Beta Beams Options Studies

T.M. Mendonça, T. Stora, E. Wildner

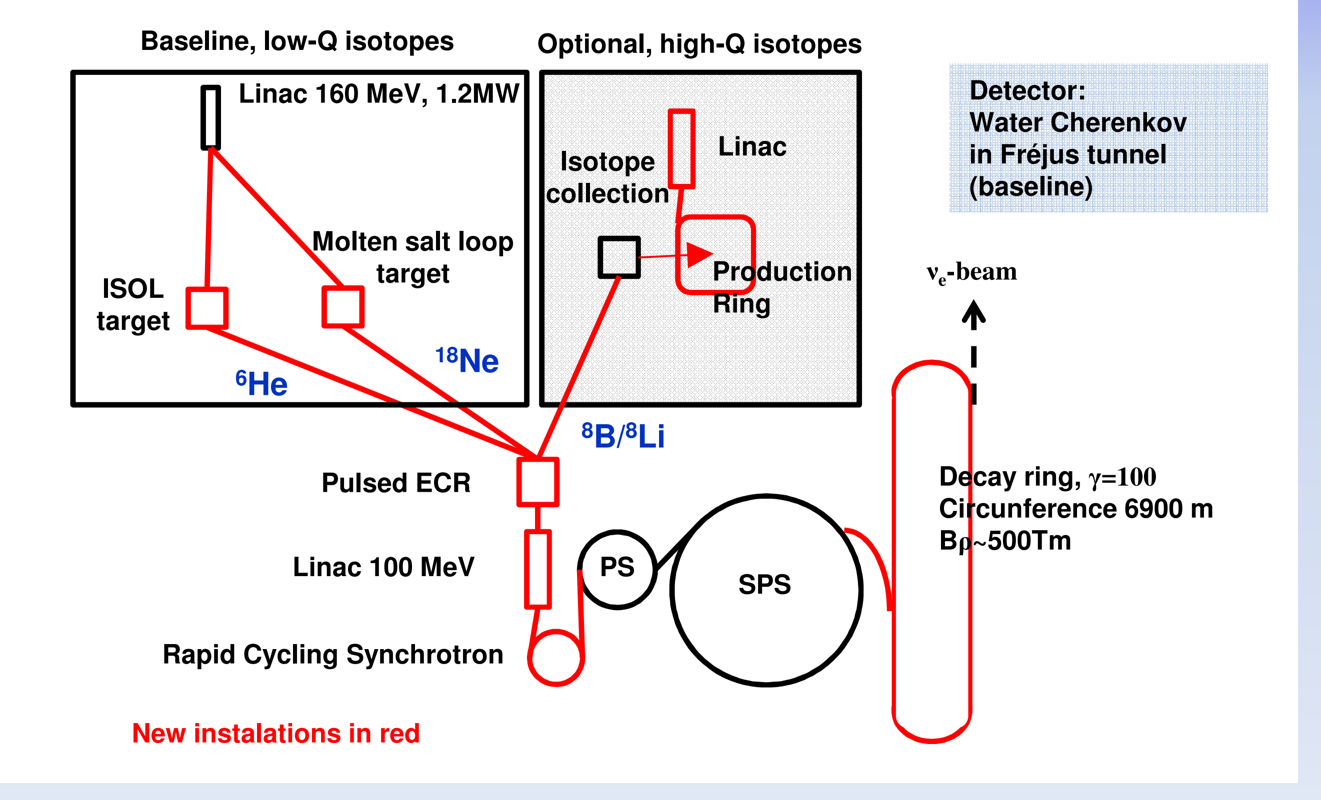
Outline

- General concept
- Layout of the facility
- Physics reach
- Motivation and challenges

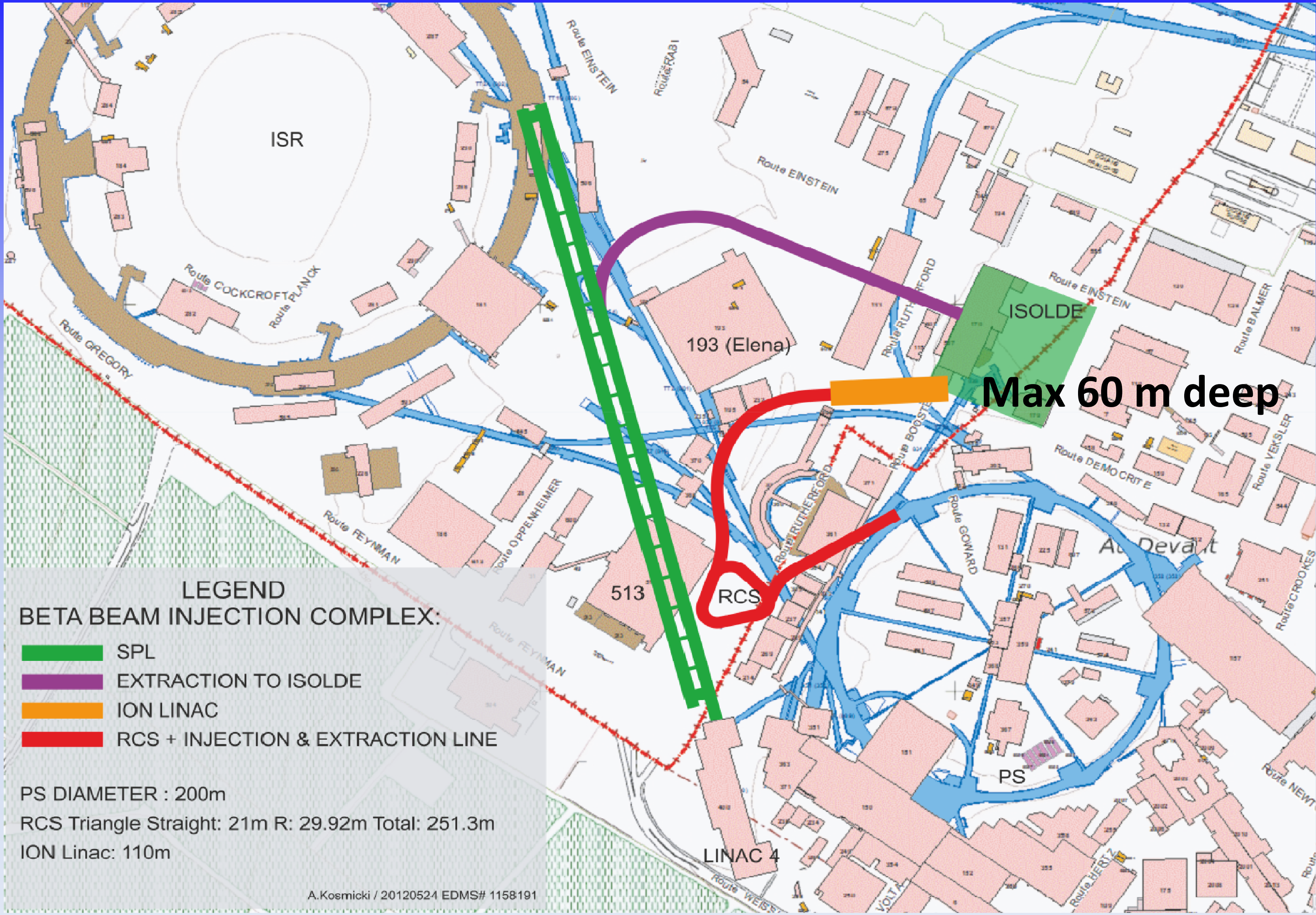
- Recent results:
  - production of baseline ions
  - production of high Q ions
  - Ion source
  - acceleration
  - decay ring

The Beta Beams Concept

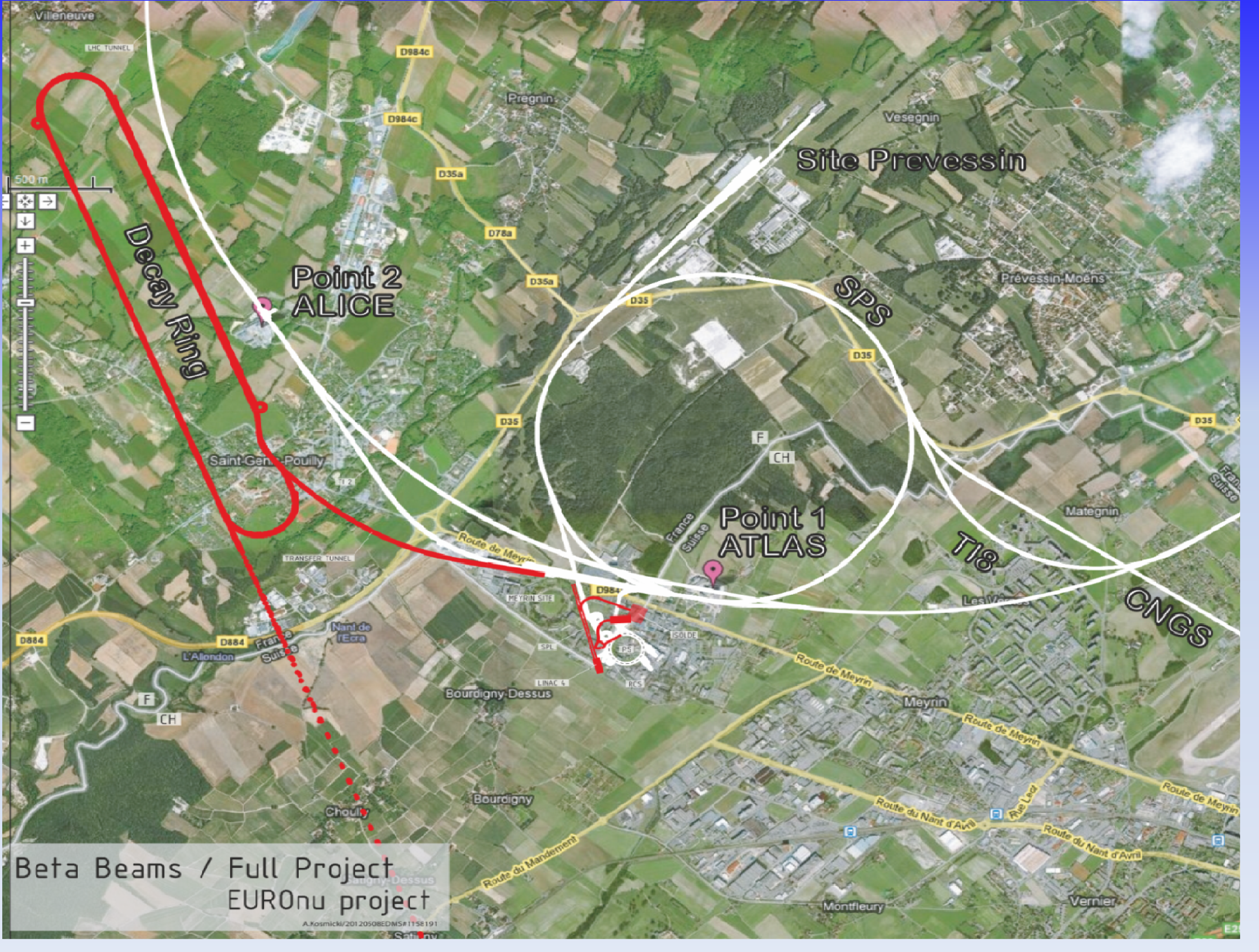
- Aim: Production of pure (anti)-ν_e beams by storing β emitting ions in a decay ring
- Accelerate ions to relativistic γ_{max}
- Use of existing CERN machines and infrastructures



The Beta Beams

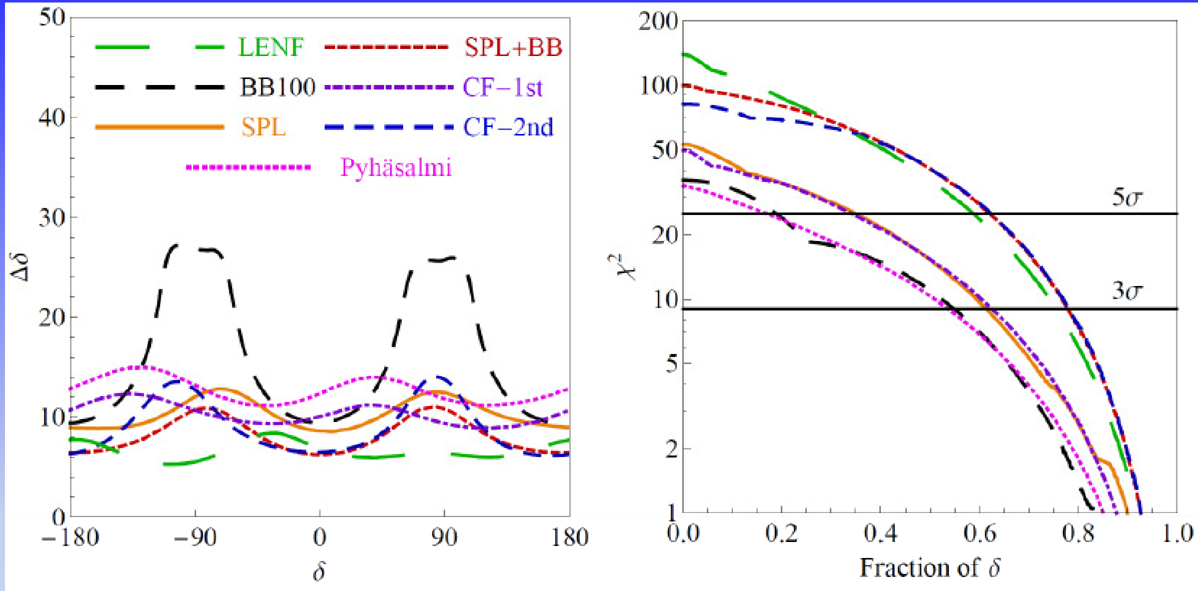


Decay Ring, Beta Beams



Physics reach from Euronu

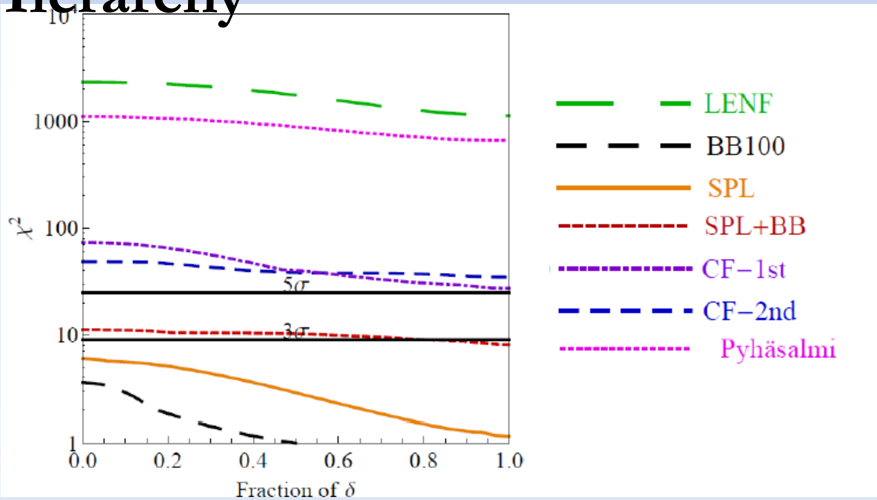
Precision and CP violation



-SPL+BB at Frejus is competitive

- For large values of θ13, measurement of δ is very dependent on assumed systematics

Hierarchy



Baselines larger than Frejus reach 5 σ

P. Coloma, E. Fernández-Martínez

Motivation & Challenges

- ➢ Choice of radioactive ions: noble gases as best candidates –
  - $^{6}He/^{18}Ne$ baseline ions
  - Optional scenario: high-Q $^{8}B/^{8}Li$
- ➢ Use of existing infrastructures and technology at CERN
- ➢ γ boost limited: upgrade of existing machines
- ➢ Decay ring size limited: cost related
- ➢ High intensities in the accelerators

Main activities

- ❖ Production of high intensities of radioactive ions
- ❖ Ion collection and source
- ❖ Stability of high intensity beams through the accelerator complex
- ❖ Losses and radiation management

Choice of radioactive ions

- Half-life
- Noble gases: chemical stability
- Charge-to-mass ratio for efficient acceleration
- $^{6}He/^{18}Ne$ baseline ions

  Optional scenario: high-Q $^{8}B/^{8}Li$

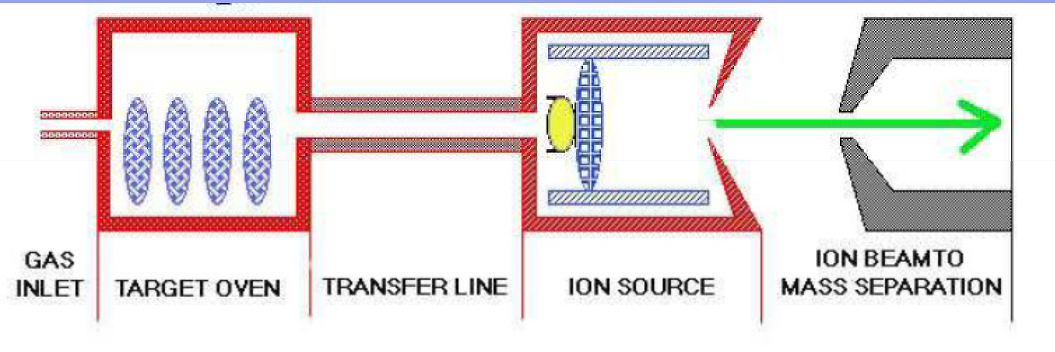
Isotope	**^{6}He**	**^{18}Ne**	**^{8}Li**	**^{8}B**
Prod.	ISOL(n)	ISOL	P-Ring	P-Ring
Beam	SPL(p)	Linac4(p)	d	^{3}He
I [mA]	0.07	7	0.160	0.160
E [MeV]	2000	160	25	25
P [kW]	140	1120	4	4
Target	W/BeO	^{23}Na, ^{19}F	^{7}Li	^{6}Li
r [10^{13}/s]	5	1	0.1	0.08

Baseline low-Q isotopes

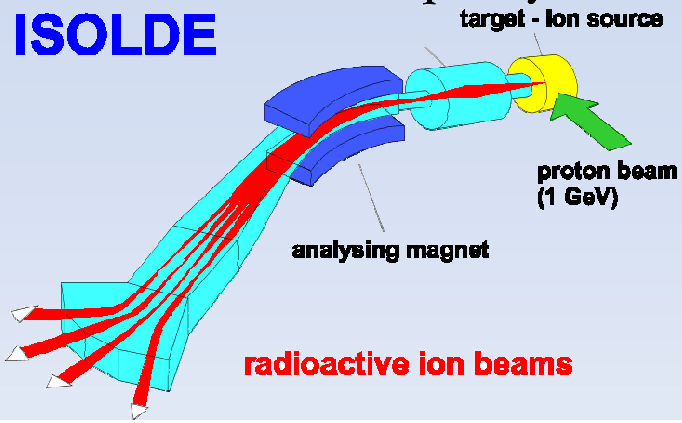
Baseline ions: ^{6}He ($T_{1/2}$=0.8 s, $Q_{\beta-}$=3.5 MeV) and ^{18}Ne ($T_{1/2}$=1.67 s, $Q_{\beta-}$ =3.3 MeV)
Production of anti- ν_e and ν_e:
3(.3)x10^{13} ^{6}He/s and 2(.1)x10^{13} ^{18}Ne/s out of the primary target
(Final report, FP6 EURISOL-DS)

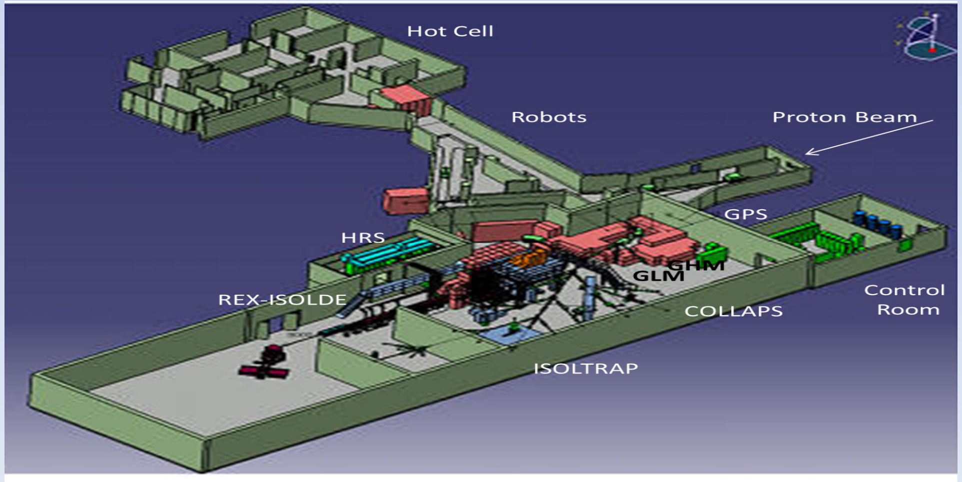
Production of radioactive ion beams based on the ISOL technique

Primary beam (MeV/u-GeV/u)



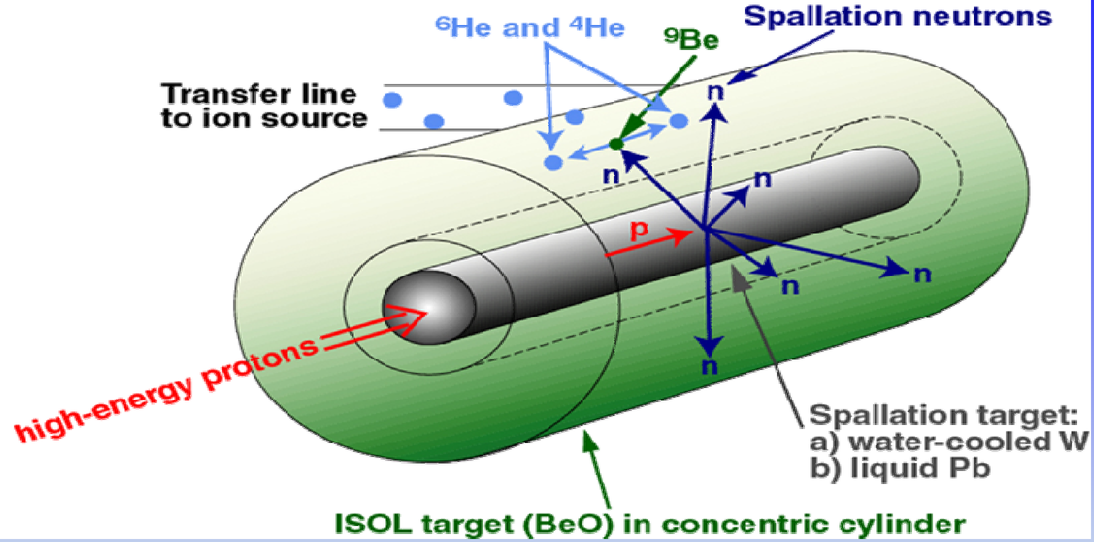
ISOL method: higher intensities and better beam quality

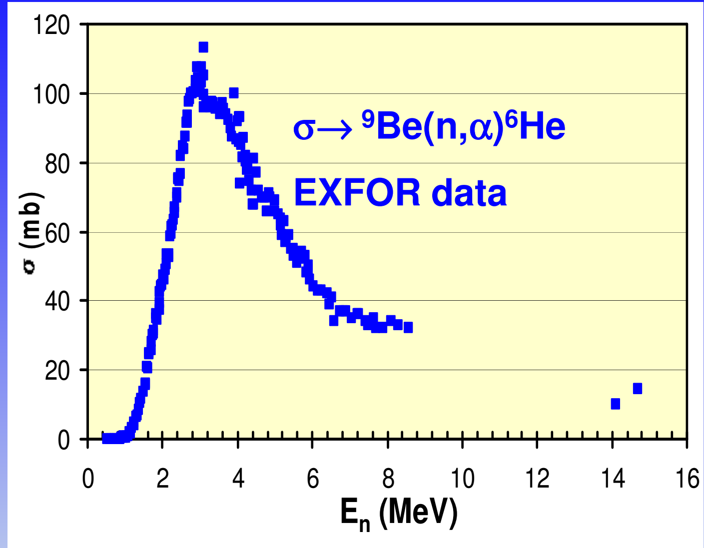




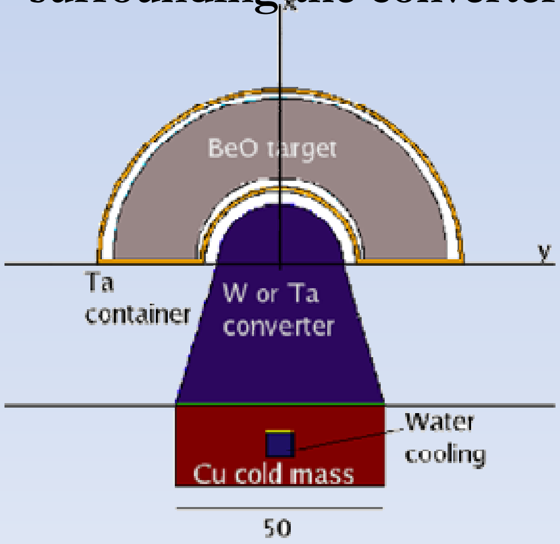
Production of ^{6}He using beryllium oxide target

Reaction: $^{9}Be(n,\alpha)^{6}He$



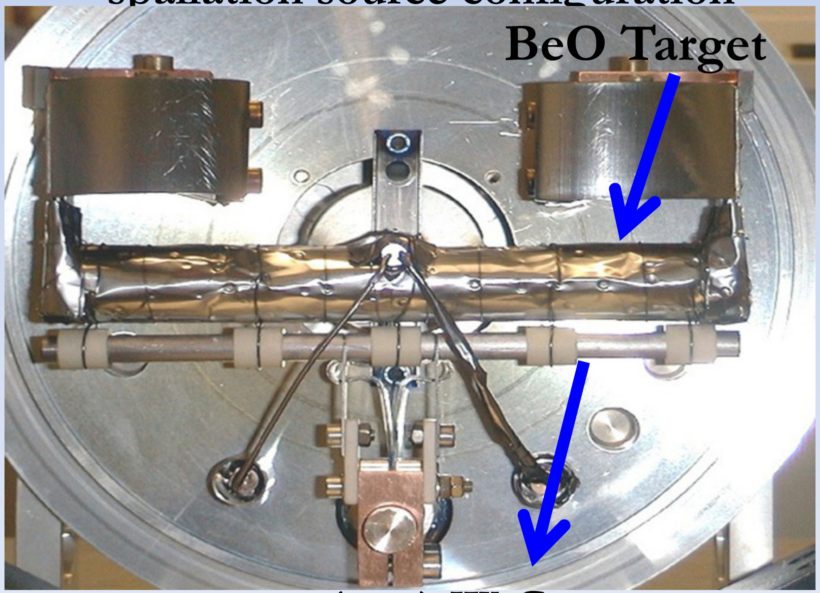


Optimized geometry: target surrounding the converter



p (1.4 GeV) →

Standard ISOLDE target and spallation source configuration



(p-n) W Converter

T. Stora et al., EURISOL-DS, TN03-25-2006-0003

High intensity ^{6}He beams at ISOLDE

Release efficiency (**>85% released**)

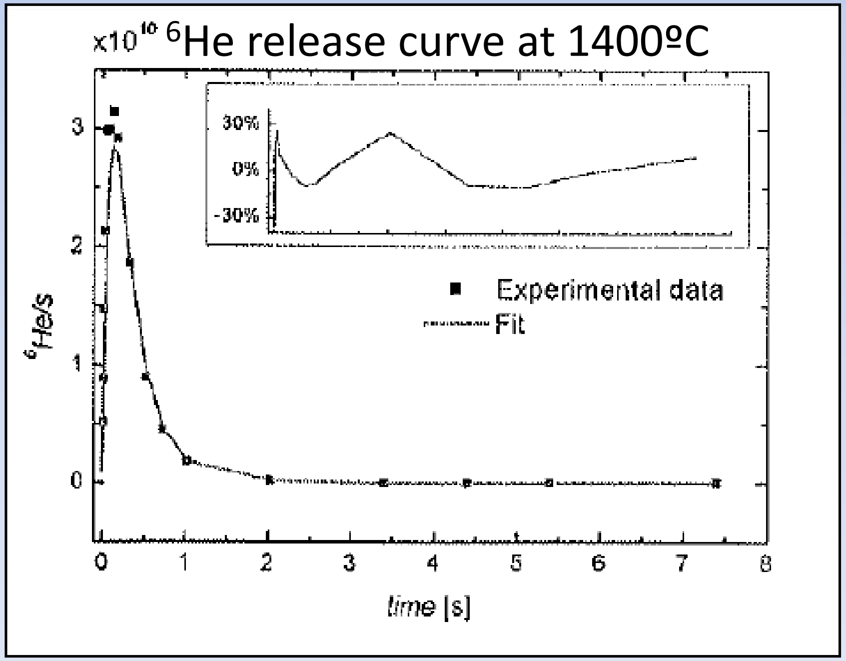
Release curve provides additional information on performance of target and ion source unit

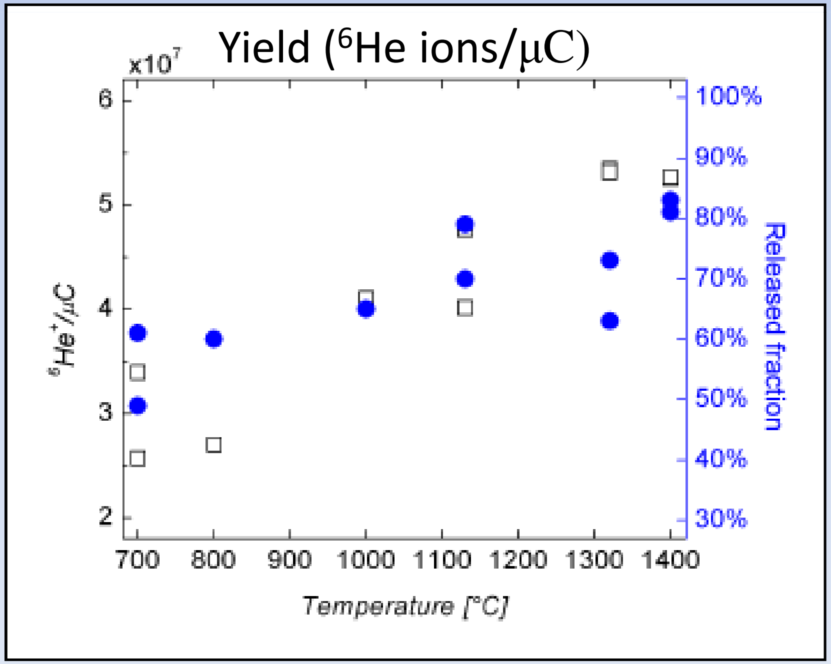
Yield determination requires measurement of entire release curve

In target rates:

- ❖ 1.3×10^{13} ^{6}He/s 100kW, 40 MeV deuteron beam
- ❖ **2×10^{13} ^{6}He/s 100kW, 1 GeV proton beam**
- ❖ 1×10^{14} ^{6}He/s 200kW, 2 GeV proton beam

M. Hass et al., J. Phys. G 35, 014042 (2008)
T. Hirsch et al. PoS (NuFact08) 090



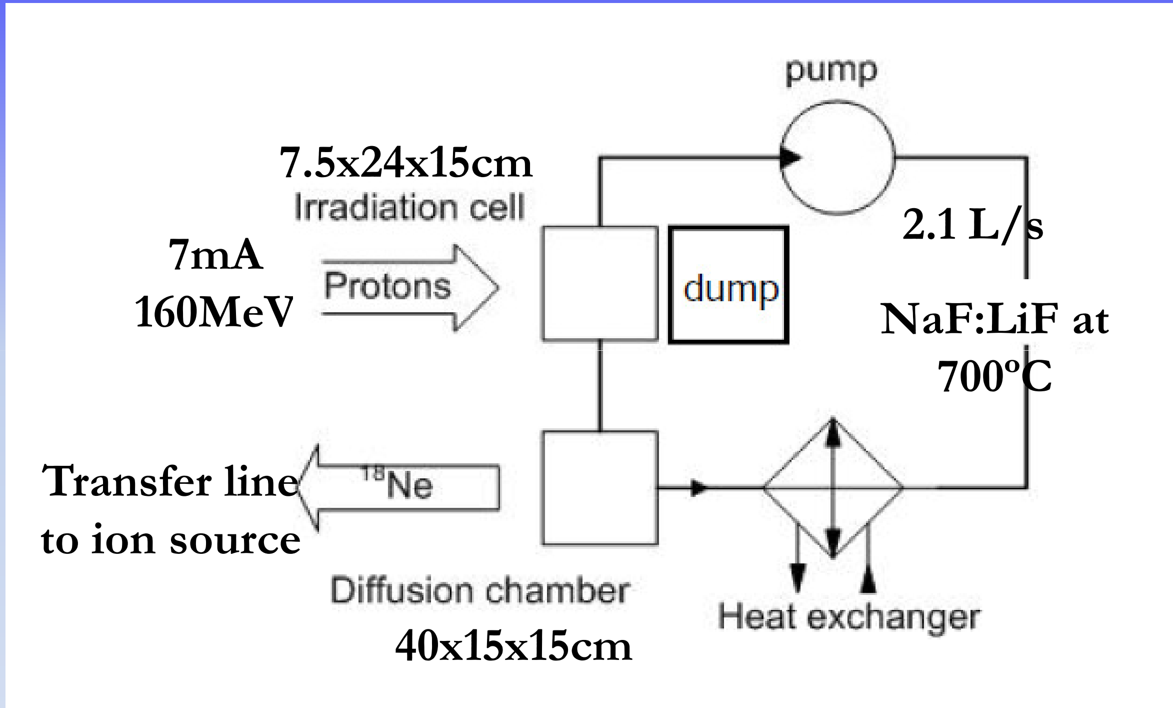


T. Stora et al., Eur. Phys. Lett. 98 (3), 32001 (2012)

Production of ^{18}Ne using molten salts: NaF:LiF

Reactions: $^{23}Na(p,X)^{18}Ne$, $^{19}F(p,2n)^{18}Ne$

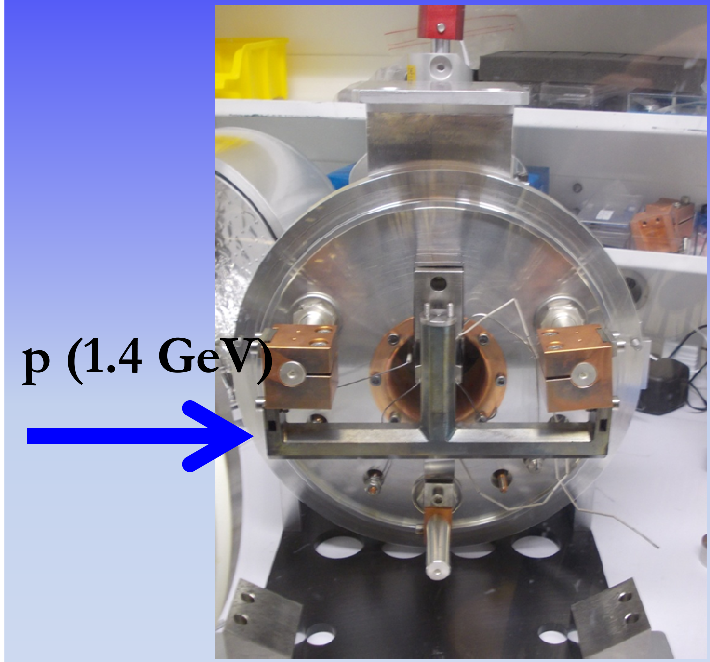
A proposal inspired from ^{18}F production for PET imaging



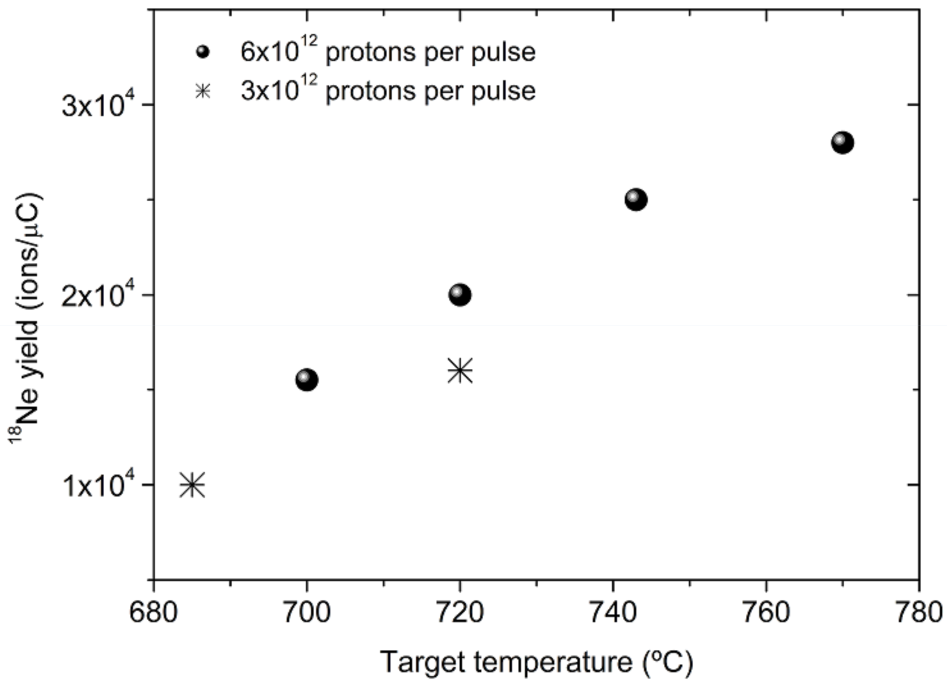
Salt	Composition [mol %]	Melting point [ºC]	Density [g/cm3] (700 ºC)	Vapor pressure [mmHg](900ºC)	Yield protons 7mA 160MeV (ions/s)
NaF-LiF	61-39	**649**	2.59	0.1	**1.0E+013**

^{18}Ne production validation at ISOLDE

ISOLDE target unit
Improved geometry for NaF:LiF molten salt



Online tests using static unit at ISOLDE:



NaF:LiF target successfully tested at ISOLDE

2.8×10^4 ^{18}Ne/uC with 6×10^{12} ppp

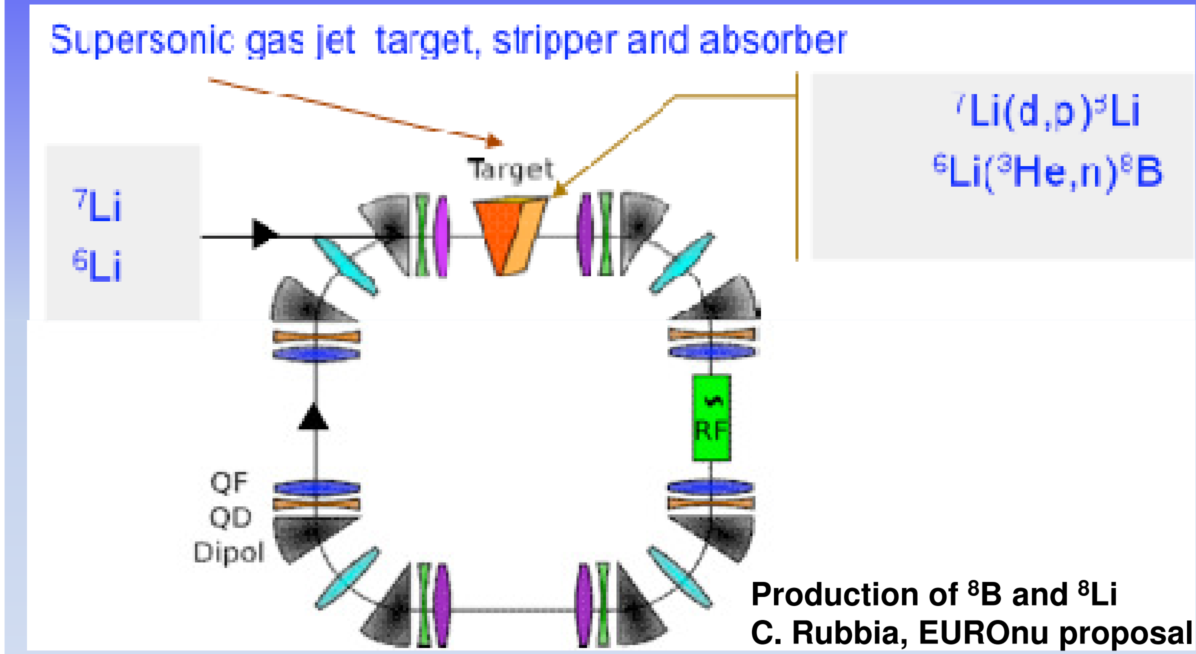
Data analysis ongoing

High-Q isotopes: $^{8}B/^{8}Li$

Production of $^{8}B/^{8}Li$ using a compact ring

25 MeV Li beam interacts with gas-jet target (D or ^{3}He) – inverse kinematics

Collection device to stop and transport ions to ECR ion source



Production of ^{8}B and ^{8}Li
C. Rubbia, EUROnu proposal

Gas jet target:

- too high density would be needed (10^{19} atoms/cm^{2})
- vacuum problems

Alternative – use of solid or liquid target in direct kinematics

feasibility under study

60 GHz ECR Ion Source

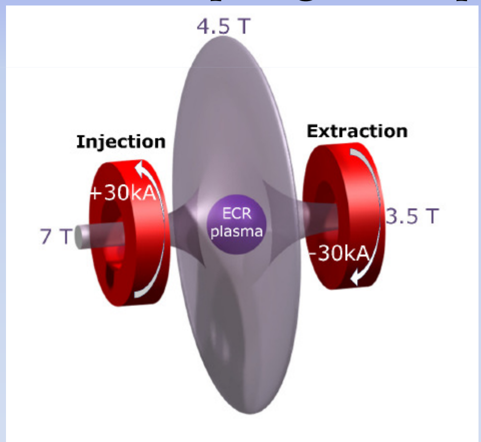
T. Lamy, M. Marie-Jeanne, P. Balint, C. Fourel, J. Giraud, J. Jacob, L. Latrasse, P. Sortais,
T. Thuillier, F. Debray, C. Trophime, S. Veys, C. Daversin, V. Zorin, I. Isotov, V. Skalyga

$5x10^{13}$ atoms.s^{-1} from the target (cw)

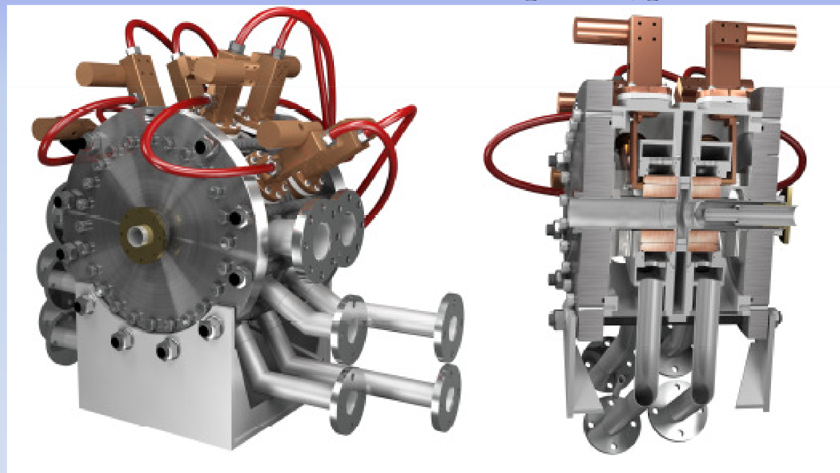
- High ionization efficiencies
- RCS cycle 10 Hz – 50 μs

16 mA $^{6}He+$ bunches to be extracted every 100 ms

SEISM cusp magnetic trap



3D view of SEISM prototype



- Mechanical design and optimization of the magnetic structure prototype
- Measurement of magnetic field map
- Experiments at 28 GHz (end of summer 2012)

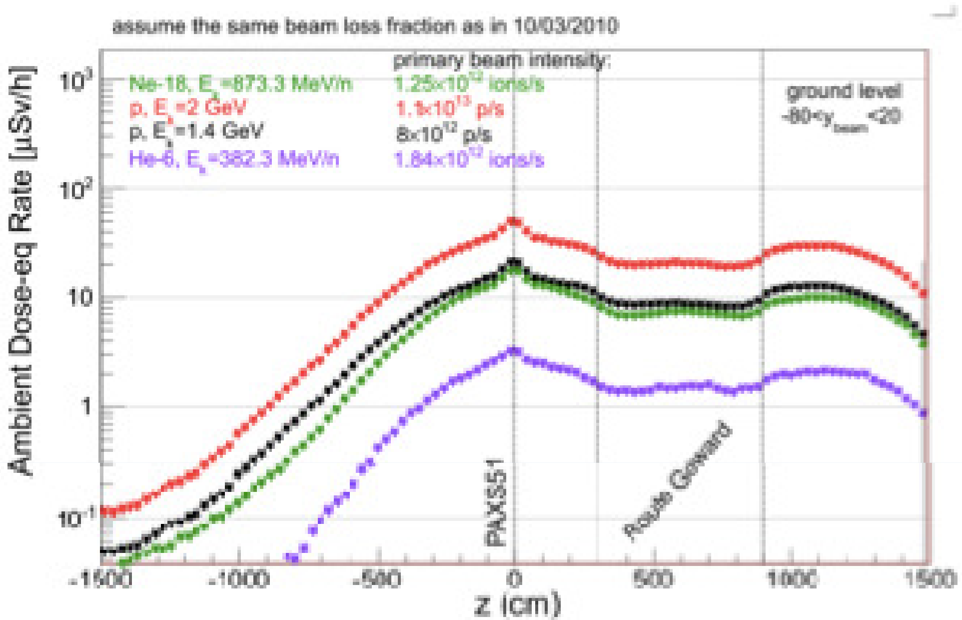
PS and SPS

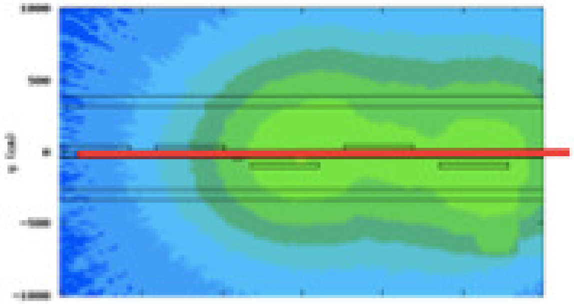
E. Benedetto, C. Hansen, E. Wildner

- ✓ Losses dominated by decay
- ✓ Losses due to charge-exchange are negligible
- ✓ Cross-sections for electron capture are very small
- ✓ Same order of magnitude as CNGS – No show-stopper for the project
- ✓ Tune scans in PS
- ✓ ^{6}He will survive, ^{18}Ne needs resonance compensation (PS)
- ✓ Studies on head-tail needed in the PS and the SPS

Radiation studies

Ambient Dose-Eq Rate [µSv/h] above the Ground Level





Dose Rates extracted assuming the same relative beam loss as of 10/03/2010 when 6µSv/h was measured by PAXS51

values at PAXS51:

Ne-18, Ek=873.3 MeV/n:	17 µSv/h
He-6, Ek=382.3 MeV/n :	3 µSv/h
p, E_k=2 GeV:	49 µSv/h
p, E_k=1.4 GeV:	21 µSv/h

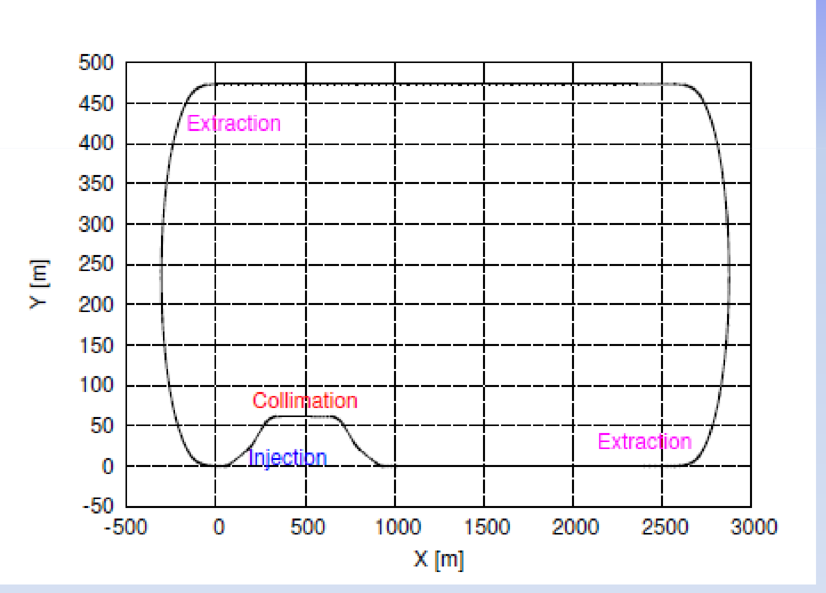
for the full proton beam intensities of 8×10^{12}p/s (E_k=1.4 GeV) and 1.1×10^{13}p/s (E_k=2 GeV) Dose Rates highest for the proton beams than for the beta beams.

Dose Rates higher by factors of 2.3, 3, 16 for p E_k=2 GeV beam losses compared to H-proton E_k=1.4 GeV, Ne-18 and He-6, resp.

Decay ring

A. Chancé. G. Burt, C. Hansen, E. Wildner

- Huge intensities must be stored in the DR
- Collective and head-tail effects are one of the main issues
- Some ways to mitigate head-tail effects were studied without success
- A beta beams with larger suppression factor could be the key by relaxing the peak intensities in the DR



- Open mid-plane magnets adopted
- Injection moved from the arcs to one of long-straight sections
- Optics suited for $^{6}He^{2+}$, $^{18}Ne^{10+}$, $^{8}Li^{3+}$ and $^{8}B^{5+}$ ions

Outlook

- Many progresses in the last years
- Production of required rates of ^{6}He validated
- Validation of molten salts on production of ^{18}Ne
  required intensities to be verified with molten salt loop
- Direct kinematics under study for $^{8}B/^{8}Li$

- 60 GHz ECR ion source prototype: experimental validation at 28GHz for summer 2012
- Radiation studies show effective doses lower for beta beams than for protons

Thank you for the attention!