Post-accelerators for EURISOL

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On behalf of the Task 6 Group

Task 6 - Summary

- Introduction
- New design of the linac post-accelerator
- Superconducting Injector
- Normal conducting Injector
- High Frequency Chopper
- Next steps

Introduction

CNRS/IN2P3 (LPC Caen, IPNOrsay), GANIL, INFN/LNL, LMU (Frankfurt Univ.)
to be implied: JYV, KVI

58 FTE persons.months from 01/02/06 to 31/10/06

User requirements -> New design of the superconducting linac

Injectors: tests on prototypes or final equipments and studies are going on

High frequency chopper: studies have really started (post-doc G.Le Dem)

Diagnostics: problems of human resources

Input for safety-radioprotection calculation given to Task 5 (beam energies, beam losses)

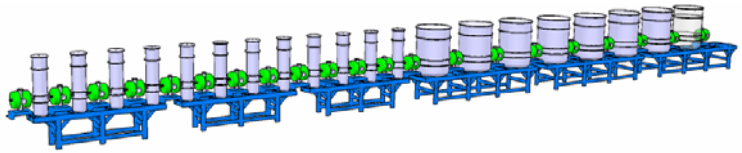
New general specifications

From: a/ "Experimental requirements", N. Orr, April 2006

b/ Task 6,9,10 joint meeting May 2nd, 2006, Orsay

1. **3 separate post-accelerators: VLE (<1 MeV/u), LE (1-5 MeV/u), and HE (150 MeV/u) Task 6 studies concern only LE & HE accelerators. VLE post-accelerator will be taken into account by the Physics and Instrumentation Task.**
2. **Beta-beam injector will be a separate machine, studied outside Task 6**
3. **For normal use, the linac post-accelerators should NOT employ stripping foils because of safety, beam loss, and beam quality considerations. However, the provision of strippers as an option is desirable for physics applications requiring short-lived radionuclides or high energy high A beams**
4. **The most flexible scheme has to be found concerning beam sharing**

Design starting point



SPIRAL-2 philosophy : Smoothest beam dynamics (regular FDO lattice, low number of β-sections), Modular solution and simple cryostats, Separated vacuum (safety with FP), Warm focusing (easier for alignement), Possibility to insert diagnostics at each period, ease of tuning

Main Hypothesis: Only 2-gap cavities (for high q/A acceptance), Max. accelerating fields 7.8 MV/m(120% Spiral2 operating point), Nominal operation for A/Q between 4 and 8

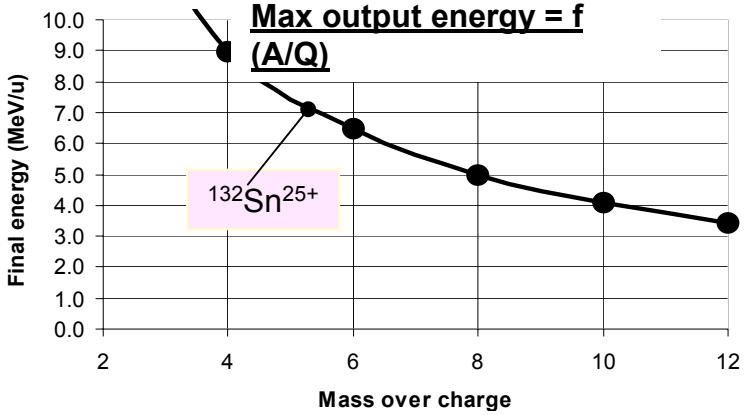
Input beam = RFQ + MEBT exit -> 585.4 keV/u for all ions @ 88.05 MHz (β = 0.035)

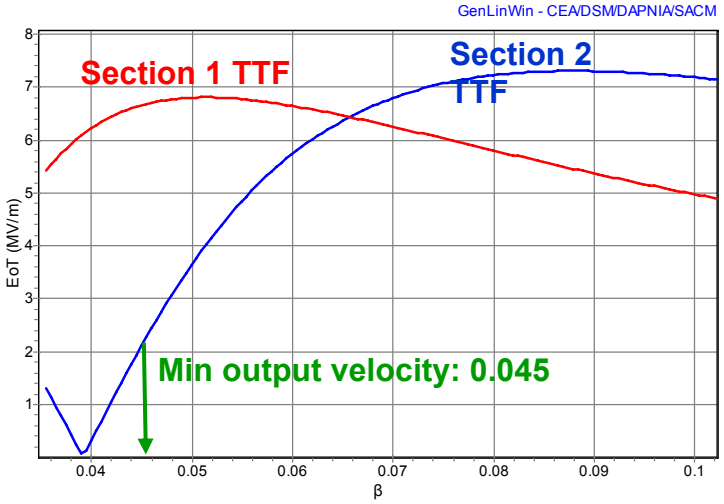
-> Emittances (trans. & long.) = 0.1 pi.mm.mrad RMS NORM

5 MeV/A linac design

One short linac, with no intermediate-energy exit, optimized for A/Q = 8

A/Q=8	Section 1	Section 2	TOTAL
Cavity Freq.	88.05 MHz	88.05 MHz	-
Cavity β	0.05	0.085	-
# cav./ cryo	1 QWR	2 QWR	-
# cavities	9 cav	14 cav	23 cav
Length	11.2 m	12.6 m	23.8 m
Output energy range	-	0.95 – 5.0 MeV/u	0.95 – 5.0 MeV/u





150 MeV/A linac design

One linac, with 2 intermediate-energy exits:

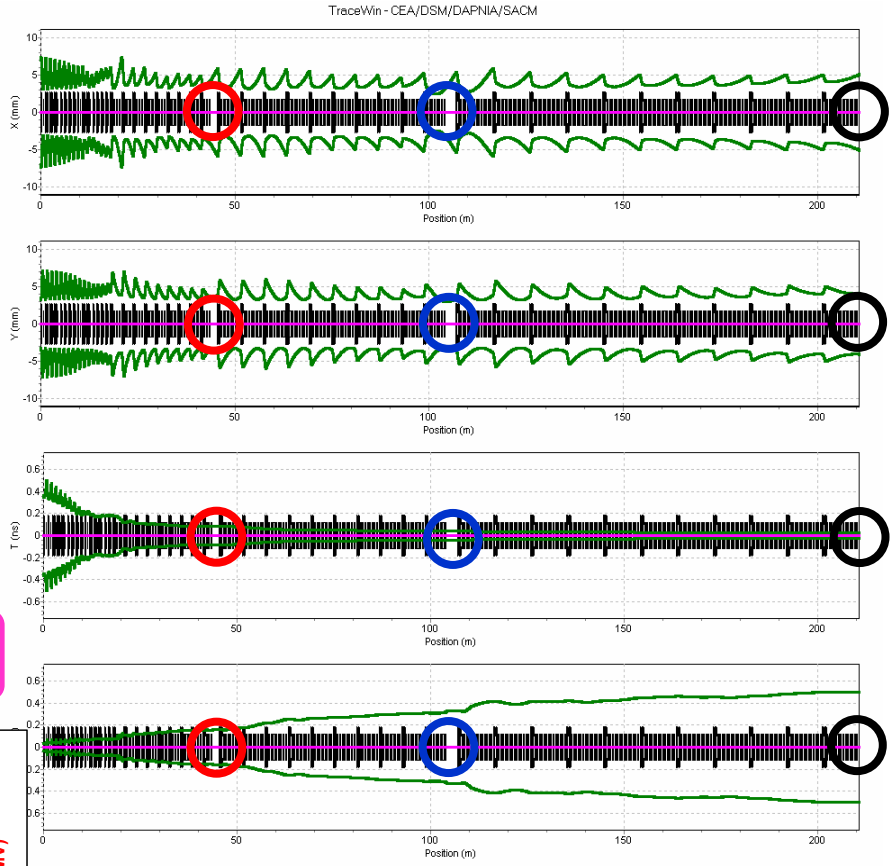
- **TTF optimized for A/Q = 8**
- **150 MeV/A max. output energy tuned for $^{132}Sn^{25+}$ (A/Q=5.28)**

$^{132}Sn^{25+}$	Section 1	Section 2	Section 3	Section 4	TOTAL
Cavity Freq.	88.05 MHz	88.05 MHz	176.1 MHz	264.15 MHz	-
Cavity β	0.065	0.14	0.27	0.385	-
# cav./ cryo	1 QWR	3 QWR	8 HWR	14 SPOKE	-
# cavities	15 cav	27 cav	80 cav	154 cav	276 cav
Length	17.9 m	26.1 m	59.0 m	103.8 m	206.8 m
Ouput energy range	-	2.1 – 19.9 MeV/A	9.3 – 62.5 MeV/A	20.0 – 150.0 MeV/A	2.1 – 150.0 MeV/A

New design of the linac post-accelerator

3 energy exits

$^{132}Sn^{25+}$ beam envelopes



Exit n°1

W_{min} = 2.1 MeV/A

W_{max} = 19.9 MeV/A (A/Q=5.28)

W_{max} = 13.1 MeV/A (A/Q=8)

$B\rho_{max}$ = 5 T.m

Exit n°2

W_{min} = 9.3 MeV/A

W_{max} = 62.5 MeV/A (A/Q=5.28)

W_{max} = 40.5 MeV/A (A/Q=8)

$B\rho_{max}$ = 8 T.m

END

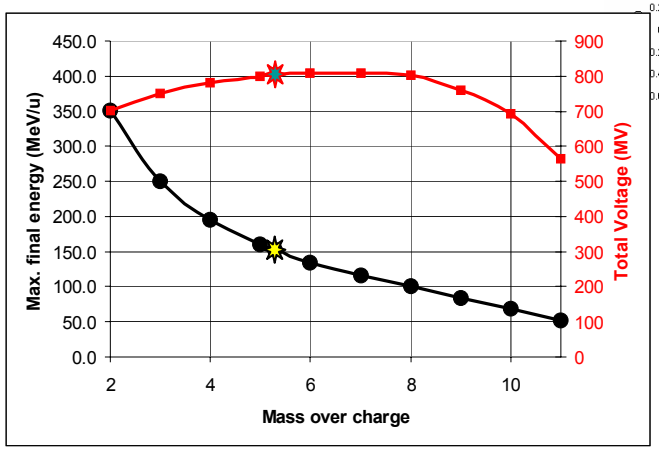
W_{min} = 20 MeV/A

W_{max} = 150 MeV/A (A/Q=5.28)

W_{max} = 100 MeV/A (A/Q=8)

$B\rho_{max}$ = 13 T.m

Linac performances Vs A/Q



- **800 MV total voltage in the required A/Q range** (100 MeV/A for A/Q=8, 200 MeV/A for A/Q=4)
- **Large acceptance up to A/Q=11**
- **Safe beam dynamics laws for every ion**

Stripping option

(…) physics applications requiring shortlived radionuclides and high energy high A beams

First try using 1 stripping station at exit n°1

- ^{132}Sn 25+ => Sn 47+ @ 20 MeV/A

=> Max. output energy becomes 254 MeV/A (instead of 150 MeV/A)

=> Transmisson is 30-35% (except if multi-charge acceleration is performed)

- ^{210}Fr 27+ => Fr 73+ (???) @ 13.5 MeV/A

=> Max. output energy becomes 229 MeV/A (instead of 103 MeV/A)

Studies to be pursued

Time & energy resolution

Time width

Δt = 25 ps (FWHM) Spec: < 100 – 500 ps => OK

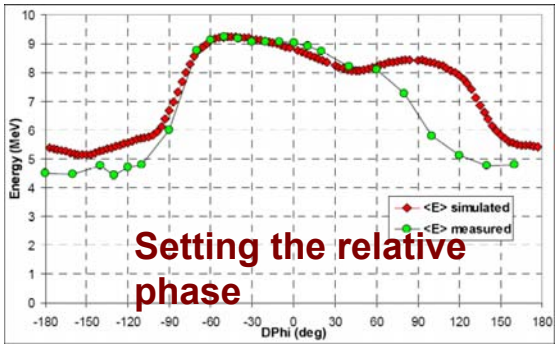
Energy spread

$\Delta W/W$ = 0.5E-3 (FWHM) Spec for Energy Definition is < 1 E-3 => Energy compression system (chicane + RF cav) should be considered… ?

PIAVE Superconducting RFQ

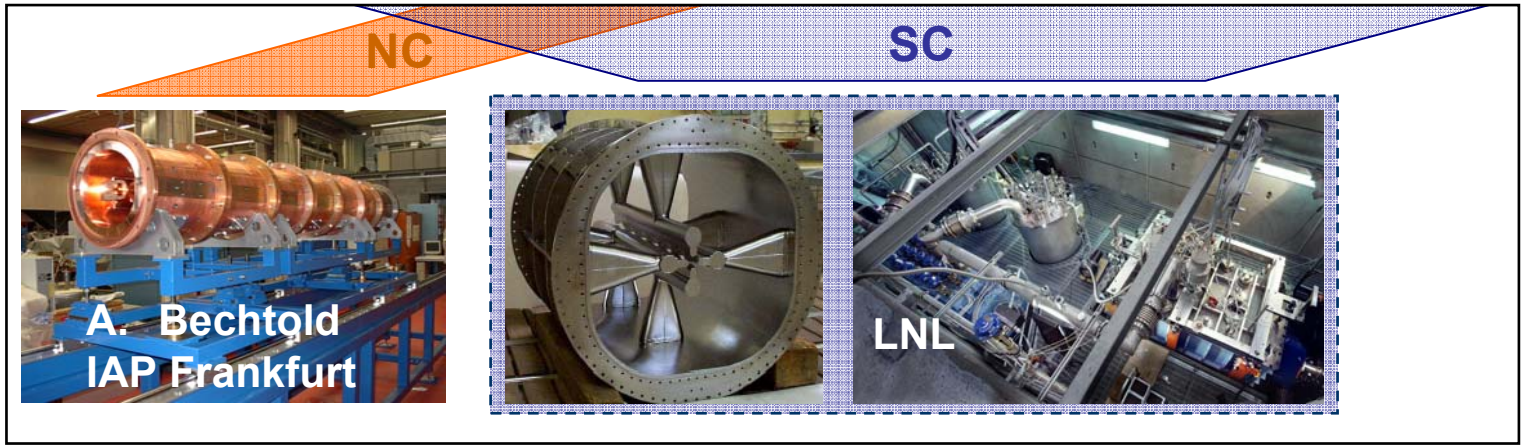
The superconducting RFQs in LNL are now in operation on the PIAVE injector
Some beam parameter measurements have been performed

	SRFQ 1		SRFQ 2	
	in	out	in	out
Energy (keV / u)	**37.1**	**351.3**	**351.3**	**585.4**
Voltage (kV)	148	148	280	280
Length (cm)	138.9		74.4	
Ncell	43		13	
m	1.2	1.8	2.7	2.8
a (cm)	0.7	0.4	0.8	0.8
R0 (cm)	0.80		1.53	
Phis (deg)	-40.0	-18.0	-12.0	-12.0
Max surface Field (MV /m)	24.1		24	
Stored energy (J)	1.8		3.5	

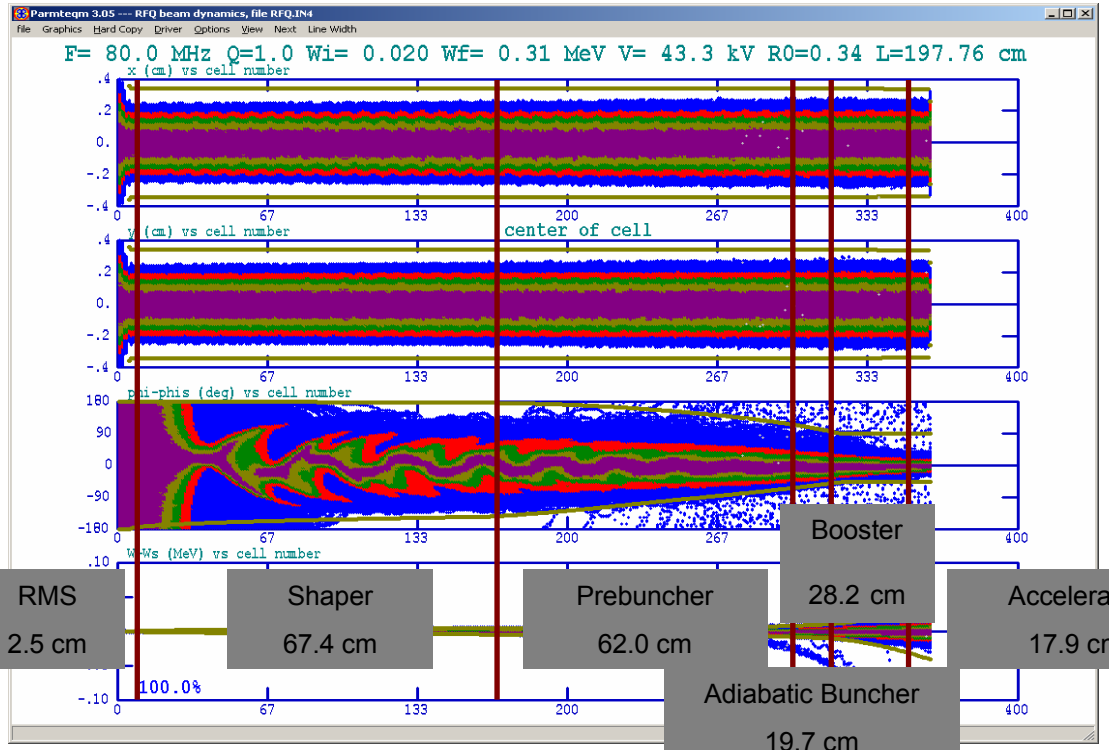


Transverse emittance measurement		
Energy at the end of PIAVE	ε_{norm} x RMS (mm.mrad)	ε_{norm} y RMS (mm.mrad)
0.58 MeV / u	0.100	0.103
1.2 MeV / u	0.200	0.125

Superconducting RFQ injector



350 → 20 kV Platform :
a 3rd RFQ in front is needed



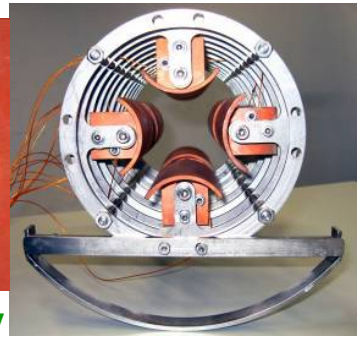
Envelopes of the new RFQ

Status of the MAFF RFQ test stand

LEBT tank on its frame

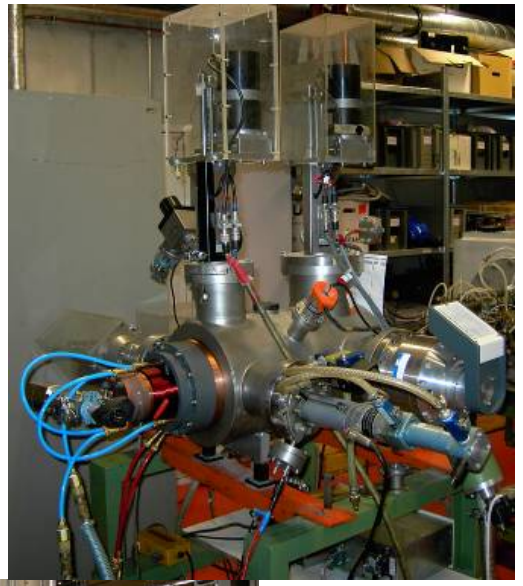
Steerer

Quads



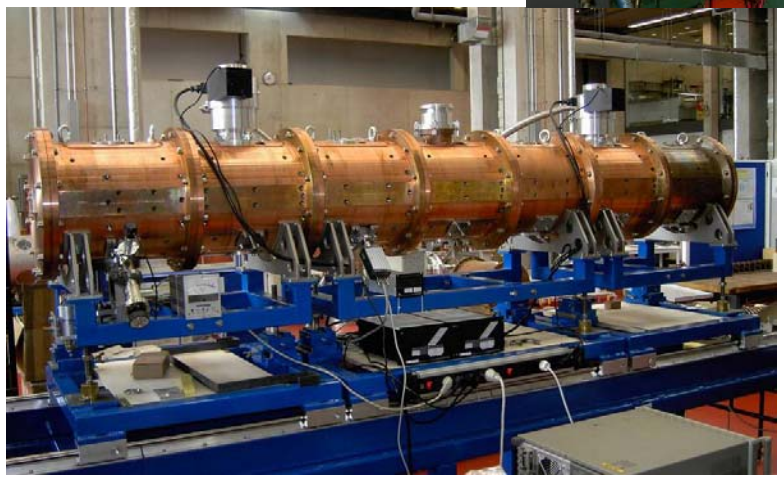
$U_{quad} \approx 3$ kV

Operation of the ion source



RFQ

length	3 m
frequency	104 MHz
m/q	≤ 6.3
Voltage	≤ 60 kV (9.5 kV *m/q)
Q-value	5750
Shunt impedance	168 kΩ*m
W_{in}	2.5 keV/u
W_{out}	300 keV/u



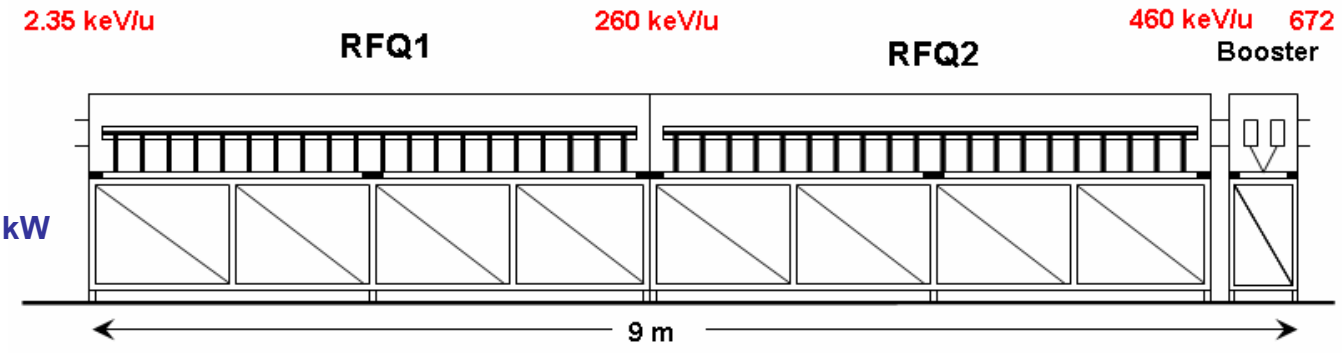
Vaccum tests of the RFQ have been performed:

pIH = 3.6 10-7 mbar

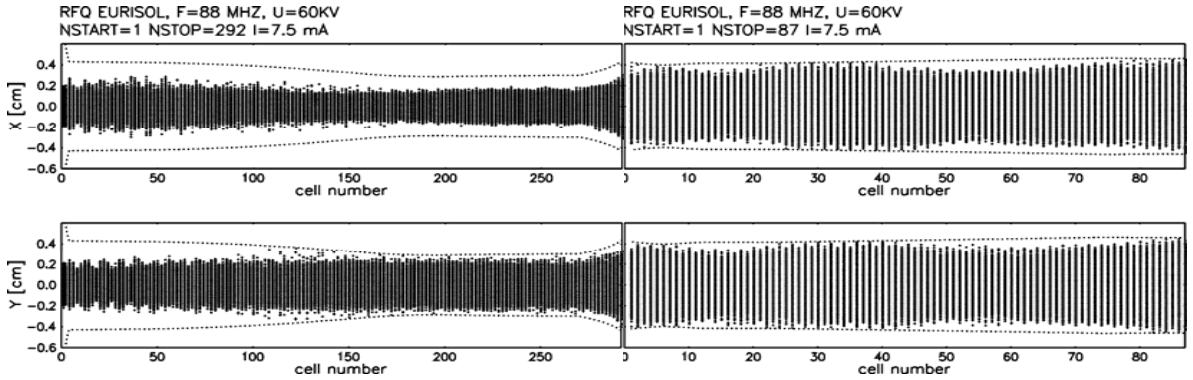
Normal conducting RFQ injector

A normal conducting RFQ tandem as injector into the SC linac

$V_{el,RFQ1}$ = 60 kV
Transm. = 100%
RF-power = 140 kW
length = 4 m



$V_{el,RFQ2}$ = 60 kV
Transm. = 100%
RF-power = 140 kW
length = 4 m



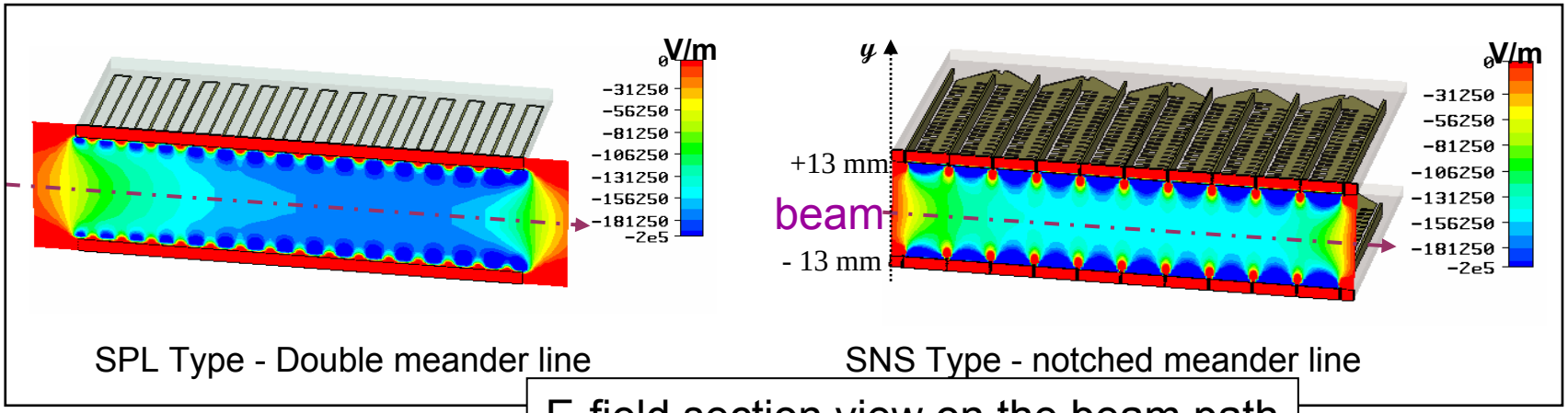
Bunch frequency required by the users: from 8.8 kHz to 8.8 MHz
(linac beam frequency = 88 MHz)

Fast chopper – β 0.04 adaptation

A careful study of the current fast choppers (SNS-LANL, SPL-CERN, ESS-FETS-RAL) has been performed.

Required parameters	
Deflecting section aperture	26 mm
Deflecting length	450 mm
Isolated bunch repetition rate	1:10 to 1:10000
Chopping pulse duration	96 ns to 0.12 ms
Pulse rise/fall time	**< 5 ns**

Simulations Results		
	SNS	SPL
Width [mm]	107	63.8
Medium plane E [kV] on the beam path (@± 2.5 kV)	150	170
Deflecting E-field @ DC Voltage	192 kV/m @ ± 2.5 kV	
Coverage factor	0.78	0.88



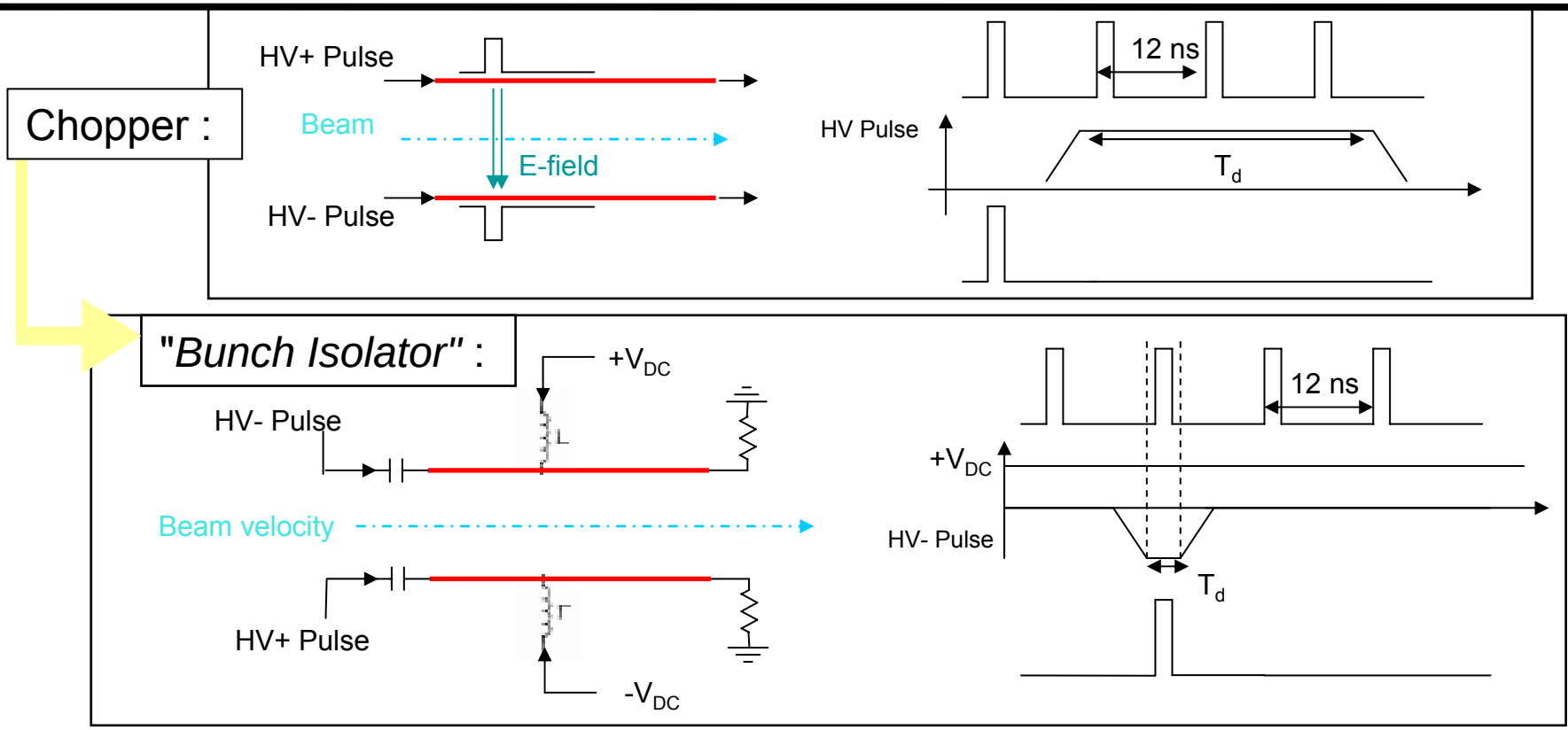
SPL Type - Double meander line

SNS Type - notched meander line

E-field section view on the beam path

Other solution: set of short capacitive electrodes

High frequency chopper



Isolated bunch repetition rate		1/10	1/100	1/1000	1/10000
Chopping pulse frequency		8.8 MHz	880 kHz	88 kHz	8.8 kHz
Chopping pulse duration (T_d) / Duty cycle	Chopper	96 ns / 80 %	1.18 us / 98 %	11.98 us / 99.8 %	119.98 us / 99.9 %
	Isolator	5 ns / (4.2 % - 0.42 % - 0.04% - 0.004 %)			

⇒The major limit is the pulse generator. A compromise will have to be found

Next Steps

- New linac design: beam dynamics to be performed into details (answer precisely to user requirements), cost study (safety constraints?)
- Beam characteristics to be confirmed by the beam preparation Task
- Detailed study of the strippers needed (technical, safety constraints)
- SC RFQ and NC RFQ: technical studies, cost comparison between both solutions
- High frequency chopper: Choose a solution type, prototyping of one of the electrodes set with the switches in the case of the capacitive electrodes, or the pulse generator in the case of the travelling wave structure.
- Diagnostics for RIB: to be started at the beginning of 2007 (problems with human resources)

Post-doc position for

- Beam dynamics calculation at GANIL-Caen-France
- RIB diagnostics development at LPC Caen-FRANCE