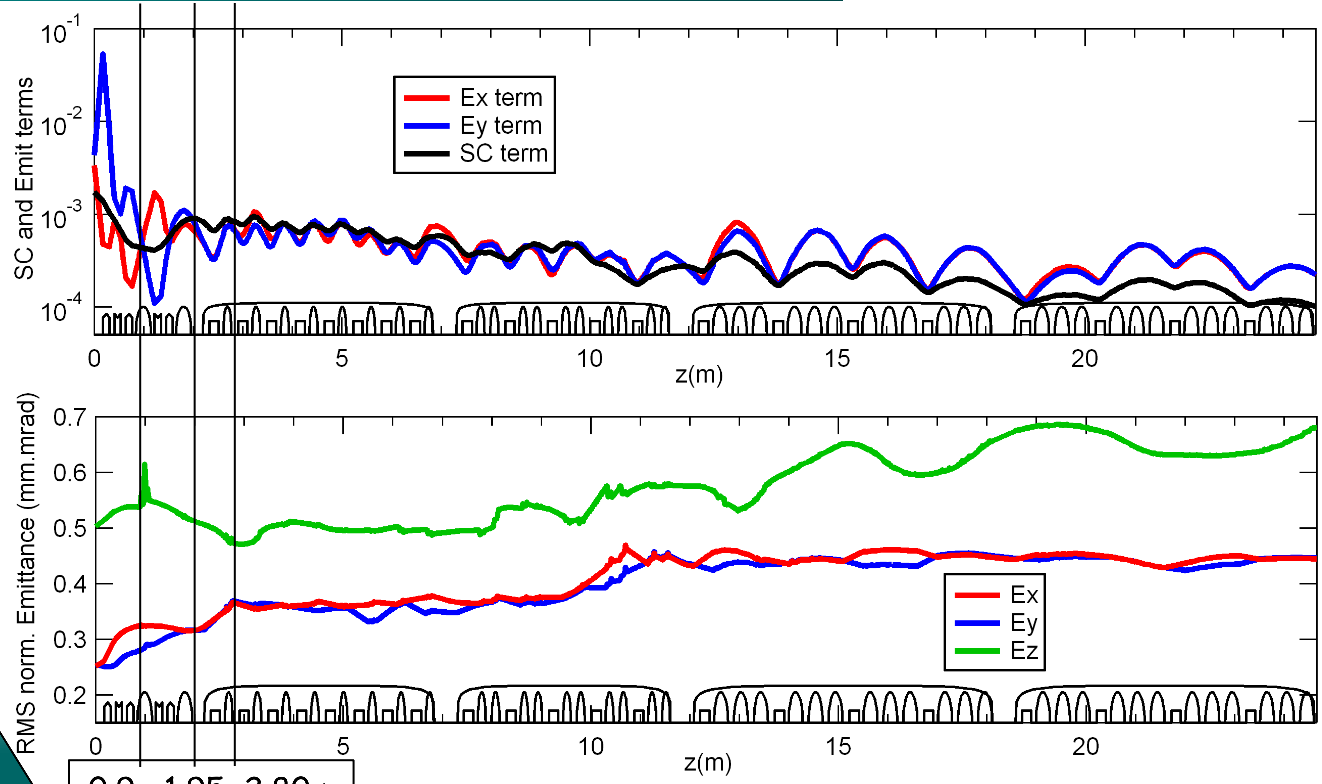
Emittance-growth issue (2)

Growing distance

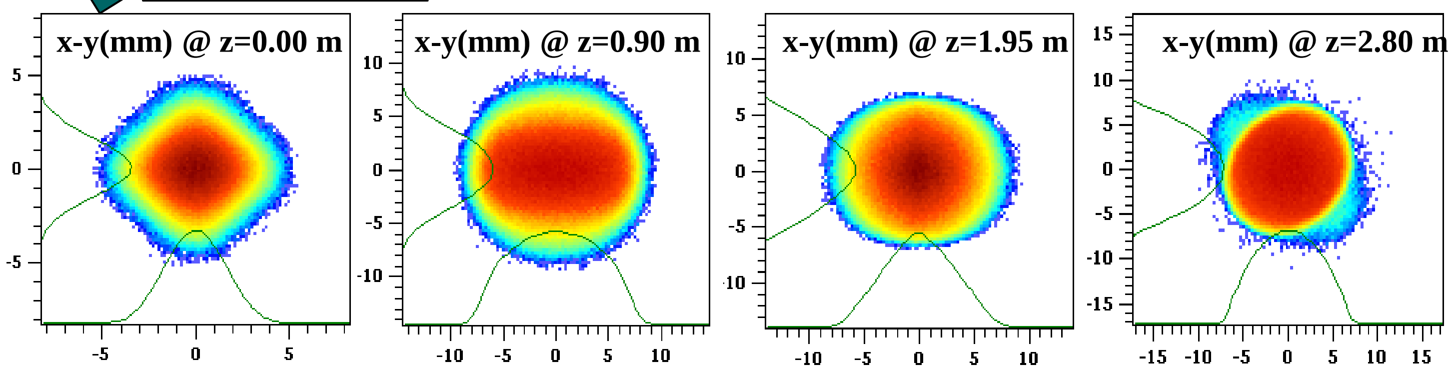
$\sim \beta c \tau_{pl}/4$

Charge redistribution

But that mechanism is not observed downstream,
or in longitudinal:
X-Y coupling ?
Resonances ?
→need additional studies



0.9 , 1.95, 2.80 m



Conclusion

Simultaneous combination of

The highest intensity
The highest power
The highest space charge
The longest RFQ
….

Unprecedented challenges
→immediate treatment

True "Laboratory" for studying physics of High Intensity Beam (Halo formation, Core-halo interaction Emittance growth, sudden particle loss)

Improve beam dynamics
Improve tuning methods