ESS Upgrades

EUROPEAN SPALLATION SOURCE

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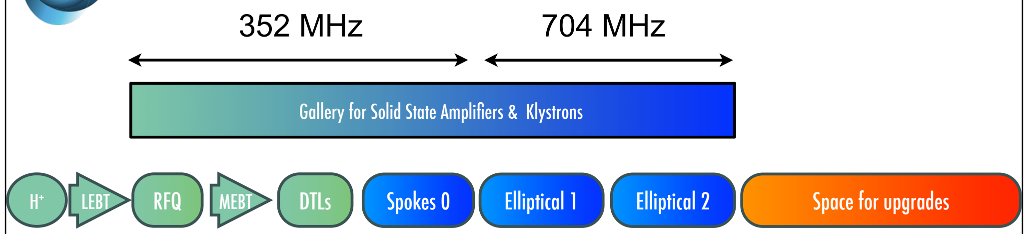
Accelerator Design Update

Linac baseline @ 5 MW



- Pulse length = 2,86 ms,
- Rep rate = 14 Hz
- Beam energy = 2.5 GeV,
- Beam current = 50 mA,

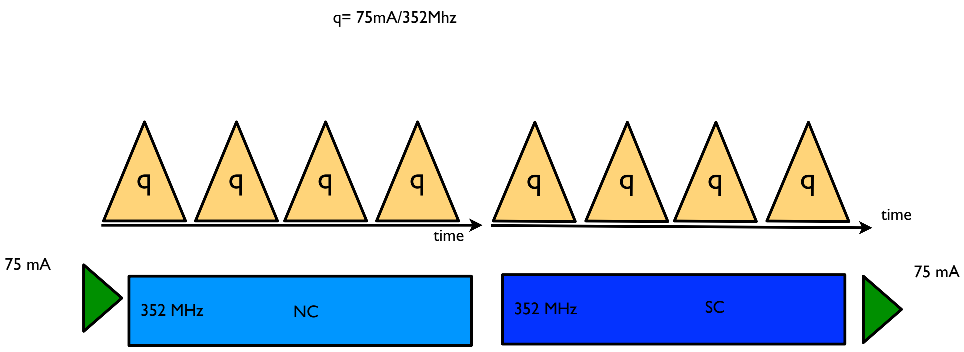
A front-end already tailored for 75 mA to induce margins for the baseline and prepare the 7,5 MW upgrade.

- Two frequencies,
- One 1,2 MW power coupler per cavity,
- One klystron per cavity,
- Two klystrons per modulator (better integration in gallery).

How to increase power?

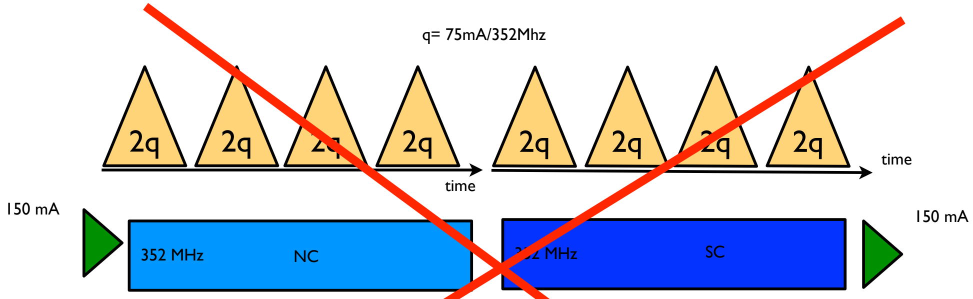
- Time structure kept constant (instrument issue):
  - Pulse length = 2,86 ms,
  - Rep rate = 14 Hz
- **Beam energy** = 2.5 GeV or higher:
  - 3 GeV? 3.5 GeV?
  - can we really play with energy? (ESS target evolutivity)
- **Beam current** = 50 mA or higher:
  - 7,5 MW would mean 62.5 mA @ 3 GeV or 75 mA @ 2.5 GeV,
  - 15 MW would mean 125 mA @ 3 GeV or 150 mA @ 2.5 GeV,

How to increase current in FE ?



2011 baseline scheme

How to increase current in FE ?

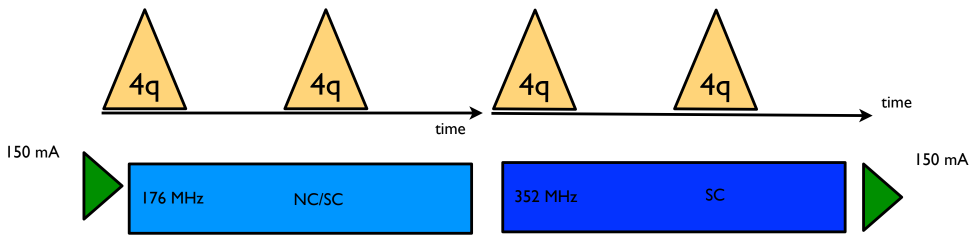


Dream scheme?

What is the limit ? 100? 125?

How to reach 150 mA in FE ?

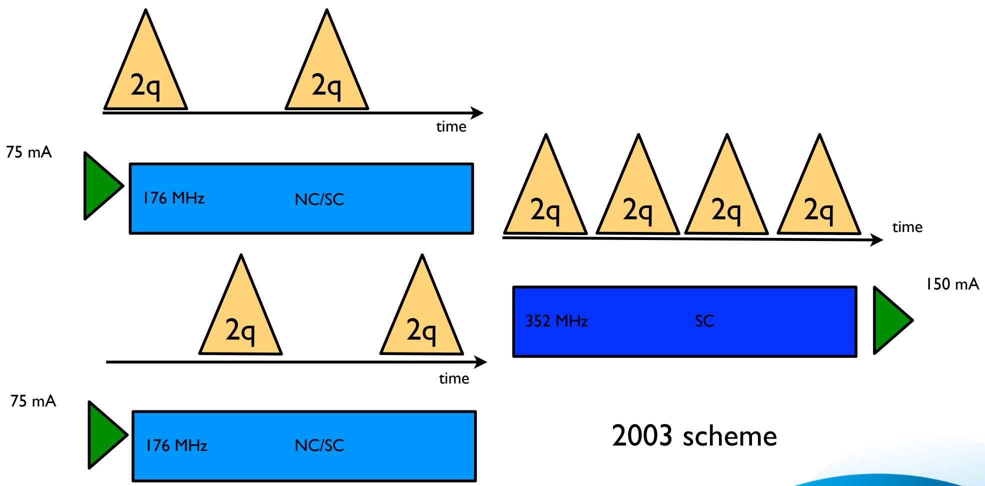
q= 75mA/352Mhz



IFMIF like scheme

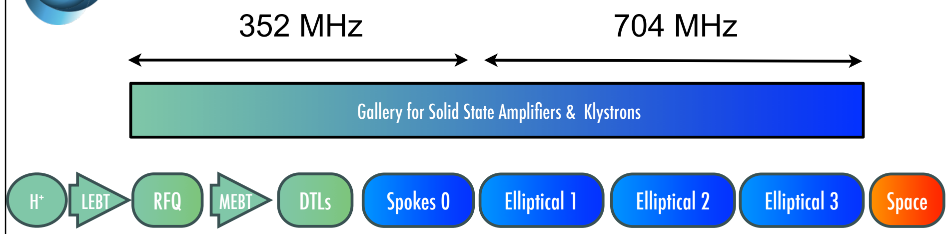
How to reach 150 mA in FE ?

q= 75mA/352Mhz



2003 scheme

How to increase energy ?



- Pulse length = 2,86 ms,
- Rep rate = 14 Hz
- Beam energy = 2.5/3/3.5 GeV,
- Two frequencies,

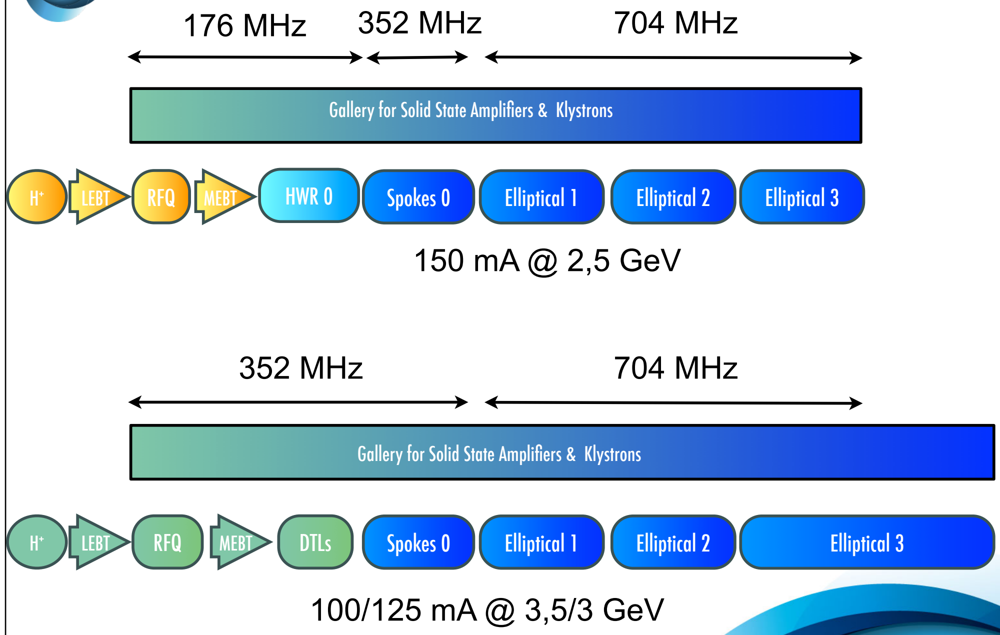
- One 1,2 or 1,8 MW power coupler per cavity,
- One klystron per cavity,
- One or two klystrons per modulator.

Two possibilities:

- Add extra modules (eventually more powerful),

- Install then Add extra more powerful modules.

How to do both?



Upgrades roadmaps to 15 MW

The evolution from the 7,5 to 15 MW version can be gradualness:

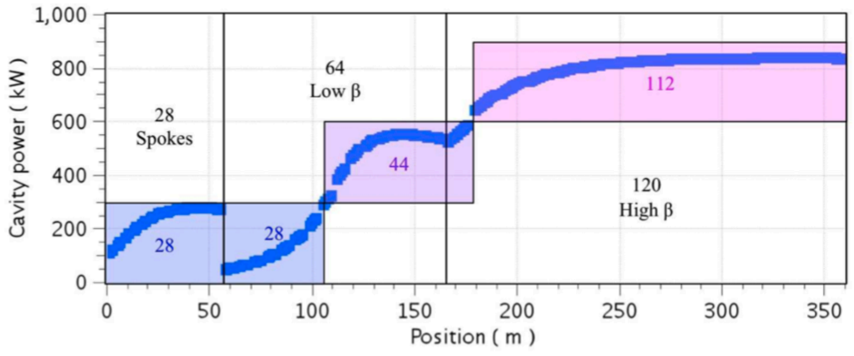
- a new klystron gallery could be build during the 7,5 MW operation years or an initially larger one would be equiped.
- one year, the source and the LEBT are changed. After shutdown, the linac would still operate at 7,5 MW.
- the frond is then progressively modified to remove DTLs, the linac would still operate at 7,5 MW.
- New modules can be added, or previous can be changed.
- **Special care MUST be taken for the anticipation of lengths.**

Let’s evaluate these scenarios

- All these layouts need to be investigated to evaluate the deltas in terms of:
  - total length,
  - geometrical betas,
  - power per cavity profile
- These layouts being calculated following two approaches:
  - the baseline for the SC part is optimised for 50 mA and the evolution are add-ons,
  - all layouts are optimised as it would be the option for day one and scaled to operate at lower/higher power.

Power distribution

- The power per cavity profile follows a non constant curve (TTF, phase advance constraints):
  - Several families of RF sources are needed to match this issue and to provide operation cost estimate.

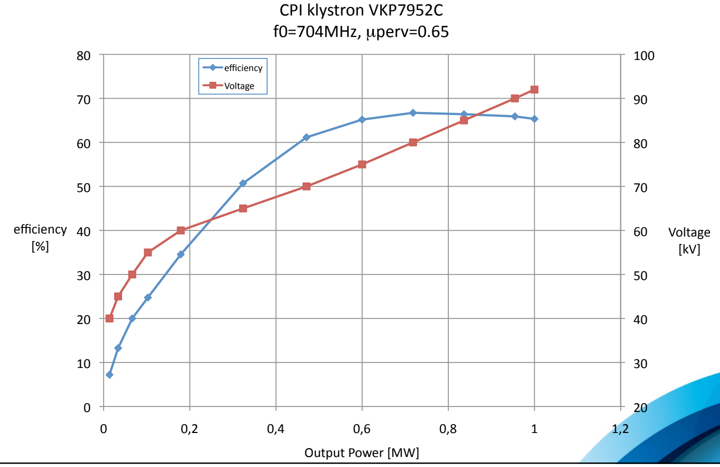


[Rathsman et al, IPAC 2011]

Operate klystrons at low power

> A klystron has its maximum efficiency at saturated power but this state is unusable for regulation: **klystrons are always used at lower efficiency than the specified value!**

> What do we loose if we change the operating power? Up to half power, efficiency drops from 0 to 10% (klystron design issue). See [Tallerico, IEEE Tr. on Electron Devices, V42, 1995].



704 MHz Saclay klystron

[Desmons]

Results

		2011 baseline	75 mA @ 2.5 GeV	150 mA @ 2.5 GeV	100 mA @ 3.5 GeV	125 mA @ 3 GeV
Power distribution (kW)		450/780/1100	1100/1400/2400	1100/1400/2400	650/1400/2300	870/1400/2300
Beta distribution		0,57/0,7/0,9	0,54/0,62/0,89	0,53/0,62/0,79	0,47/0,66/0,88	0,47/0,67/0,85
Phase1	L (m)	362,6	362,2	390,4	362,3	368,3
	Prf cons (MW)	17,6	20,2	21,0	20,1	20,4
	Peak current (mA)	50	50	50	50	50
	Nr RF sources	212	218	246	214	229
	W out (GeV)	2,5	2,5	2,5	2,5	2,5
Phase2	L (m)	427,9	362,2	390,4	362,3	368,3
	Prf cons (MW)	25,9	27,9	29,3	27,5	28,2
	Peak current (mA)	75	75	75	75	75
	Nr RF sources	252	218	246	214	229
	W out (GeV)	2,5	2,5	2,5	2,5	2,5
Phase3	L (m)	558,5	427,1	402,5	465,4	431,5
	Prf cons (MW)	47,7	49,6	48,8	49,7	48,8
	Peak current (mA)	150	150	150	100	125
	Nr RF sources	332	258	254	278	269
	W out (GeV)	2,5	2,5	2,5	3,5	3,0

A 10% drop at half power is assumed
=> pessimistic (see CPI klystron)

Next steps

- Capital cost, operation cost and integrated costs have to be evaluated for all these layouts to complete the study.
- Cryogenic extra cost must be included (higher energy).
- At this stage, we can conclude:
  - higher the current, higher the capital cost for Phase 1,
  - higher the energy, higher the integrated cost,
- CPI klystron behaviour will be used to update the study.
- What do we pay now? later? We should be capable soon to give inputs.