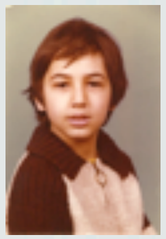
EUROPEAN
SPALLATION
SOURCE

Plans for the ESS Linac

Steve Peggs, ESS
for the ESS collaboration

8 Work Packages



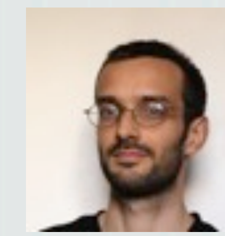
Romuald Duperrier (30 years ago)

Steve Peggs

Cristina Oyon

Josu Eguia

Work Packages in the Design Upgrade



Guillaume Devanz

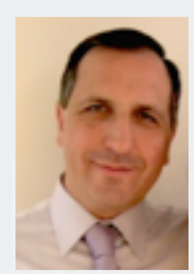
1. Management Coordination – ESS (Mats Lindroos)
2. Accelerator Science – ESS (Steve Peggs)
3. Infrastructure Services – Tekniker, Bilbao (Josu Eguia)
4. SCRF Spoke cavities – IPN, Orsay (Sebastien Bousson)
5. SCRF Elliptical cavities – CEA, Saclay (Guillaume Devanz)
6. Front End and NC linac – INFN, Catania (Santo Gammino)
7. Transport, Mags, PSs – Århus University (Søren Pape-Møller)
8. RF Systems – Uppsala university (Roger Ruber)

Mats Lindroos

Sebastien Bousson

Roger Ruber

Søren Pape Møller



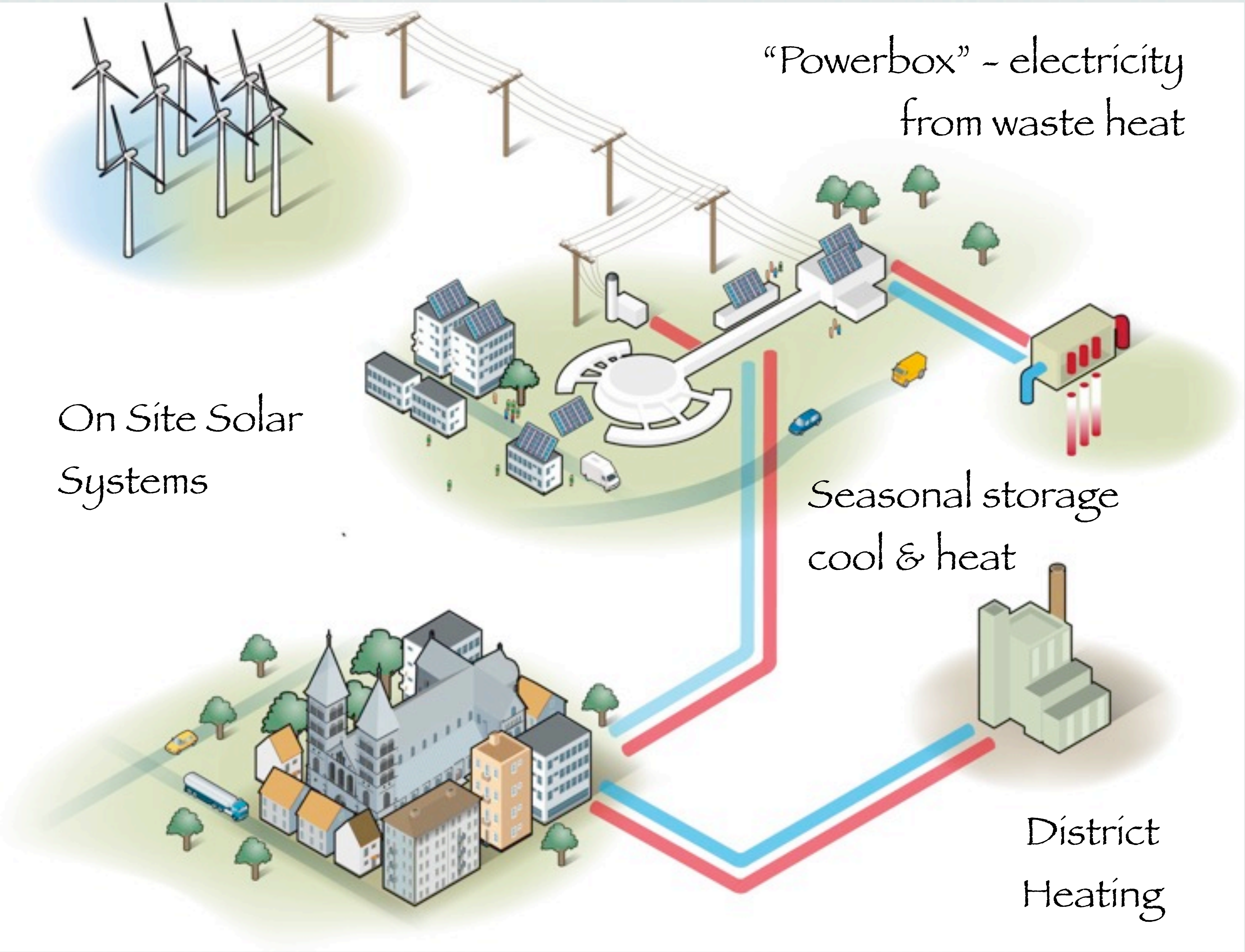
Santo Gammino

Where? When?

Design Update phase: TDR	Jan 2011 - Dec 2012
Decision to proceed	2013
ESS Construction phase	2013-2018
First neutrons	2018-2019
Operations	2019++

Artists view - 2018

ESS energy management



Include research, development & demonstration of emerging energy technologies.

Goal: carbon neutrality.

Eg options on wind turbine farms

High level parameters

Bilbao "B" and Scandinavian "S" parameters (2009) were almost identical

		B		S
INPUT				
Average beam power	[MW]		5.0	
No. of instruments			22	
Macro-pulse length	[ms]	1.5		2.0
Pulse repetition rate	[Hz]		20	
Proton kinetic energy	[GeV]	2.2		2.5
Peak coupler power	[MW]	1.2		1.0
Beam loss rate	[W/m]		<1.0	
OUTPUT				
Duty factor		0.03		0.04
Ave. current on target	[mA]	2.3		2.0
Macro-pulse current	[mA]	75		50
Ion source current	[mA]	$\sim$90		60
Total linac length	[m]		$\sim$420	

Current baseline:

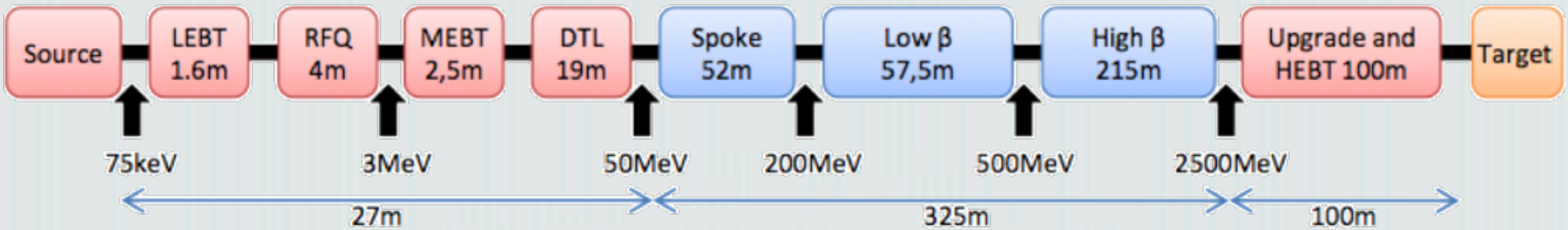
- 5 MW long pulse
  no ring; H+
- 2.0 ms pulses
- 20 Hz repetition rate
- 2.5 GeV energy
- Low losses, <1 W/m
- High reliability >95%

"Design Update" baseline:

- Shorter pulse 1.5 ms?
- Higher current 75 mA?
- Lower rep rate 17 Hz?

What are the issues?

DU Baseline



The DU baseline will be optimised for a beam power of 5 MW

- eg for 50 mA & not 75 mA, although ....

... upgrade options will be preserved where reasonably possible

- power upgrade to 7.5 MW? (15 MW?)
- extra cryomodules in the "Upgrade & HEBT" section?
- 1.5 ms long pulses?
- (second target station, interleaved 40 Hz repetition rate?)
- (H^- beams, ring & short pulses?)

Reliability trades against performance (at fixed cost)

- 75 mA is not as reliable as 50 mA

RF Frequencies

352 MHz & 704 MHz will be used in NC and SC RF structures

- Why not leverage 1.3 GHz infrastructure & experience?

According to the *Frequency Advisory Board* report (Harrison et al)

``... the FAB agrees with the Project that a lower frequency ... produces a better optimised and a lower risk solution to meet the design goals. The baseline 704 MHz design is shorter, larger aperture (beneficial in regards to beam loss), and lower impedance"

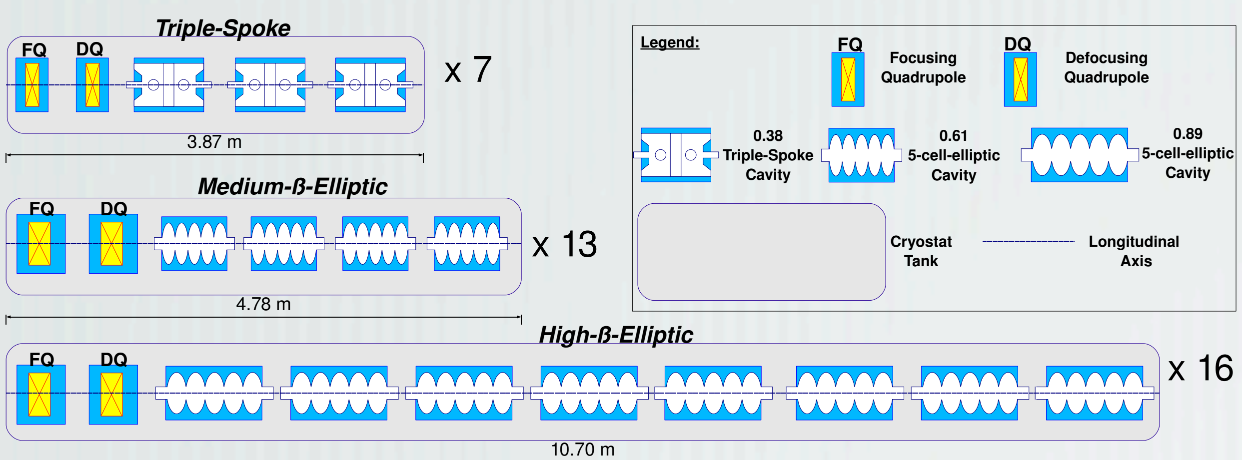
``... the FAB finds little difference for any frequency in the range of 600-800 MHz. In our opinion the exact frequency choice should be based on the project's collaborative strategy."

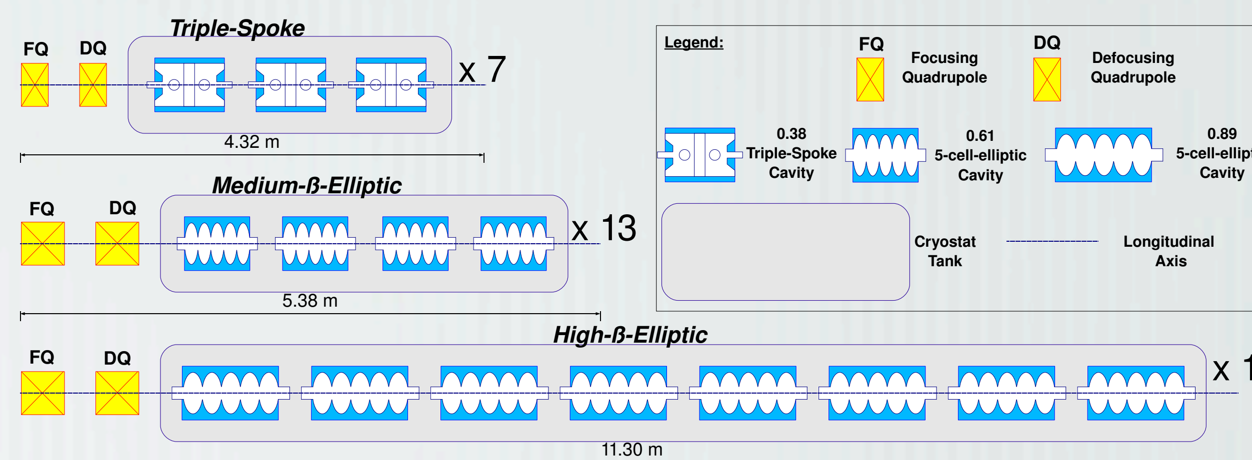
- 352 MHz & 704 MHz: the same as for SPL, MYRRHA, ...

Cryogenic segmentation

FLASH cryostat is continuous

SNS cyrostats are segmented





We are evaluating both options for ESS

Cryogenic segmentation

The 2 major technical drivers are:

1. Minimising total site power through efficient energy engineering
2. High reliability - minimise the downtime due to failed components

Total heat load per linac $[kW]$ eq. at $4.2\ K$	Segmented	$(4.2\ K$ op.)	Spoke temp.	5.797
		$(2\ K$ op.)		6.233
	Not segmented	$(4.2\ K$ op.)		3.199
		$(2\ K$ op.)		3.222

A. Ponton

Other factors:

- Minimise the linac length
- Risk of accidental contamination
- De-coupling the (cold) magnet & instrumentation development

Perhaps the best question is "How many segments?" (hybrid solution)

Cryomodules will be designed to have static & dynamic heat load as low as reasonably achievable.

- production CMs may differ "significantly" from prototypes (~2013)

Other Cryomodule issues

"Plug-compatible" CMs (as at ILC) would

- make design integration easier across the collaboration
- enable cavities from different sources in the prototype CMs
- permit multiple vendors in production line CMs
- reduce the set of standard beam instrumentation & magnets

Standard shipping containers have an inside length of ~12.03 m

- we are considering moving to 6 elliptical cavities per CM, not 8

Geometric betas

The optimum β_G depends strongly on pulse current (50 mA or 75 mA)

- respecting the power coupler limit of 0.9 MW, at 5 MW beam power
- hence also depends strongly on pulse length, rep rate, ...
- β_G depends only weakly on sub-scenarios (at fixed transition energies)

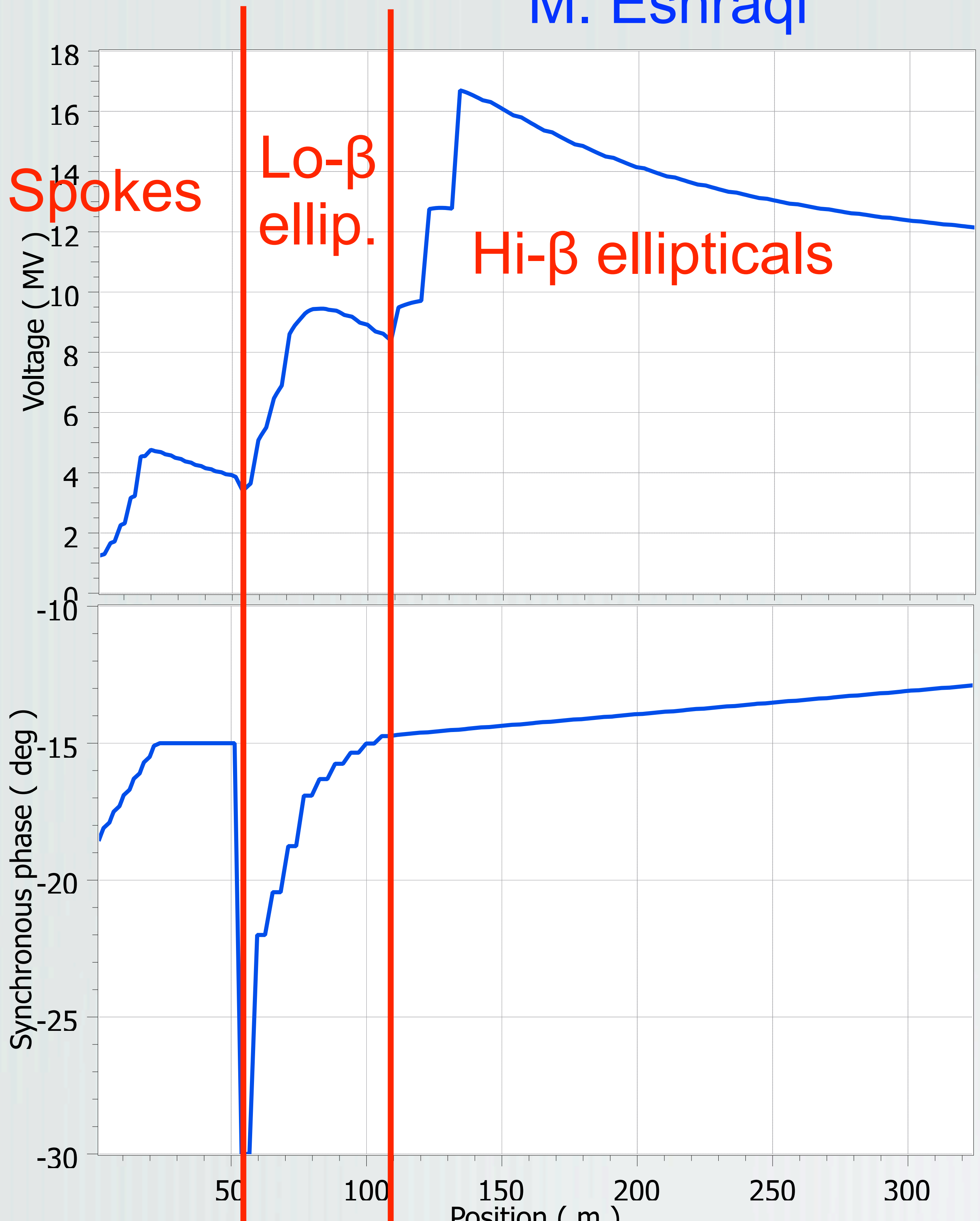
Structure	Geometric beta β_G	Maximum voltage [MV]	Maximum gradient [MV/m]
Spokes	0.54 ± 0.01	5.6	8.0
Elliptical 1	0.67 ± 0.01	10.1	14.1
Elliptical 2	0.83 ± 0.01	18.5	21.1

Must fix β_G's before spoke and cavity design can proceed. Imminent.

Go with a single elliptical beta (family)? Not in the DU baseline, but ...

50 mA optics

M. Eshraqi



Even under ideal conditions there is a spread of gradients/voltages

- β < 1

Accommodate realistic "yield curves"

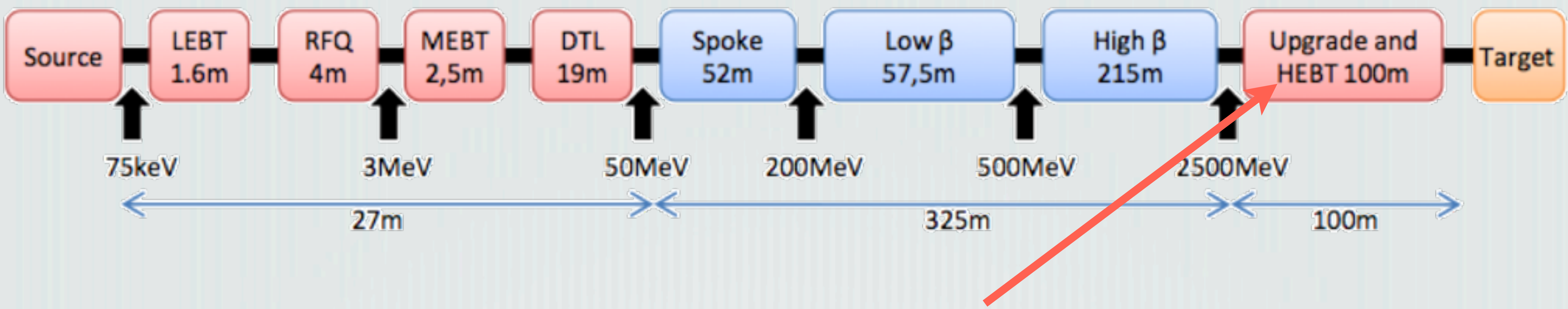
- as production line proceeds?
- manage manufacturers risk

Describe "expected" performance of peak surface field?

eg 50 MV/m ± 10% ??

The devil is in the details .....

Linac layout



What can extra cryomodules in the 100 m section do?

1) potential power upgrade to 7.5 MW, with 1 Target Station or 2
   - cf SNS & J-Parc planning

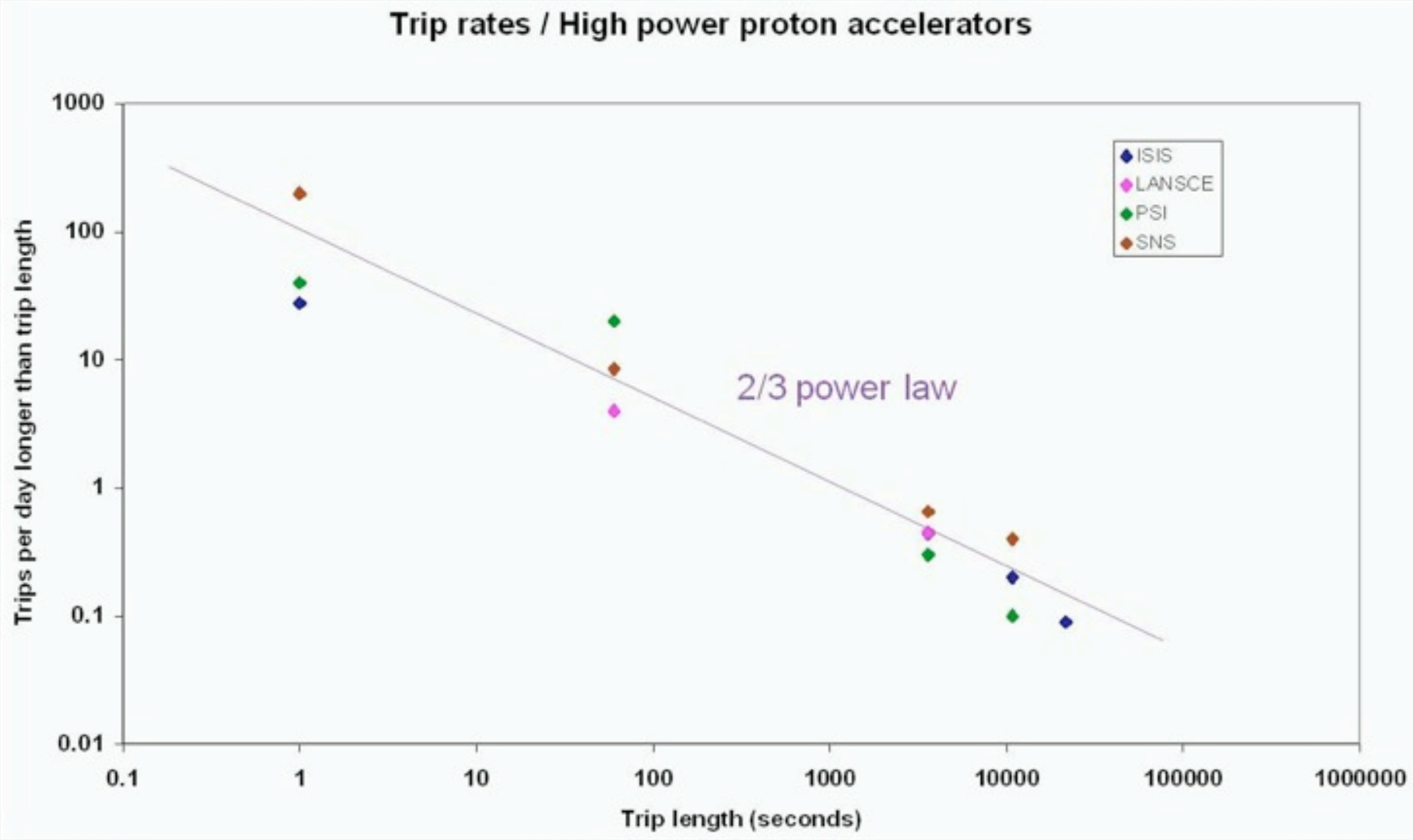
2) production line QA contingency
   - sorting?

3) hot spares for reliability
   - following ADS (MYRRHA/Eurotrans) “fault tolerant” studies
   - response time desired is < 100 s, not required to be < 3 s

Reliability

Cannot derive reliability from first principles!

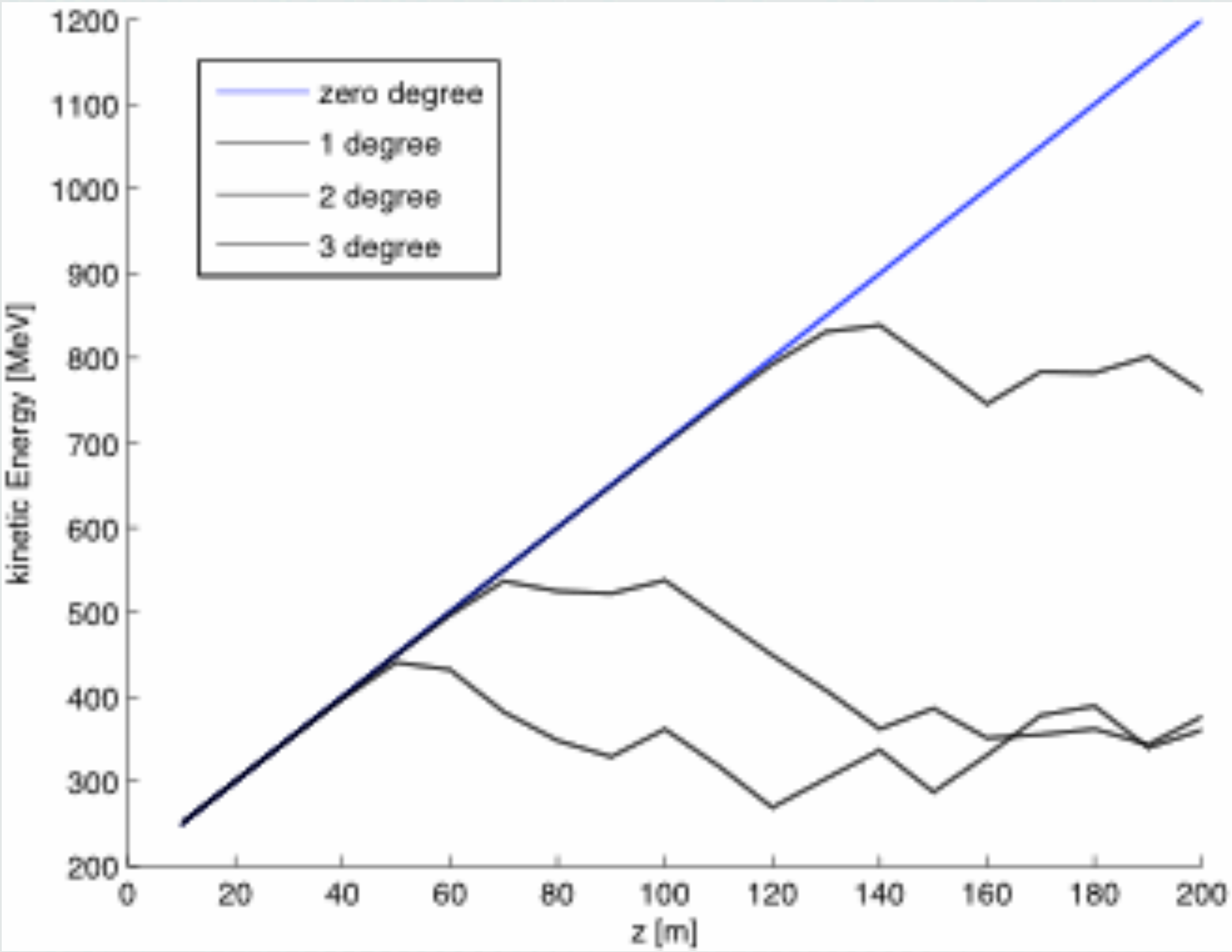
Empirical evidence (ISIS, LANSCE, PSI, SNS) suggests a universal power law for cumulative probability distribution of trip rate vs. trip length
- exponent of ~ -2/3
- for trips of less than one day in duration.



D.Findlay & C.Plostinar, 2010

J.Galambos et al, CPL04, 2008.

Models of beam loss



SNS reduction to 0.2 W/m is great news ... but why are weaker quads better?

1) ".. particles fall out of the .. longitudinal acceptance .. not matched to downstream quad[s] .. are lost .."? [Zhang et al]

2) H- beams suffer intrabeam scattering? [Lebedev]

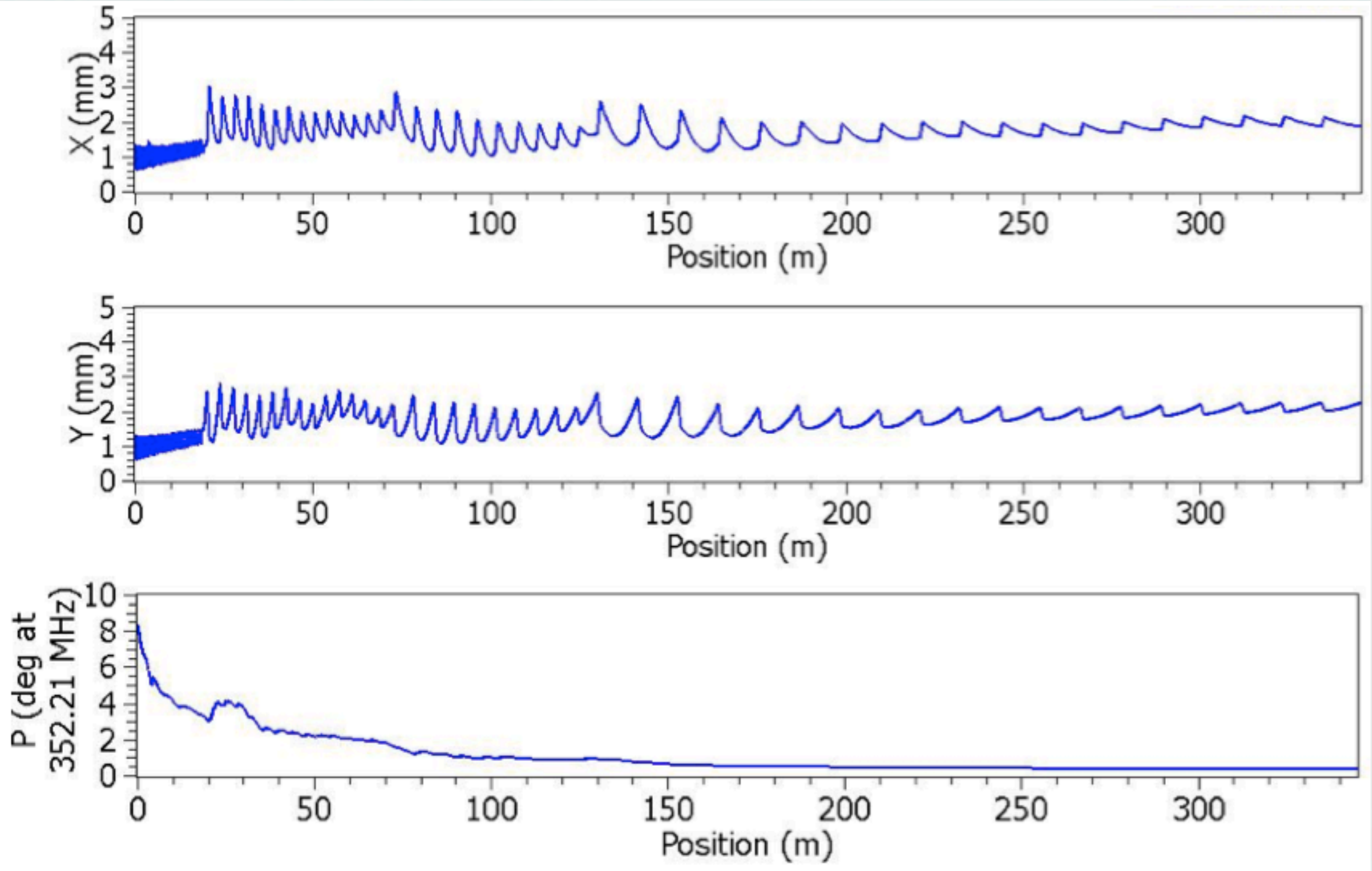
3) Space charge transverse/ longitudinal resonances?

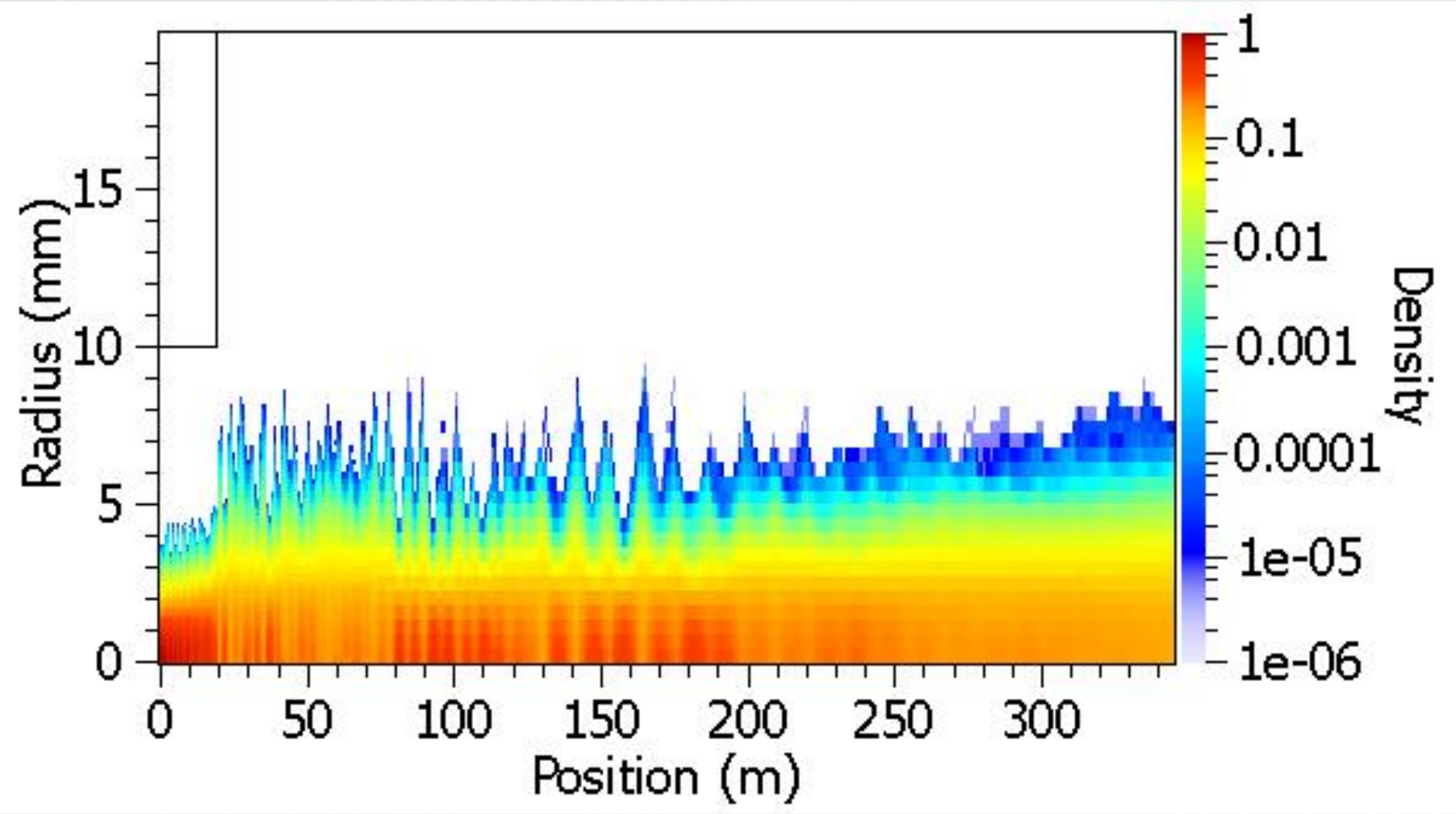
Does "invisible" longitudinal halo come from the RFQ? DTL?

Can it be suppressed in linac design?

Can halo (6D) be seen (instrumentation) & suppressed (collimators)?

Optical & simulation performance





Expect transmission of more than 99% through a more realistic ESS RFQ, with negligible emittance growth.

Remove halo with a MEBT collimator?

Outermost particles do not exceed a radius of 10 mm.

> 99.9% of the particles are confined within 5 mm.

The RMS transverse beam size approximately constant at 3 mm

Summary

1) Integrated collaboration & core teams will produce a Technical Design Report by the end of 2012

2) Prototyping & testing superconducting cavities & cryomodules by the end of 2012

3) Maintaining low beam losses < 1 W/m is a major challenge.

4) “Reliable, high power, inexpensive: pick two.”

- Reliability costs money and/or performance.
- Upgrade options cost money even if not implemented

Job Advert: RF Group Leader

RF Systems Physicist/Engineer	Ref: LD/10/1nn
Description of position The employee will lead the RF Group within the Accelerator Division of the ESS-AB. The group leader will play a major role in the preparation of a "complete and reviewable" Technical Design Report for the ESS, to be delivered by the Design Update collaboration by the end of 2012. The ESS RF group will continue to expand after 2012, to play a key role during ESS fabrication and installation, and becoming a central player during RF system commissioning, operations, and subsequent development.	

See adverts for this position in CERN Courier, Physics Today, and at http://ess-scandinavia.eu/jobs

Applications opened yesterday!