WG B – beam dynamics in high intensity Linacs

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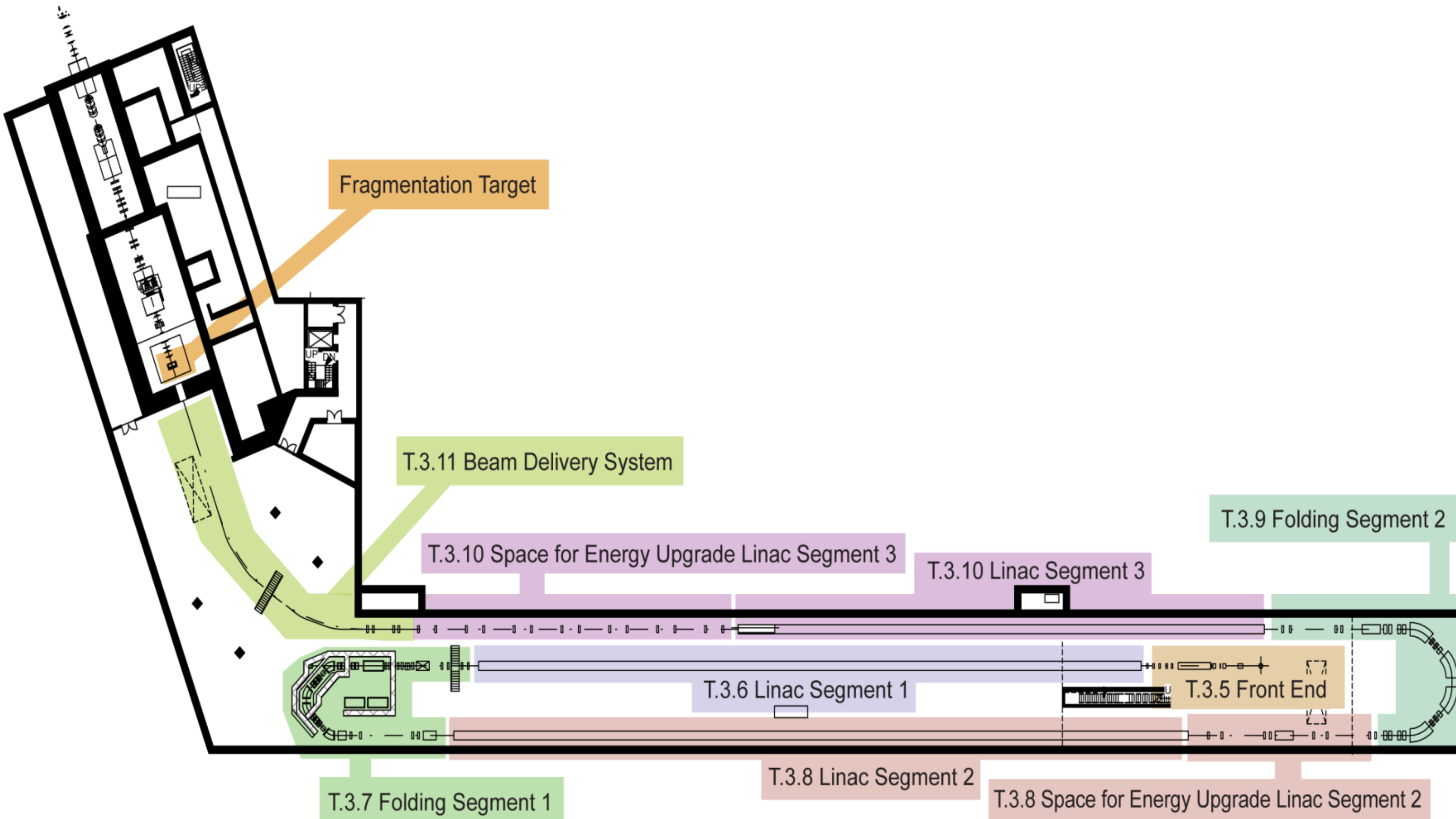
overview

- General beam dynamics for future projects
  - ESS,SPL,IFMIF-EVEDA,PROJECT-X,FRIB,SARAF,SPIRAL2+ CSNS
- Comparing simulations and measurements
  - JPARC,SNS,UNILAC,SARAF.
- Instabilities, Reliability and other high intensity issues

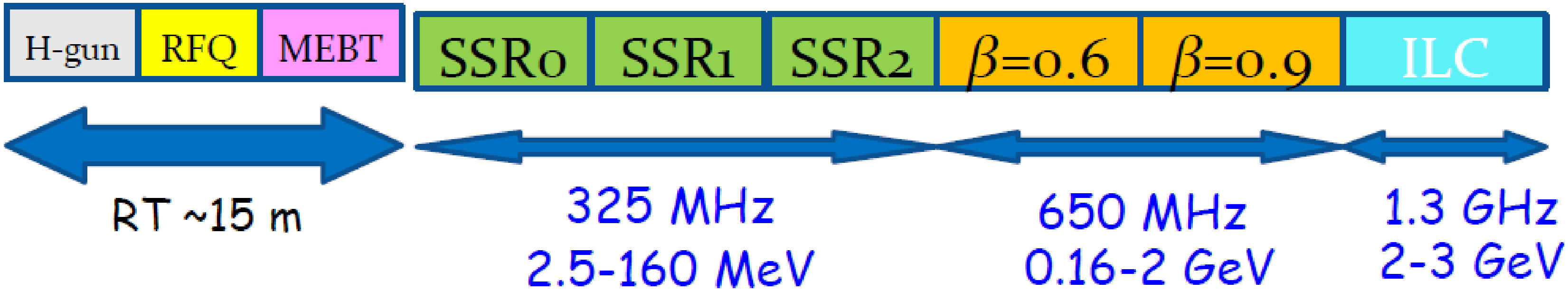
Future projects

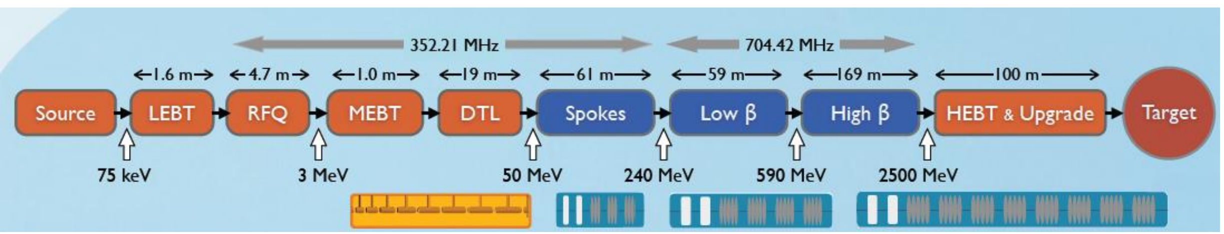
	ESS	SPL	IFMIF-EVEDA	PROJ-X	FRIB	SPIRAL2
Particle	p	H-	D	H-	All! Up to U	p,D, A/q=3
Power(MW)	5	4	5-1.1	3	0.4	0.2
Energy(GeV)	2.5	5	40-9	3	0.200/u	40 MeV (D)
Peak current(mA)	50	64	125	1	2	1-5
Duty cycle	4%	2%	CW	CW	CW	CW
	Long pulse operation	High rep rate (50Hz)	Space charge dominated	Low current	Simultaneous acceleration of up to 5 charges	Upgrade A/q=6

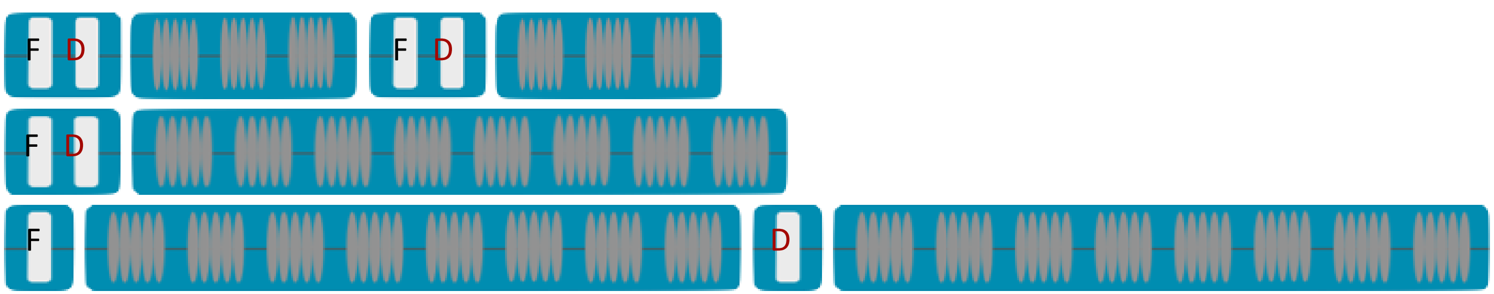
Sketch layout - FRIB



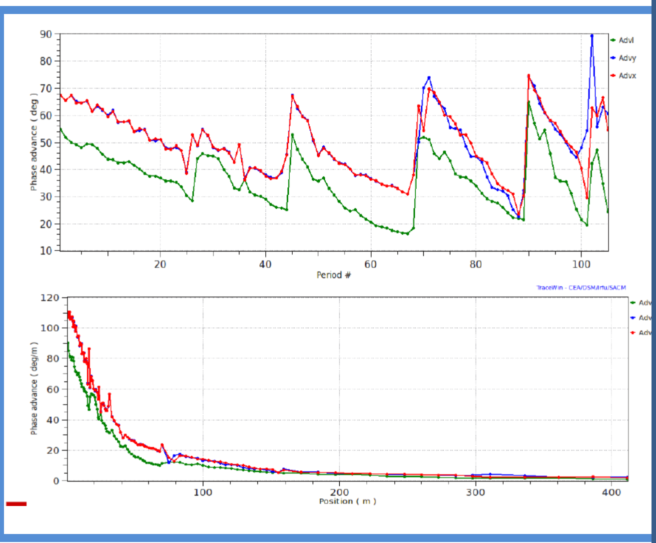
Sketch layout ProjectX,ESS,SPL.

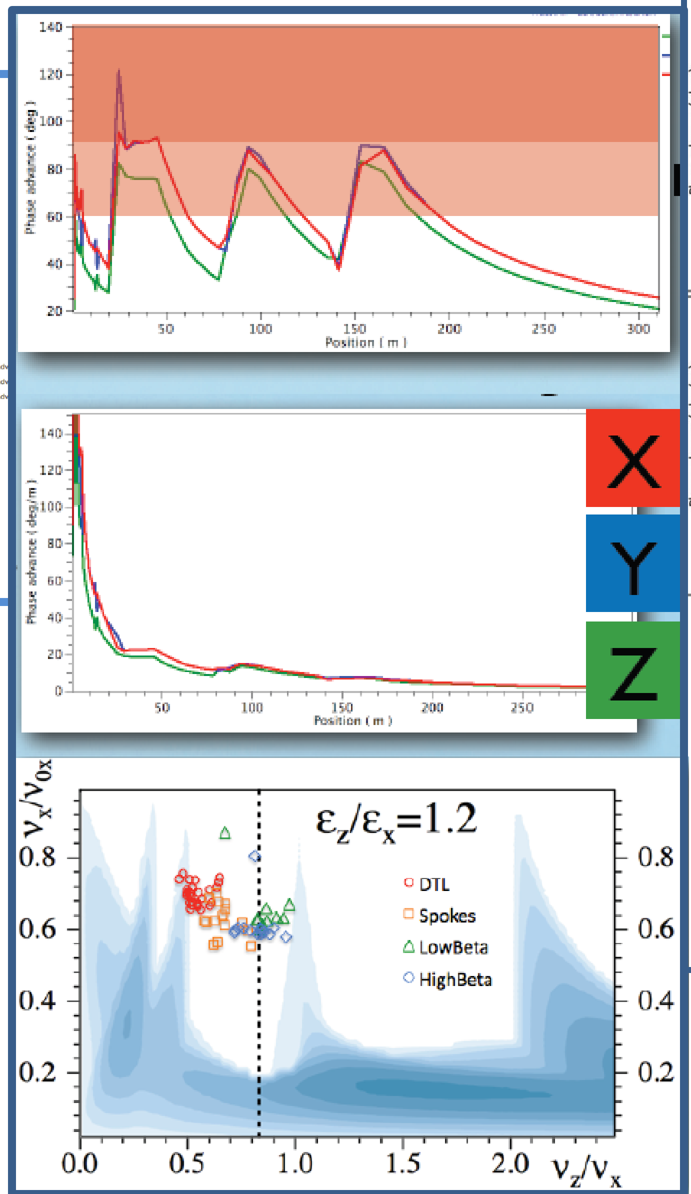


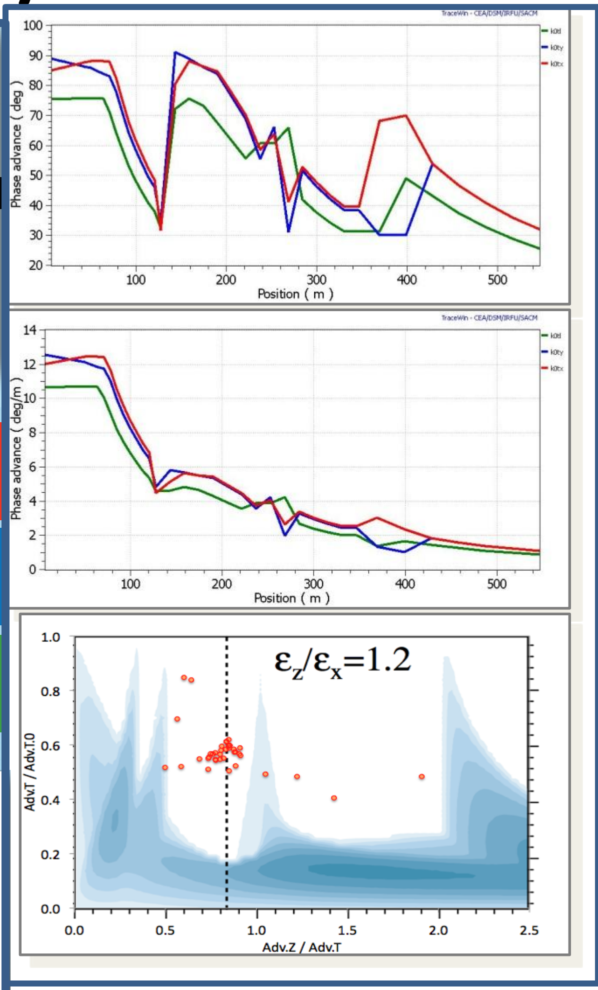




Future projects-beam dynamics







Design philosophy

Is the Design philosophy based on

- » Smooth phase advance per meter
- » Sigma0 <90 deg
- » Avoid resonances by accurate choice of transverse and longitudinal phase advance

the one that <u>operationally</u> gives the best performance AND minimises the losses?

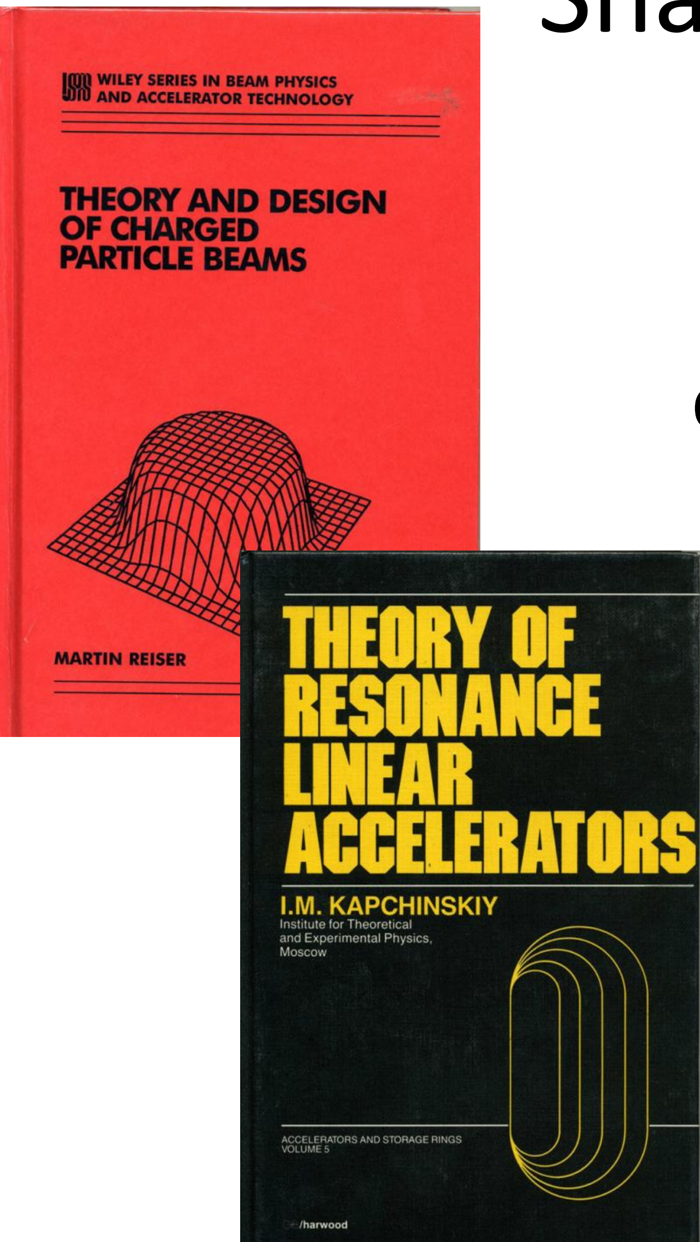
Emittance, halo and losses

- Discussion:
  - Dynamics of the core and dynamics of the halo are different and in some cases it is better to accept (some) emittance increase but control the losses [SNS]. Halo particles experience almost zero-current phase advance whereas the core particles experience the full current.
  - The standard linac recipe is relevant for the core of the beam and probably to avoid halo formation but it is not applicable to the halo that already pre-exist in the beam , i.e. coming from the source and/or the RFQ . [in SNS scraping at low energy reduced losses all along the linac,MOIB01; and also MOPD12 and TH01A02]
  - More information is needed on the input particle distribution. How can the beam distribution (tails, correlation) be measured out of the source and/or out of the RFQ . The loss pattern dependence on the beam input particle distribution (tail) is probably more than we have assumed so far.
  - The computing codes, as of today, agree on the rms, on 99% envelope but seem to disagree on the halo-to be verified. Are the fields in the computer codes described accurately enough to predict down to 10-6 ?

Emittance, halo and losses

- Presentation TH01B,TH01b02,th01B03 :
  - End-to-end simulations are necessary.
  - Space charge non-linearities, depending on the beam input distributions, can cause emittance growth and halo formation.
  - Some specific error distribution that cause resonant amplitude build up
  - Octupole components off the beam self field and dodecapole components in the quad might reduce the acceptance of the machine
  - HOM must be considered also for hadron machines
  - Halo formation is not necessarily accompanied by emittance growth, halo is difficult to detect also in simulations, therefore a quantification of halo by halo parameter is a quality factor for a given machine design.
  - Halo is acceptable at low energy (limit of 100W/m acceptable at low energies) but it must be collimated out before acceleration to high energies.
  - Theoretical model of an inhomogeneous beam shows that mismatch can delay disruption due to break-up modes.

Shall we go by …..



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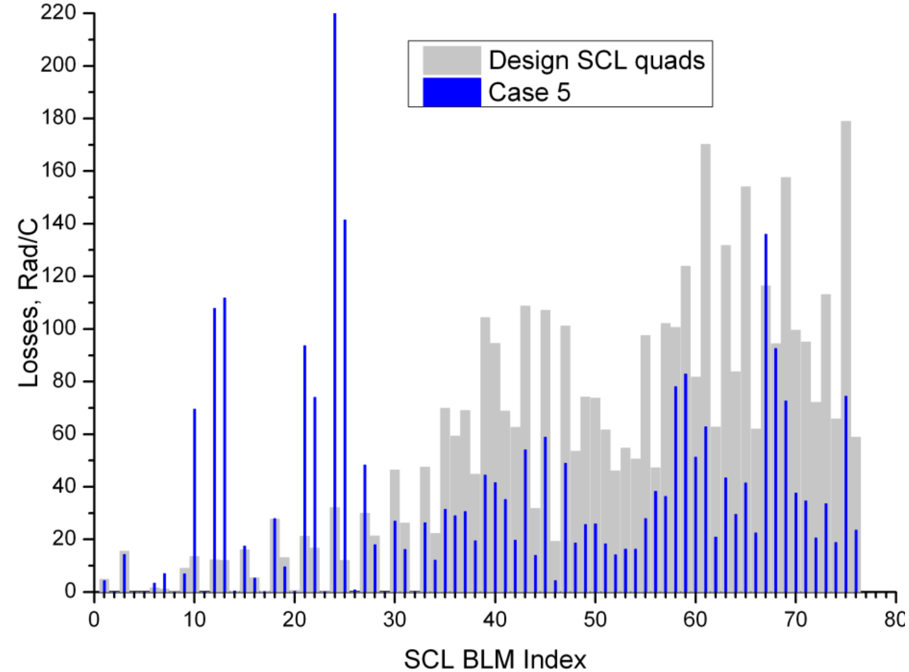
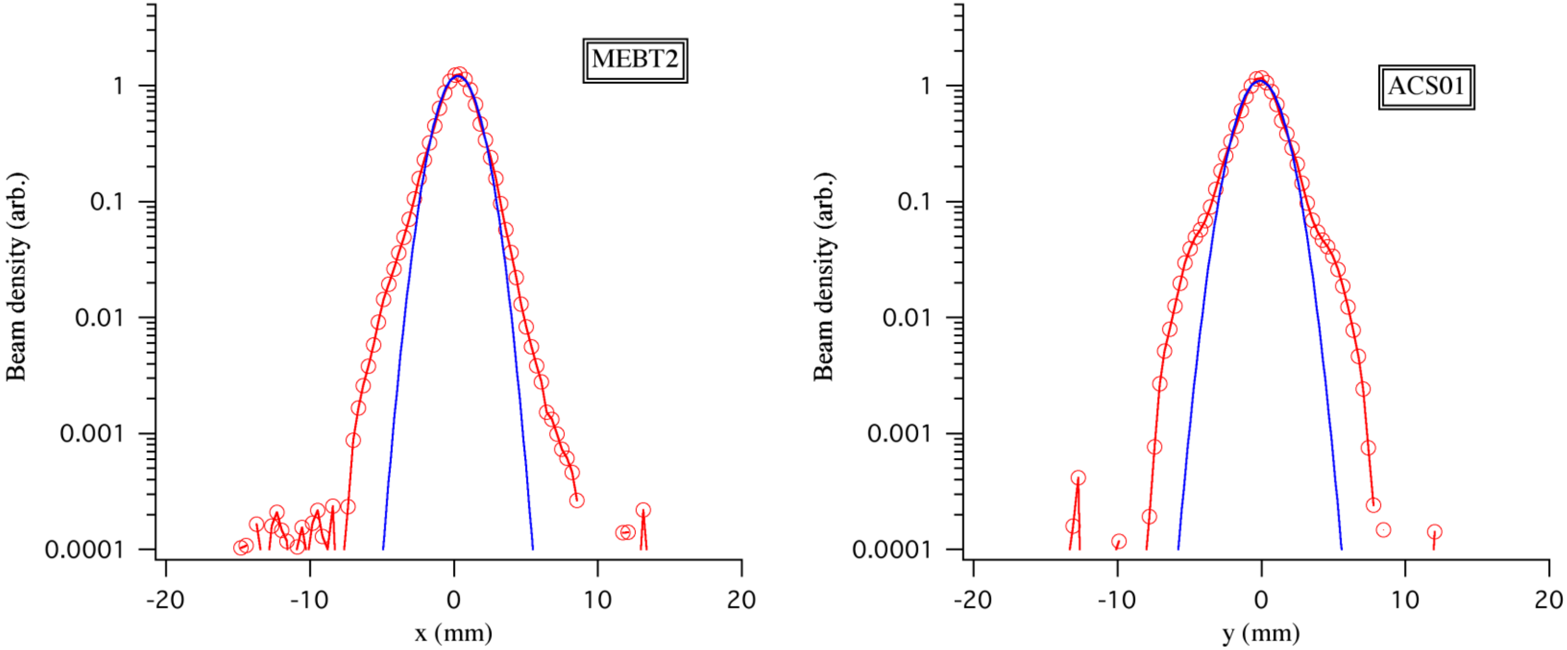


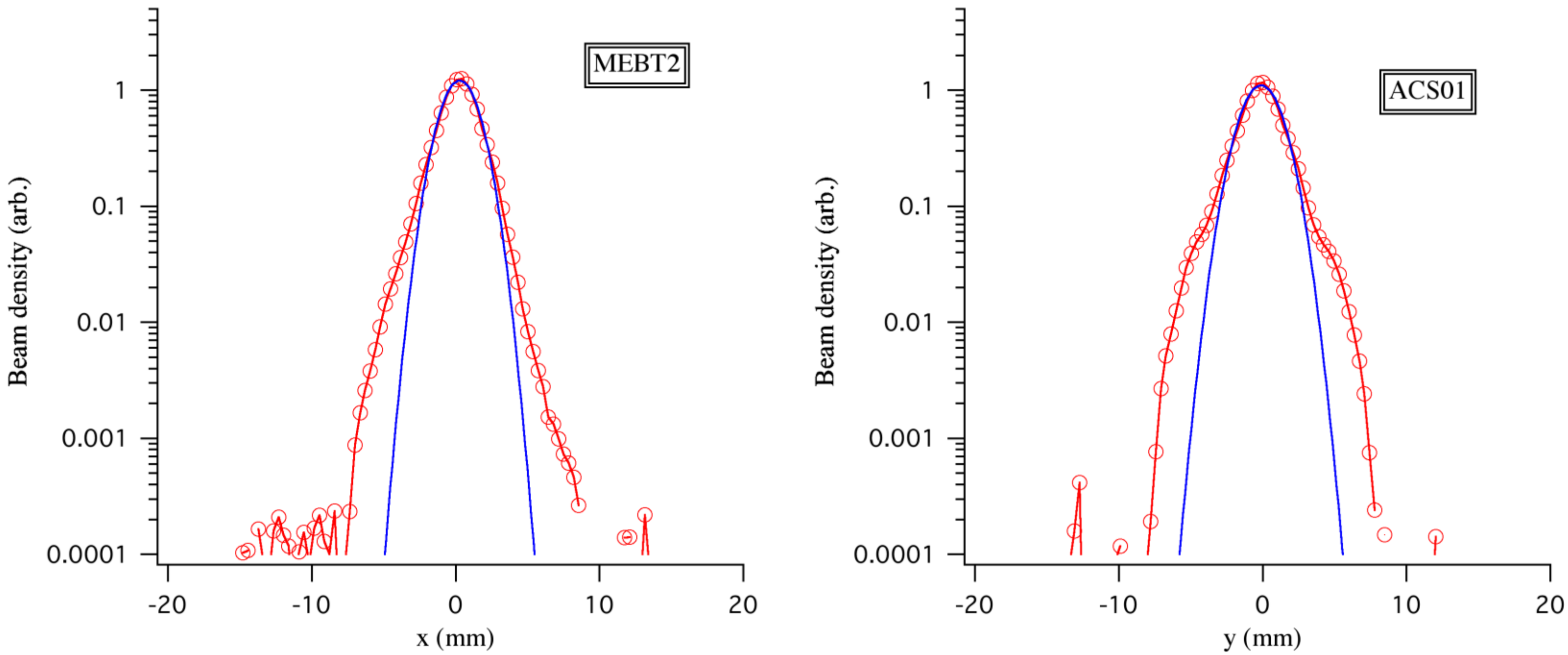
Empirical optimisation of the loss pattern by reducing quadrupole gradients? TH01A03

JPARC

- Observation :
  - Excessive emittance growth in the DTL, not in the SDTL
  - Halo formation in the SDTL but not in the DTL
- Emittance growth is not necessarily accompanied by halo formation

- Beam dynamics simulation (IMPACT) were a very useful tool to understand these phenomena.




MEBT2
Beam density (arb.)
1
0.1
0.01
0.001
0.0001
-20
-10
0
10
20
x (mm)
ACS01
Beam density (arb.)
1
0.1
0.01
0.001
0.0001
-20
-10
0
10
20
y (mm)

SNS

- Beam dynamics of the beam centre (orbit and longitudinal properties) is described accurately enough by the codes
- Envelope : agreement between measurements and model is very good up to the CCL and less good in the SCL
- Machine fine tuning is done with BLM, scrapers in the MEBT also reduce the losses
- Longitudinal mismatch in the CCL is measured and reproduced by simulation (is this a cause of halo formation?)
- Intrabeamstripping – see later

UNILAC and SARAF

- UNILAC , TH01A04
  - Very good agreement between experimental observations and DYNAMION simulations.
  - Thorough campaign of optimisation of the existing set-up, focus on the matching to the RFQ
  - Removal of injector bottleneck in two steps (RFQ re-machining and then RFQ redesign-2009).
  - End to end simulation are necessary
- Saraf , TH01A01
  - Tuning of the RFQ by comparison of measurements, em field calculations and beam dynamics (TRACK).

H- intrabeamstripping

- Not considered so far in all the loss pattern calculations.
- Cross section was measured by M. Chanel et al, in LEAR in 1987, recalculated recently from electron detachment data available at BNL.
- Might be the explanation for some unexplained high energy losses in SNS, might be the explanation of the difference between empirically optimised settings and theoretical settings. Short experiment soon at the SNS (end of the year).

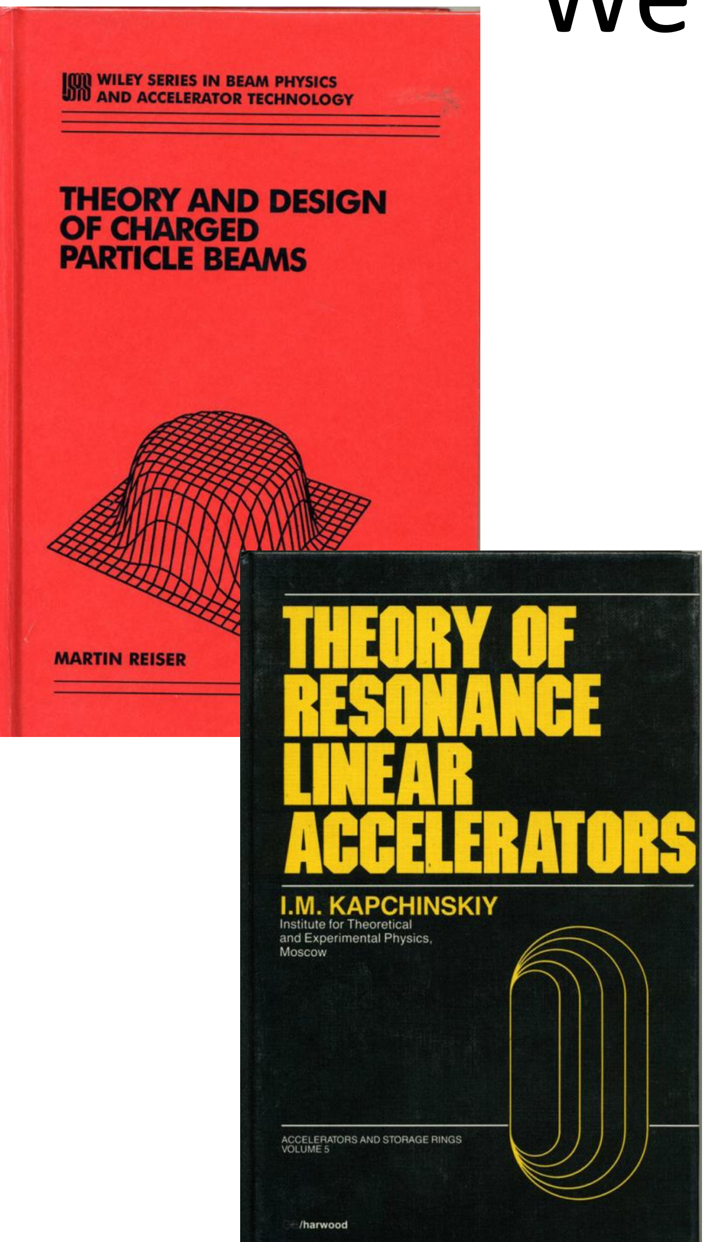
Matching and transfer

- Importance of careful simulation of transition and matching lines, where the emittance and halo degradation are most at risk.
- Emittance growth up to 96% depending on solenoid settings in the LEBT line [TH0105].
- Error studies are important when dealing with high power beam in transfer lines [TH0104].

Conclusions

- More information on the input beam distribution is needed to better predict loss patterns
- Scrapers at low energy (after source and after the RFQ) mitigate the losses at high energy. Indication that a good fraction of the halo is present in the beam before the DTL
- Dynamics of the core is mastered, dynamics of the halo could be mastered if sufficient information on the input 6D beam distribution was available. This is beyond the reach of standard diagnostics tool implemented in existing machines.
- "Standard recipe " remains a guideline for the design of the linac. but it needs to be adjusted to give more weight to halo formation and loss control in addition to emittance growth and rms envelope
- Intrabeam stripping studies should be further pursued and included in the design codes.

We shall go by .....



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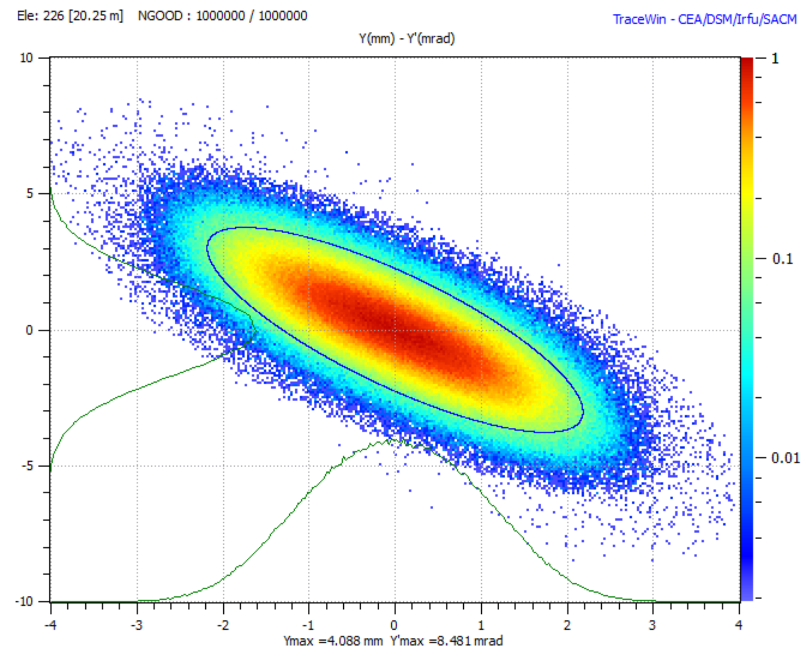

Measured beam input distribution which includes halo pre-existing in the beam.