Ion production for the betabeams

Thierry.Stora@cern.ch
ISOLDE Target and Ion source team

Beta beams : 1st concept

EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

30-6-2001

A novel concept for a $\overline{\nu}_e$ neutrino factory

P. Zucchelli [1)]
CERN, Geneva, Switzerland

6 Acknowledgements
The author is indebted to T. Nilsson, J. Panman and B. Saitta for their attention, comments and suggestions.

References
[1] T. Nilsson, Private communication.
[2] H. L. Ravn, Sources for Production of Radioactive Ion Beams, IEEE PAC95 proceedings, p. 858.
[3] J. Lettry et al., Pulse shape of the ISOLDE radioactive ion beams, Nucl.Instr.Meth. B126 (1997) 130. Numbers updated according to T. Nilsson, private communication.

ISOLDE was already there

PS/OP/Note 2002-181

The acceleration and storage of radioactive ions for a neutrino factory

The beta-beam accelerator working group: B. Autin, M. Benedikt, M. Grieser, S. Hancock, H. Haseroth, A. Jansson, U. Köster, M. Lindroos*, S. Russenschuck and F. Wenander

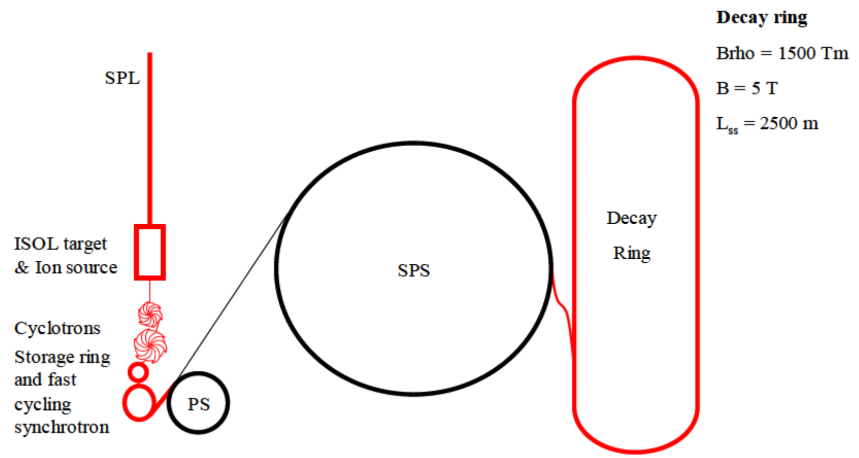


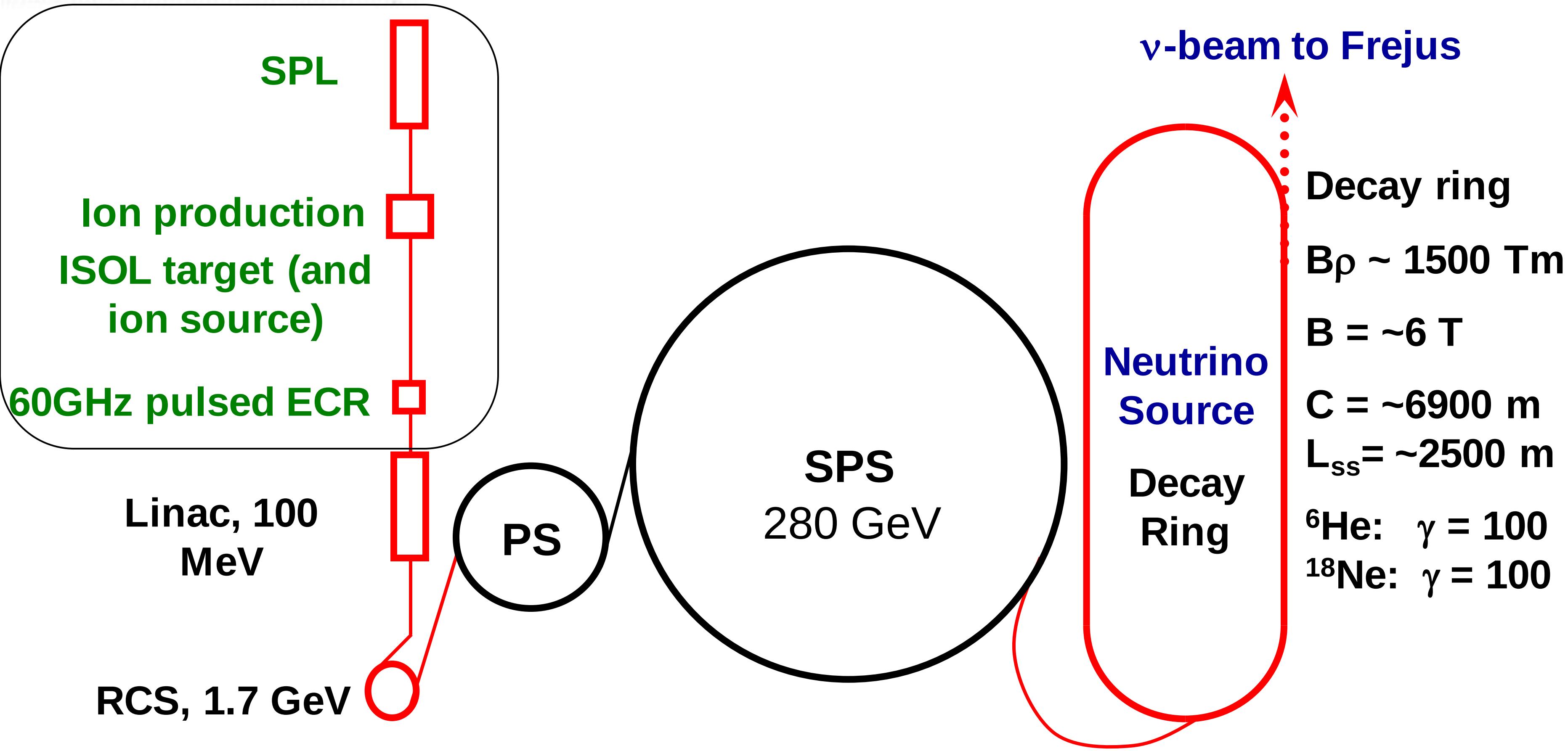
Figure 1: The CERN baseline scenario

10 years ago

Baseline scenario

be exploited to its fullest. The estimated intensities from an EURISOL-type target station of the required ions, ^{6}He and ^{18}Ne, would be sufficient for a beta-beam facility.

Beta Beam baseline (FP6 EURISOL-DS)



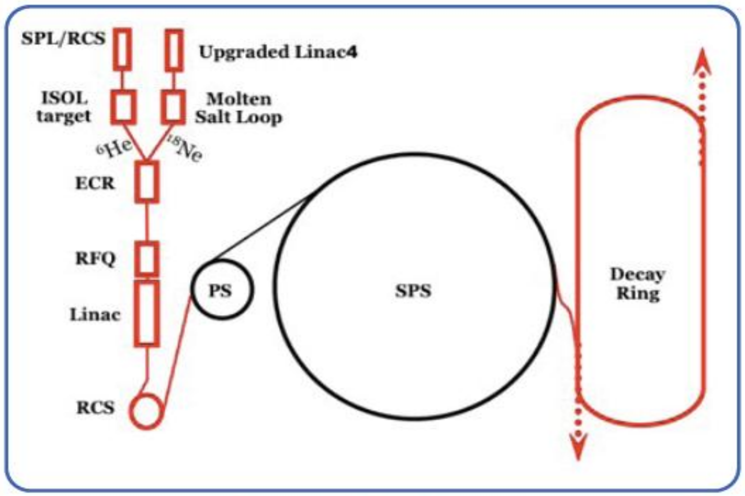
2-6 years ago

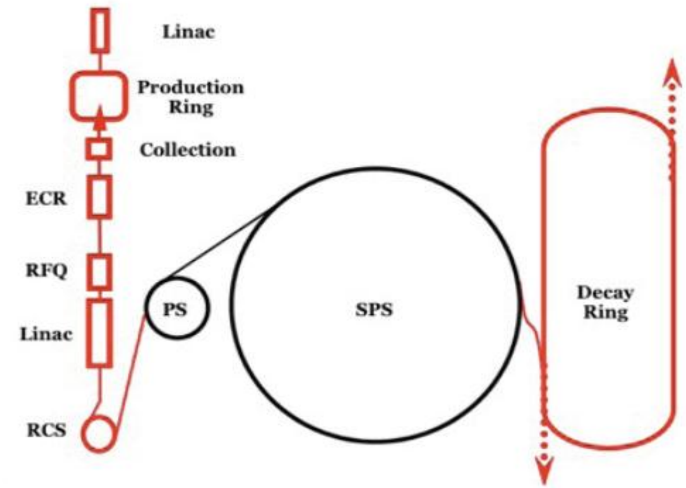
EPJ A 47, 24 (2011)

Two Baselines

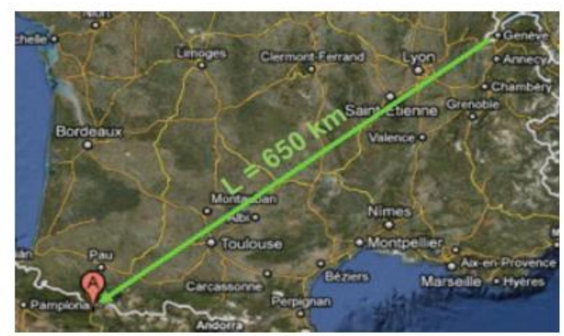
BB OVERVIEW

- **Currently two different baselines** (both with γ=100) **are under investigation**
- **^{6}He & ^{18}Ne: L ≈ 130 km**
- **^{8}Li & ^{8}B: L ≈ 650 km**





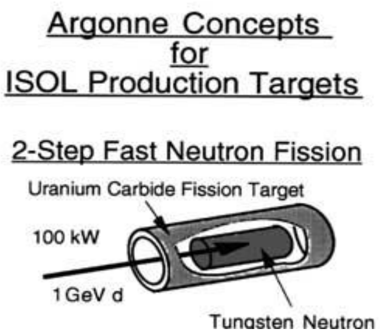
Chosen as EURONu's baseline



25 minutes ago !

C. Hansen

Production of ^{6}He

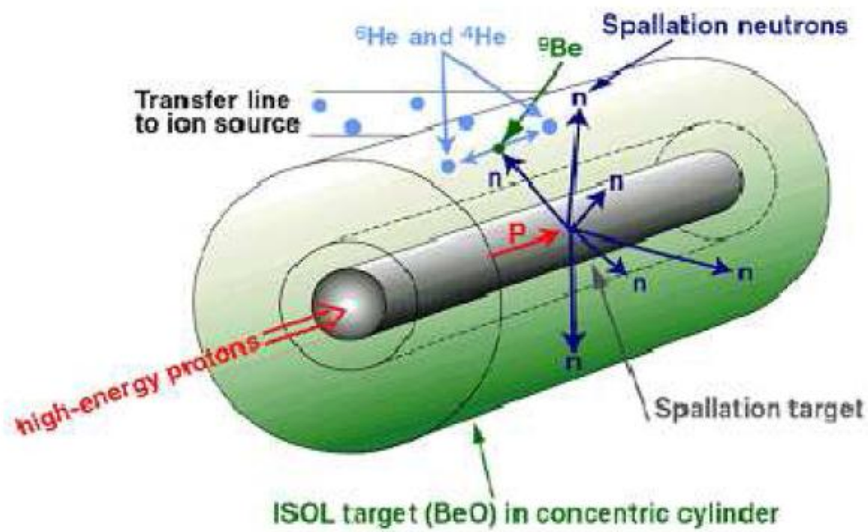


Original idea,
J. Nolen (1995/2002)

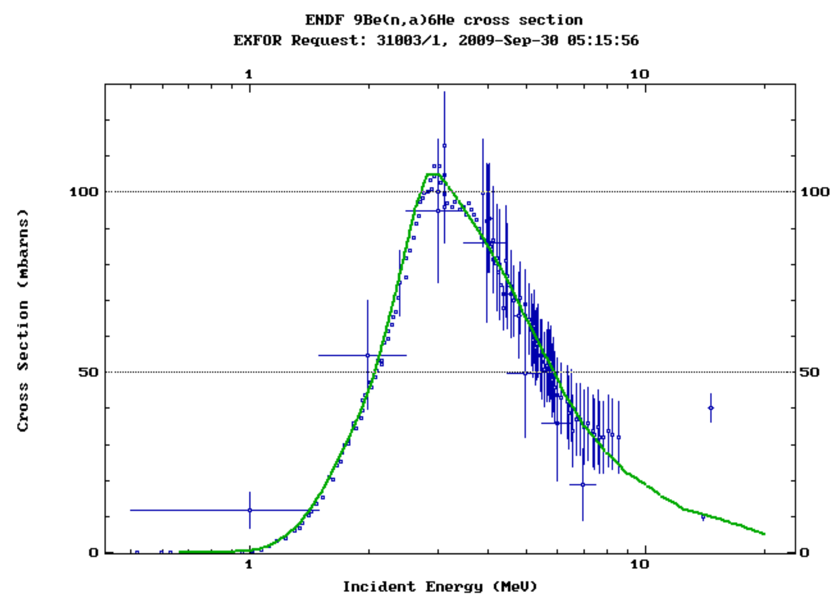
$^{9}Be(n,\alpha)^{6}He$

2.9 10^{19} $\overline{\nu e}$

(6 10^{13} ^{6}He/s out of target for 2 yrs)



EURISOL RTD report (2003)

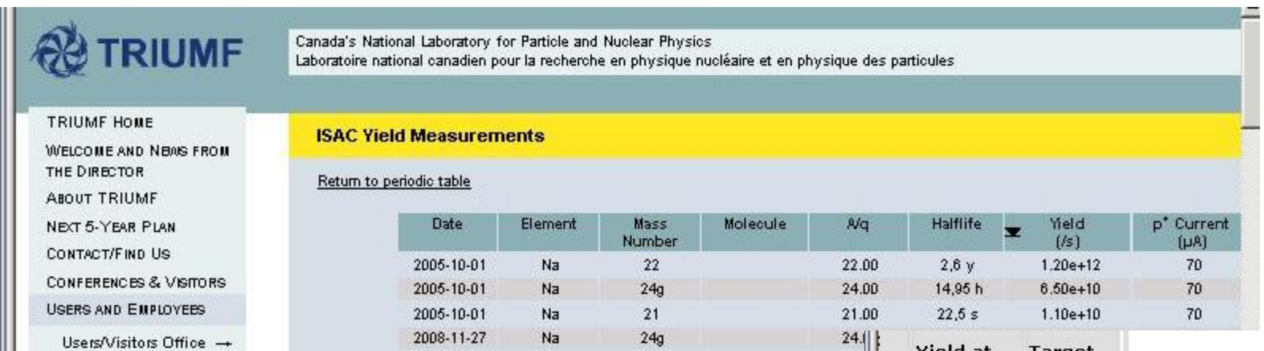


ENDF/EXFOR cross sections

How does 10^{13} isotope/s compare to present figures in ISOL facilities ?

Beams of **10^{12} ions**/s are documented at TRIUMF and CERN-ISOLDE

This corresponds to ~**10^{13}/s (neutral)** isotopes from target


TRIUMF
Canada's National Laboratory for Particle and Nuclear Physics
Laboratoire national canadien pour la recherche en physique nucléaire et en physique des particules

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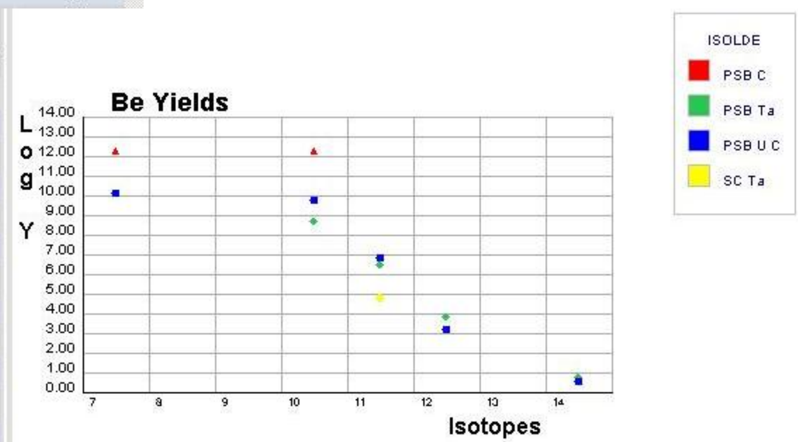
ISAC Yield Measurements

Return to periodic table

Date	Element	Mass Number	Molecule	A/q	Halflife	Yield (/s)	p⁺ Current (μA)
2005-10-01	Na	22		22.00	2,6 y	1.20e+12	70
2005-10-01	Na	24g		24.00	14,95 h	6.50e+10	70
2005-10-01	Na	21		21.00	22,5 s	1.10e+10	70
2008-11-27	Na	24g		24.[illegible]			

15% post acceleration eff. in 2005

B*	Yield at ISOLDE (ions/μC)	Target material
B	2.0E+12	C
B	1.4E+10	UC_x
B	2.0E+12	C
B	4.9E+08	Ta
B	6.0E+09	UC_x
B	3.4E+06	Ta
B	7.0E+06	UC_x
B	7.0E+03	Ta
B	1.5E+03	UC_x
B	6.1E+00	Ta
B	4.0E+00	UC_x



Post acceleration of multicharged isotopes

TRIUMF

acceleration of radioactive charge bred ions

2008 November 11

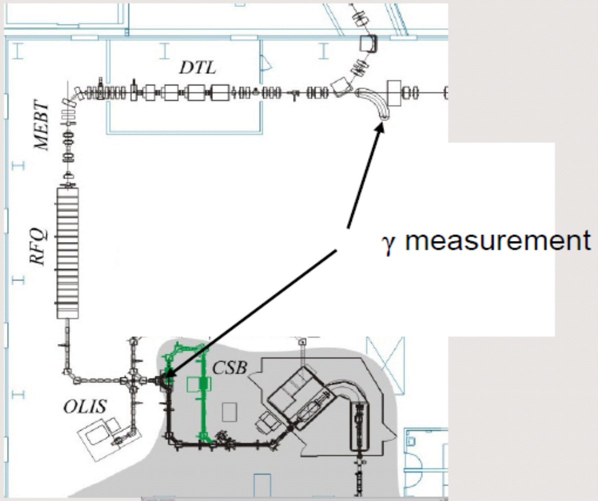
measure γ radiation of $^{80}Rb^{14+}$ after charge breeding
⇒1.1 10^5 ions per sec

radioactive beam is accompanied by ~100 nA $^{40}Ar^{7+}$

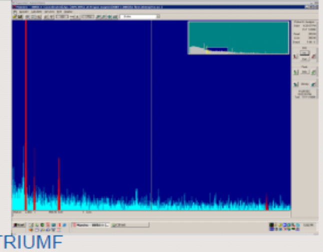
inject beam into RFQ,
accelerate to 150 A keV,
drift through DTL,
analyze energy with magnet

transmission for $^{40}Ar^{7+}$ 33%

measure γ radiation of $^{80}Rb^{14+}$ after acceleration
⇒3.5 10^4 ions per sec (32%)



γ spectrum
after acceleration



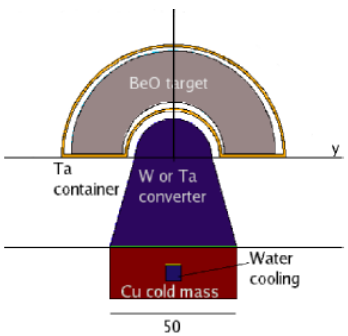
F. Almes, ECRIS 2010

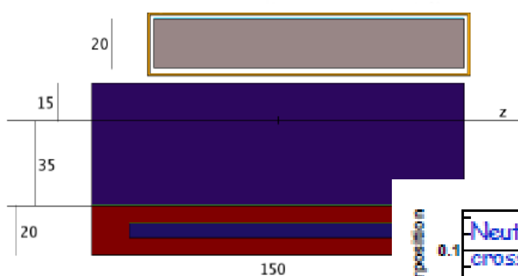
Optimization of ^{6}He production

MCNPx, N. Thiollieres et al., CEA (EURISOL-TN-03)

2 10^{13} ^{6}He/s 100kW, 1 GeV proton beam

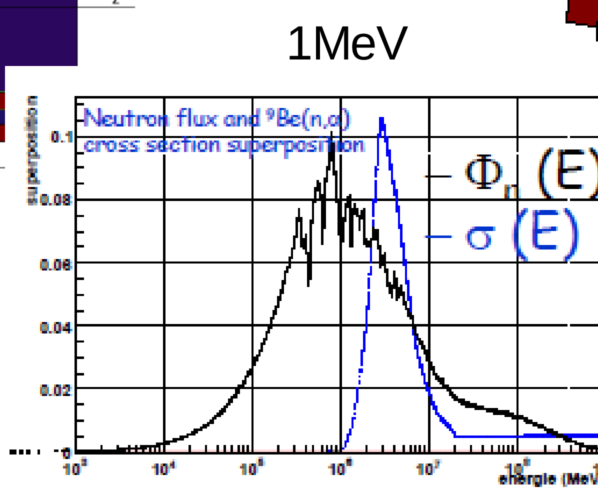
10^{14} ^{6}He/s 200kW, 2 GeV proton beam

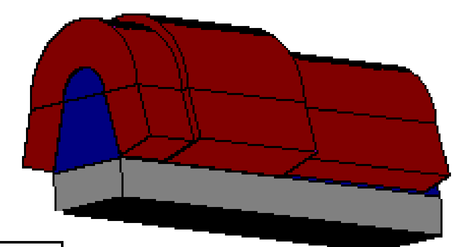




Ø3cm , 15cm

σ(beam)=6mm; d(BeO)=50%

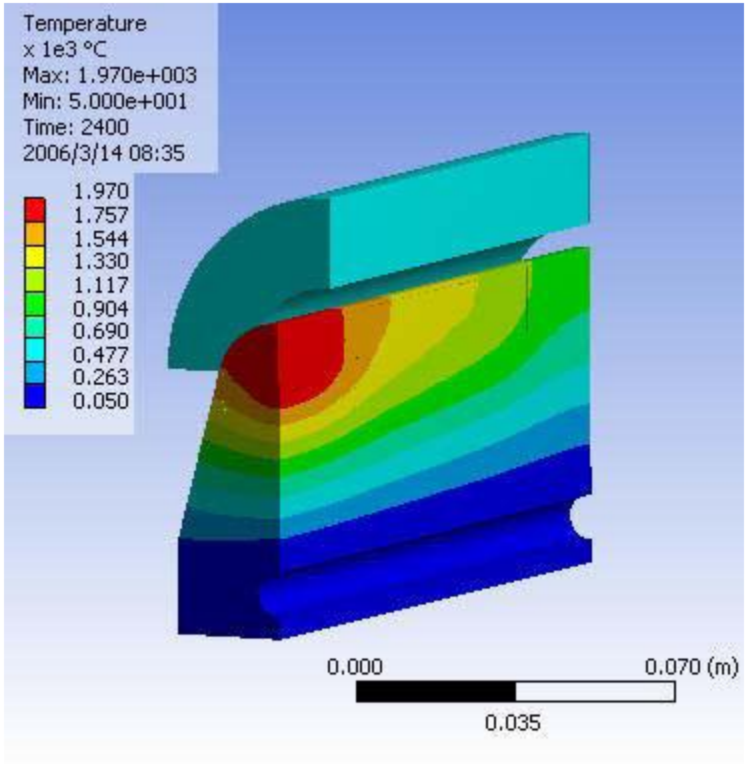


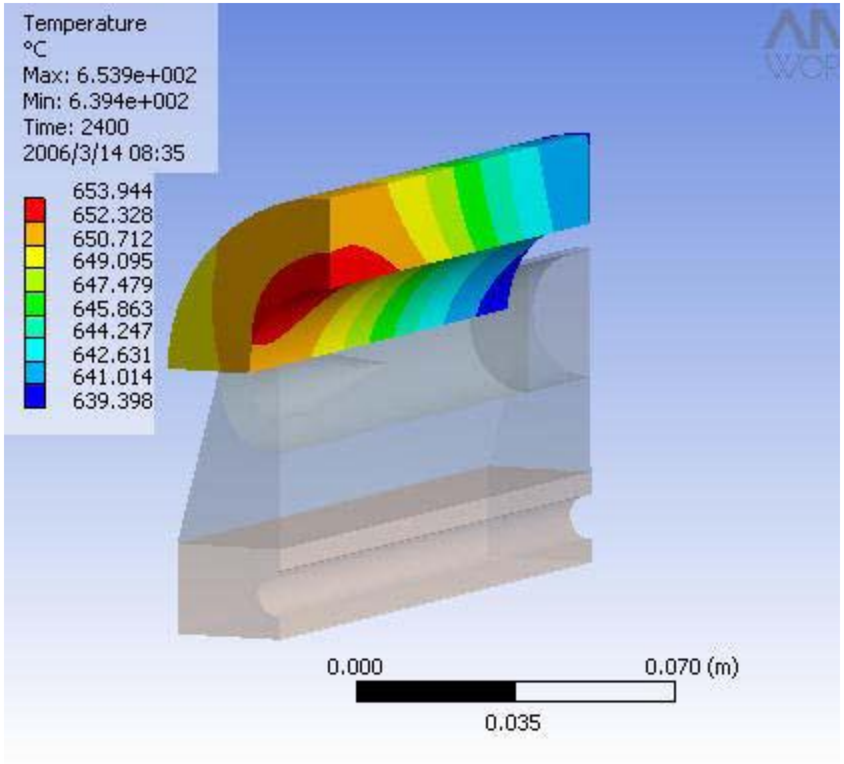


Optim. For 2GeV
Ø3cm , 24cm

Heat load on H_2O-cooled W conv.

35 kW deposited

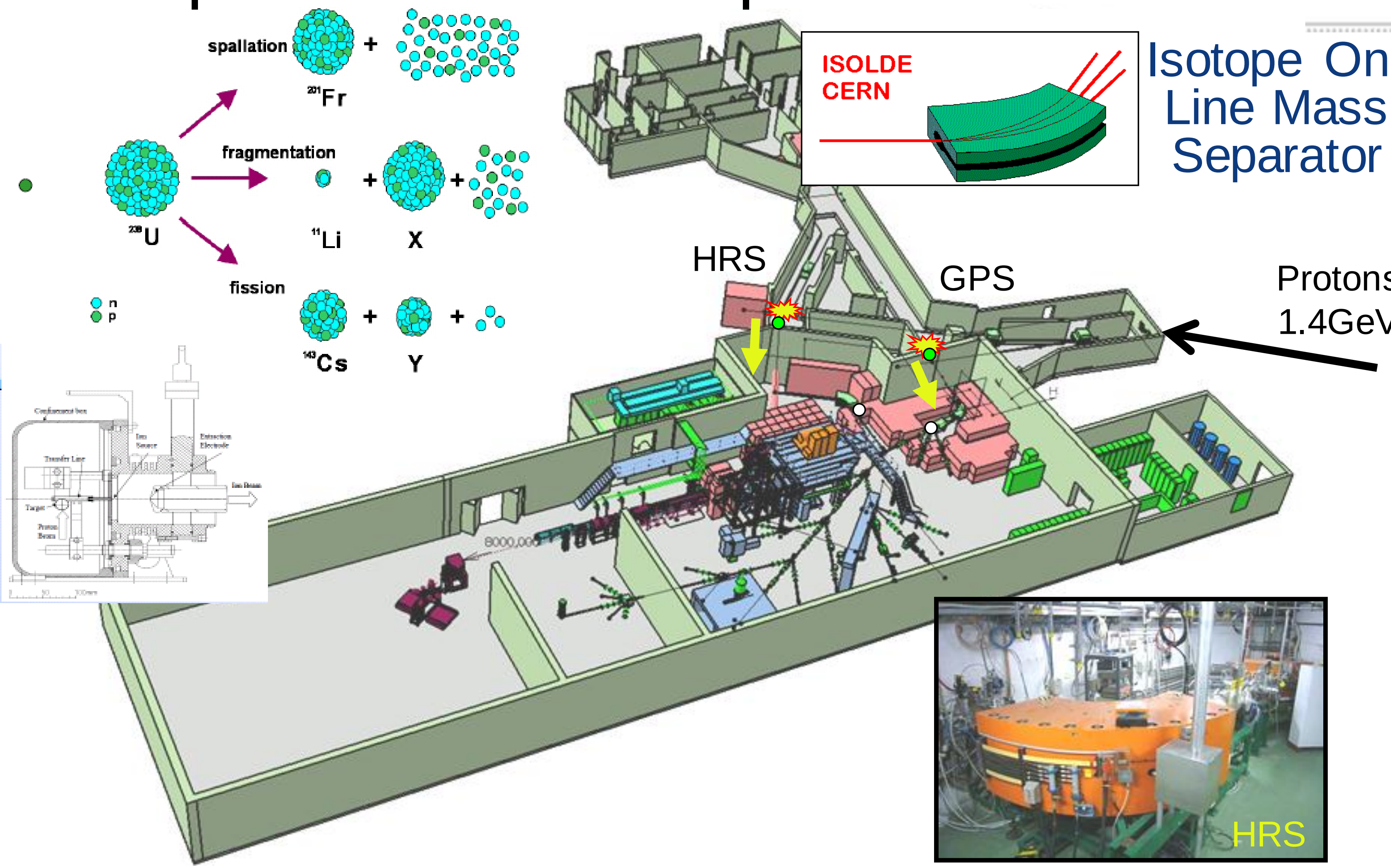




S. Marzari

We might want to further evolve this concept: H2O-cooled W slices like ISIS target

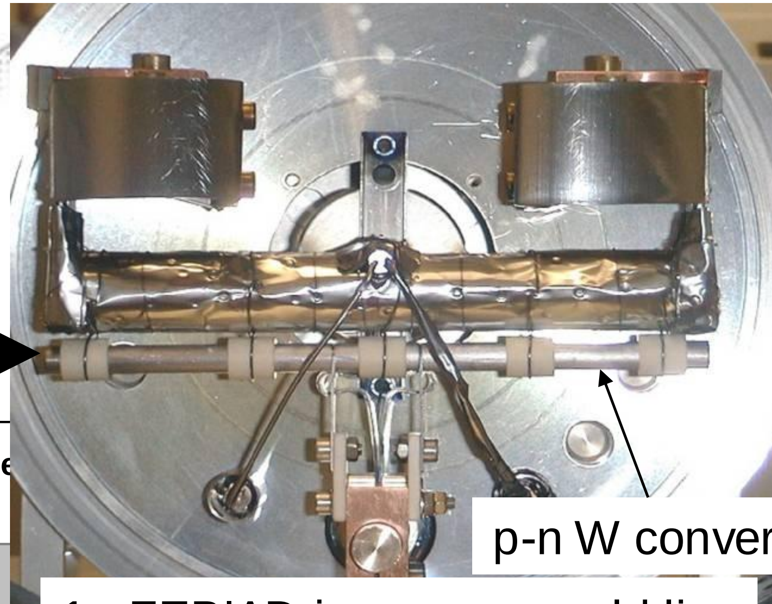
Experiment on 6He production/release



Isotope On-Line Mass Separator

Tests done with 1.4GeV p at CERN-ISOLDE (2009

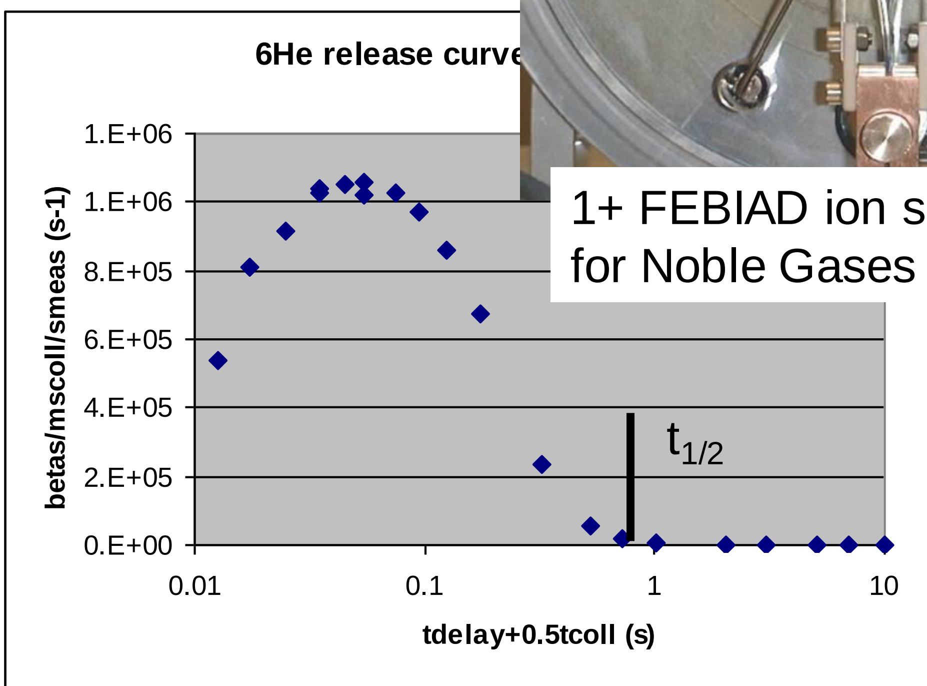
1.4 GeV from PSB



p-n W converter

1+ FEBIAD ion source, cold line for Noble Gases

80 porous BeO pellets



>85% released

Release efficiency
operation temperature
outgasing
materials compatibility
ageing, etc…

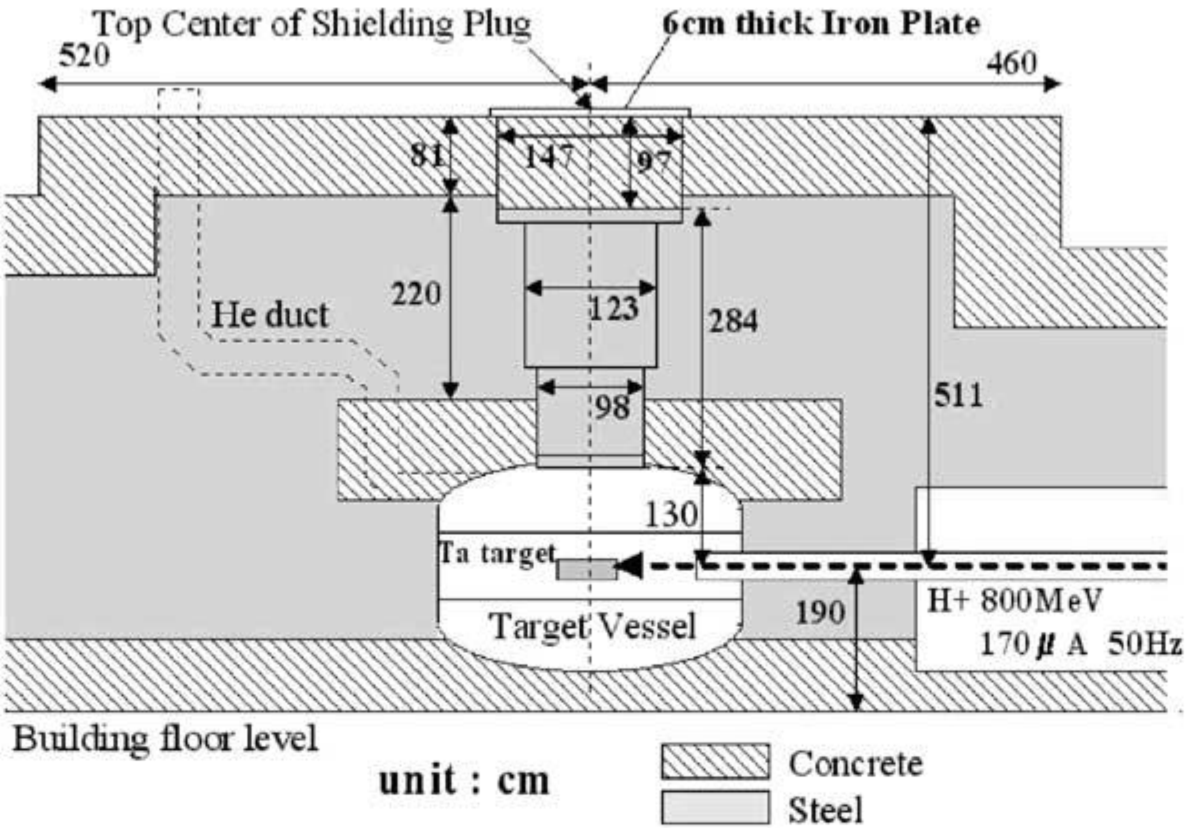
CERN, GANIL, Soreq/Weizman, Bratislava

100-200kW target operation range

TRIUMF (Canada) operates ISOL Radioisotope beams
at 0.5GeV, 40kW, cw protons
with 1 target / month

ISIS (RAL, UK) operates W/Ta proton to neutron converter
at 0.8GeV,160kW, 50Hz (10ms)
for 300 days

ISIS target station (140kW, 0.8GeV p)

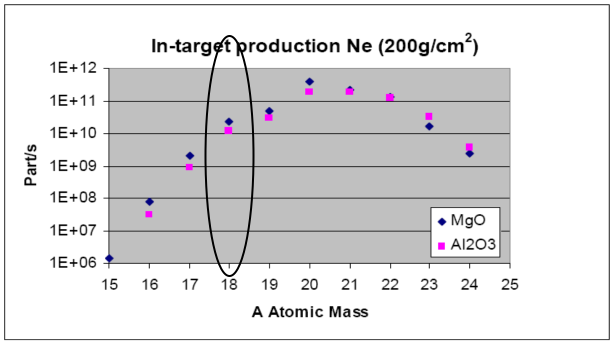


This needs adaptation for target station for ISOL production

Also a 100kW direct target station layout during EURISOL-DS

Production of ^{18}Ne ions for ν_e

- Direct spallation of 1 GeV protons onto thick oxide targets Al (p,X) ^{18}Ne

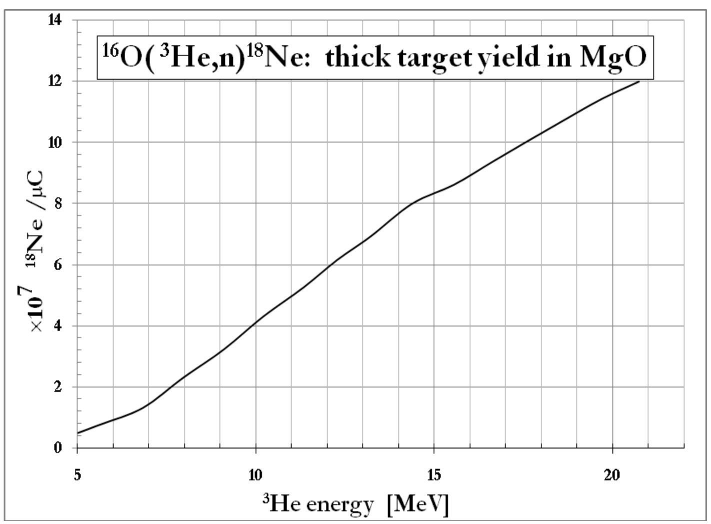


Silberberg-Tsao,
Thin target approx.

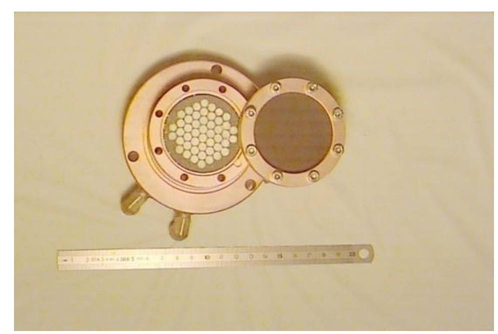
Nominal parameters:

3 10^{10} part/s (Fluka)

Production of 10^{19} ν_e
Out of the target
1 10^{13} ^{18}Ne/s for 8 years



M. Loiselet, S. Mitrofanov
Validated at 9kW at LLN.
Needs ~ 100mA, ^{3}He 21MeV, Ø60cm target



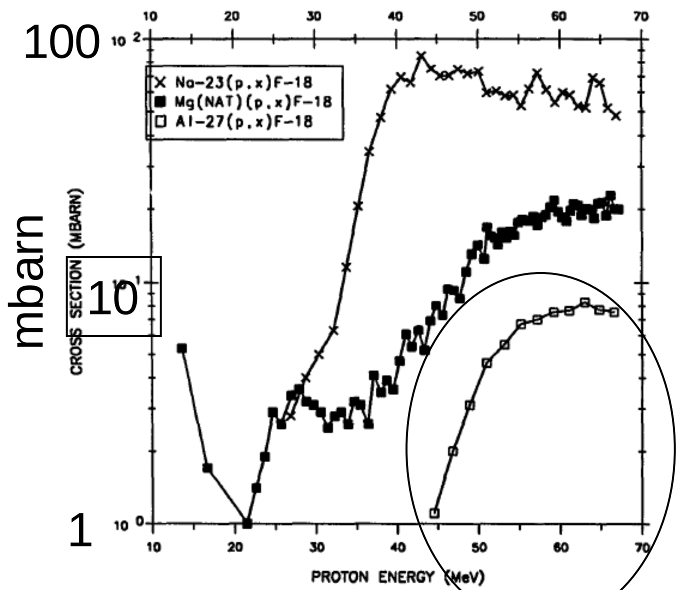
A new proposal in 2009

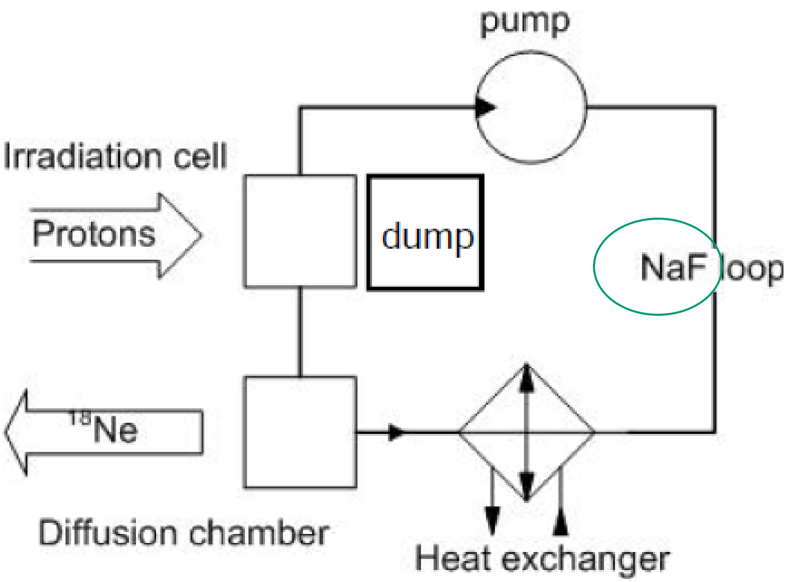
Inspired from 18F production for PET imaging:

$^{19}F(p,2n)^{18}Ne$: threshold 16MeV, peak at 1.6mbarn @ 30MeV (M. Loiselet, S. Mitrofanov)

$^{24}Mg(p,\alpha p2n)^{18}Ne$: threshold 39 MeV, cross-sections ?

$^{27}Al(p,X)^{18}Ne$: ~ 4 mbarn @ 50-70 MeV (Lanulas-Solar, 1988&1992)





T. Stora

Production of ^{18}Ne ions for ν_e

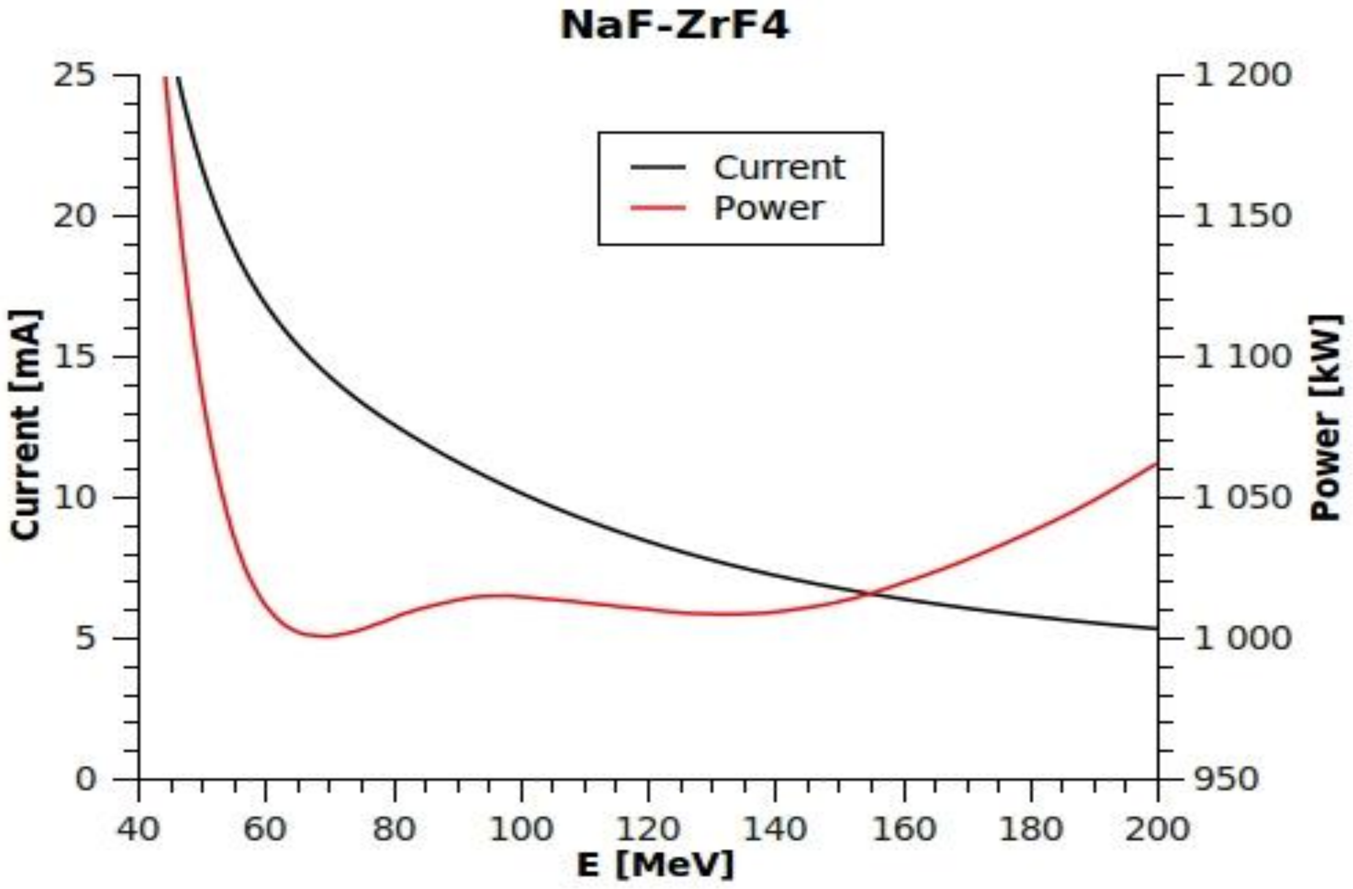
Selection of a suitable eutectic comprising Na and F nuclei :

Salt	Composition [mol %]	Melting point [C]	Density [g/cm3] (700 C)	Viscosity [cP] (700 C)	Vapor pressure [mm Hg] (900 C)	Yield proton 6mA 160MeV	Yield helium3 6mA 160
Naf-BeF2	57 – 43	340	2.01	7	1.4	8.8E+012	7.1E+012
NaF-NaBF4	8 – 92	384	1.75	0.9	9500	8.4E+012	6.9E+012
NaF-ZrF4	60 – 40	500	3.14	5.1	5	1.0E+013	8.2E+012

NaF : melting point at ca 1000°C

D. F. Williams, Assessment of Candidate Molten Salt Coolants for the NGNP/NHI Heat-Transfer loop, ORNL/TM-2006/69, Oak Ridge National Laboratory,
Oak Ridge, TN (2006)

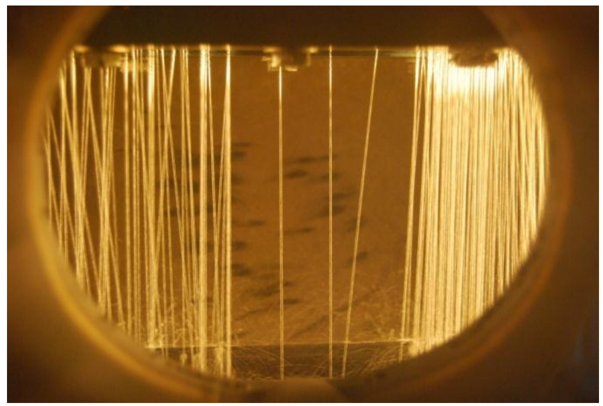
Intensity/energy p-beam for 10^{13} $^{18}Ne/s$



P. Valko, T. Stora

We need a molten salt MW-range ISOL target; Proton Linac as driver

Scaling of the diffusion chamber



E. Noah @ IPUL Lab,
Molten Pb/Bi
EURISOL DS

M. Fujioka , Y. Arai, Diffusion of Radioisotopes from Solids in the form of Foils, Fibers and Particles, Nucl. Instr. and Meth. 186 (1981) 409

Diffusion coefficient [mm2.s-1]	Hole radius [mm]	Released fraction Cylinder	Released fraction Sphere
5.0E-004	0.25	0.25	0.35
1.0E-003	0.25	0.35	0.47
2.5E-003	0.25	0.5	0.63
2.8E-003	0.25	0.53	0.66
5.0E-003	0.25	0.64	0.76
5.0E-004	0.1	0.54	0.67
1.0E-003	0.1	0.68	0.79
2.5E-003	0.1	0.83	0.9
2.8E-003	0.1	0.85	0.91
5.0E-003	**0.1**	**0.91**	**0.95**

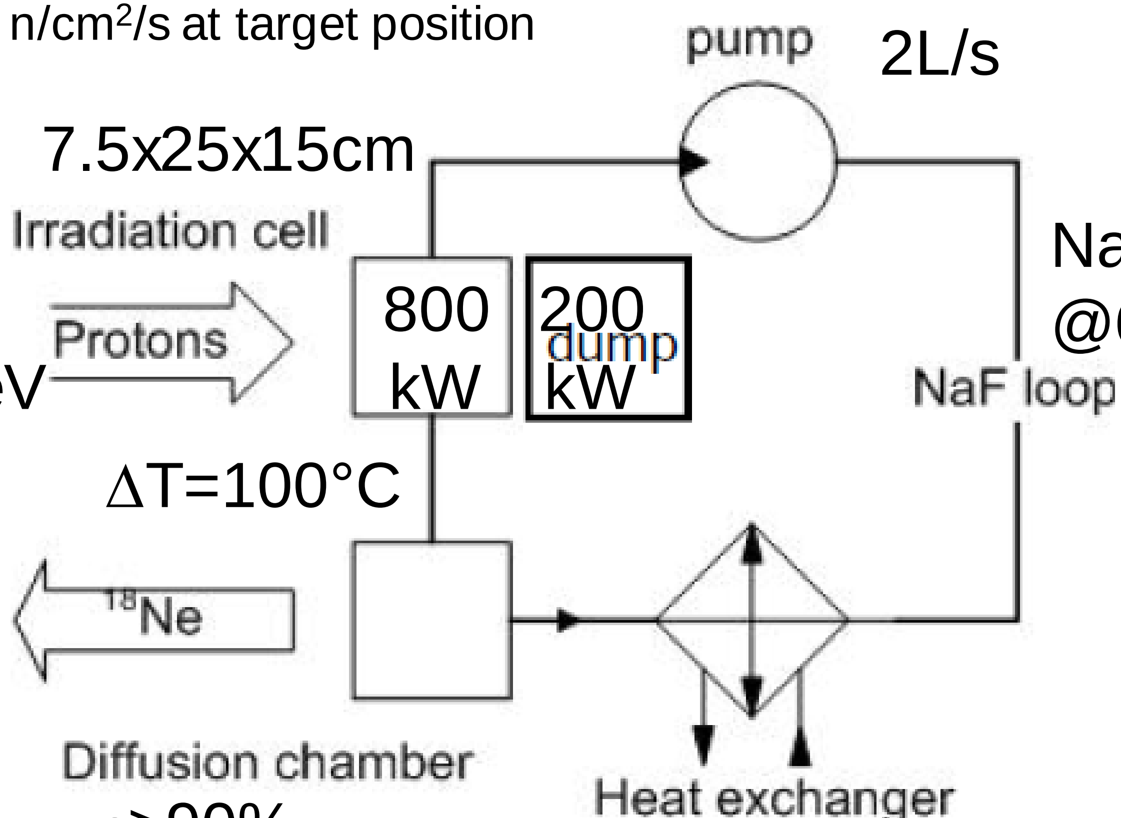
$D = 2\text{-}4\ 10^{-5}\ cm^2/s$ for Kr and Xe
D estimated at $4\text{-}8\ 10^{-5}\ cm^2/s$ for Ne

RJ Kedl, A Houtzeel, ORNL-4069: 1967-06

After 4 $\tau_{diffusion}$, ie 0.5s

^{18}Ne production target 10^{13}/s

23Na(p,pn)22Na requires a yearly salt exchange
Neutron : 5 10^{13} n/cm^2/s at target position



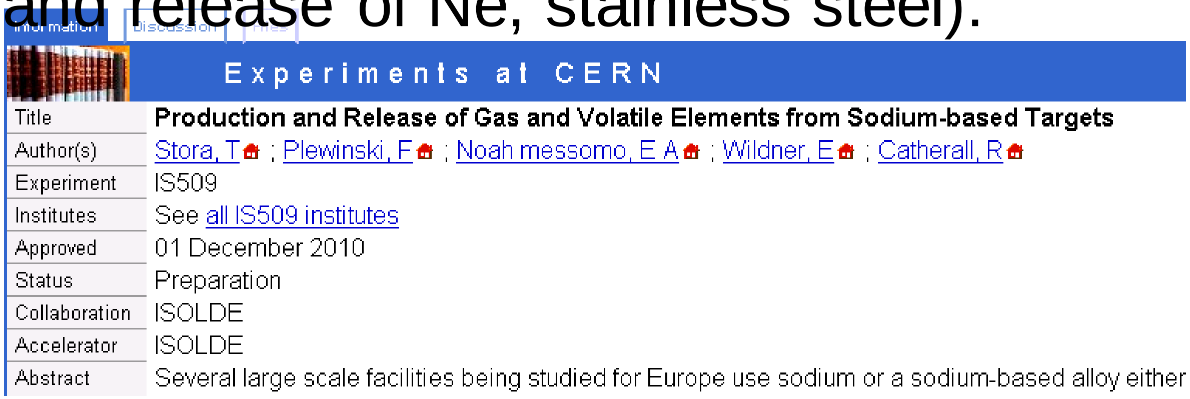
T. Mendonca PJAS-CERN,
ESS,
Comelius University

Upcoming activities

Selected items will be prototyped and tested:

-Diffusion chamber (collab. D. Heuer, LPSC-CNRS Grenoble)

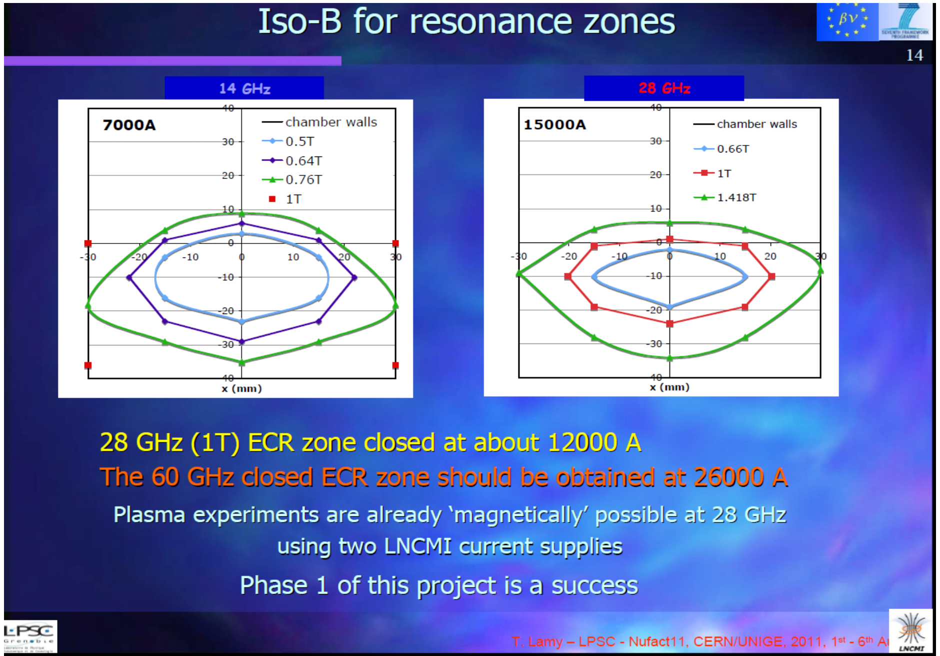
-Static molten salt unit at CERN-ISOLDE (transfer to ion source, production and release of Ne, stainless steel): INTC, Sept 2011


Experiments at CERN

Title	Production and Release of Gas and Volatile Elements from Sodium-based Targets
Author(s)	Stora, T ; Plewinski, F ; Noah messomo, E A ; Wildner, E ; Catherall, R
Experiment	IS509
Institutes	See all IS509 institutes
Approved	01 December 2010
Status	Preparation
Collaboration	ISOLDE
Accelerator	ISOLDE
Abstract	Several large scale facilities being studied for Europe use sodium or a sodium-based alloy either

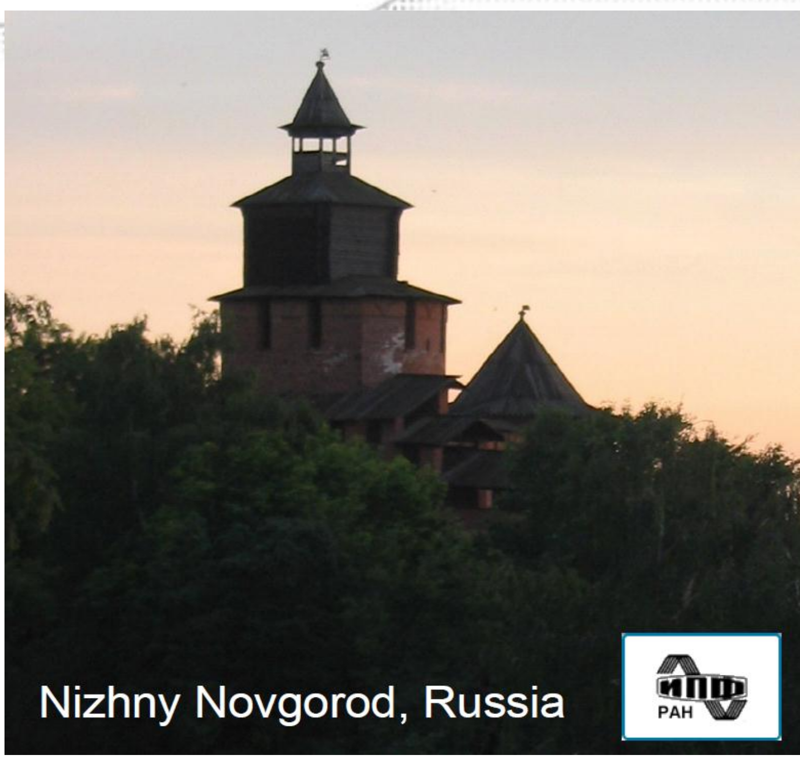
-Physical characterization of molten salt (Ne diffusion, viscosity, surface tension, etc)

Progresses on 60GHz ECR



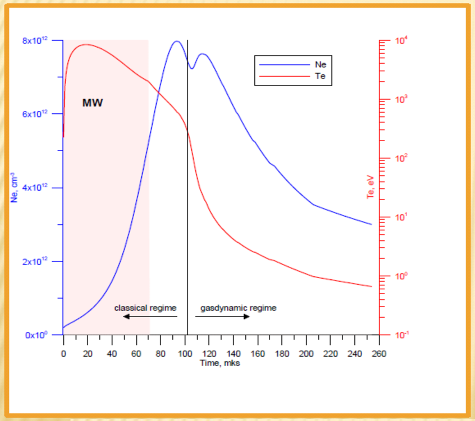
T. Lamy, LPSC, WG3

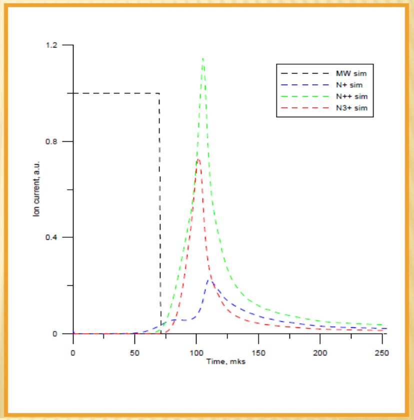
And on Preglow mode



V. Zorin, V.Skalyga, I. Izotov, S. Golubev, S. Razin, A. Sidorov, A. Vodopyanov

Simulation of micropulses





- 75 GHz experiments will be done in 2010 - 2011

Institute of Applied Physics Russian Academy of Sciences

ECRIS 2010

JYVÄSKYLÄN YLIOPISTO UNIVERSITY OF JYVÄSKYLÄ

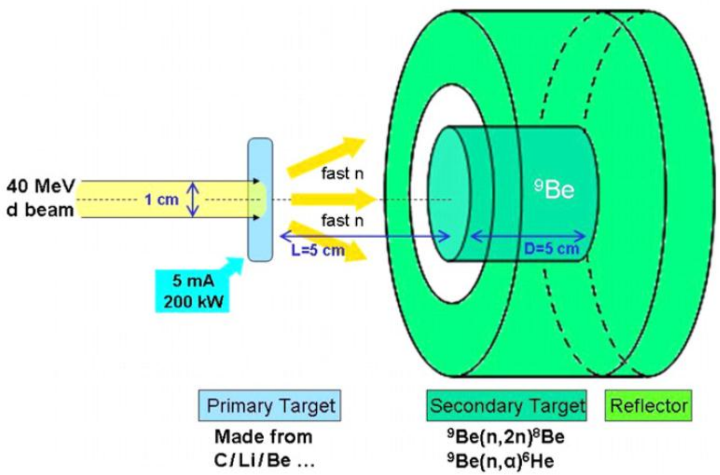
Influence of initial plasma density and mean electron energy on the Preglow effect

I. IZOTOV [1], A. SIDOROV [1], V. SKALYGA [1], V. ZORIN [1], O. TARVAINEN [2], V. TOIVANEN [2], H. KOIVISTO [2]
[1] Institute of Applied Physics Russian Academy of Sciences (IAP RAS), Nizhny Novgorod , Russia; mailto: izotov@appl.sci-nnov.ru
[2] Department of Physics, UNIVERSITY OF JYVASKYLA, Finland

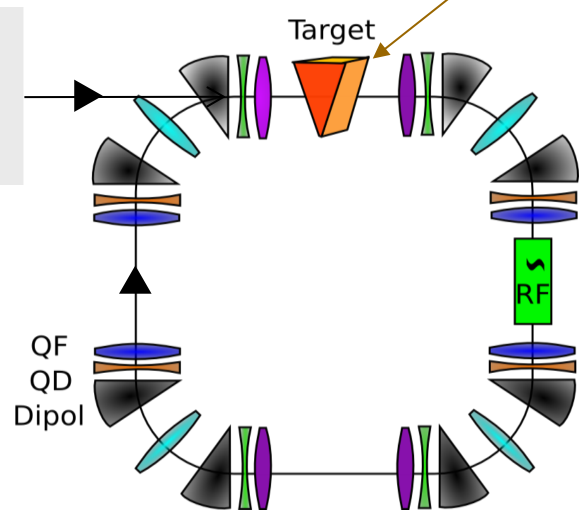
Other options

^{7}Li
^{6}Li

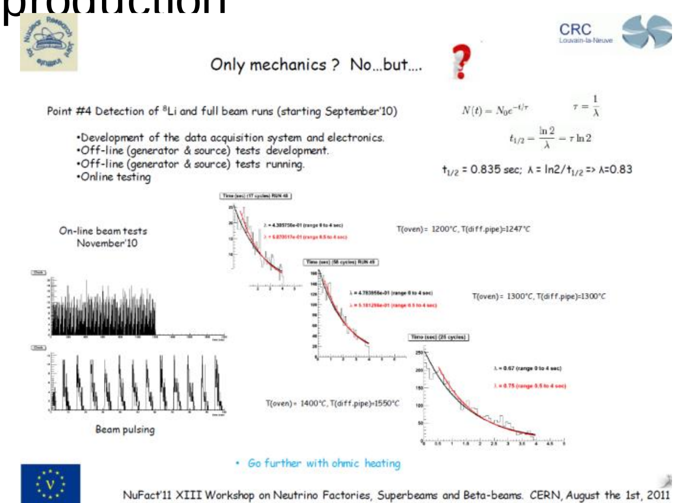
$^{7}Li(d,p)^{8}Li$
$^{6}Li(^{3}He,n)^{8}B$



For 6He and 8Li production
M. Hass et al.



For 8B and 8Li production
C. Rubbia et al.



S. Mitrofanov, WG3

Proton drivers at CERN ?

Linac 4 upgrade: 160MeV, ca 1.6 mA on average.

PSB upgrade : 2 GeV proton, 4-6 μA on average for (HIE)-ISOLDE.

RCS : 2 GeV proton, 10(20?)μA on average for (HIE)-ISOLDE

Conclusion - Baseline ion production

The status on the **100kW-1MW** high power targets for isotope production for the beta-beams have been reviewed.

The proposed technologies do not **break records** for present high power target design/operation.

First successes on 60GHz pulsed ECR prototype operation and modelling

Still some prototyping remains to provide figures, no show stopper so far.

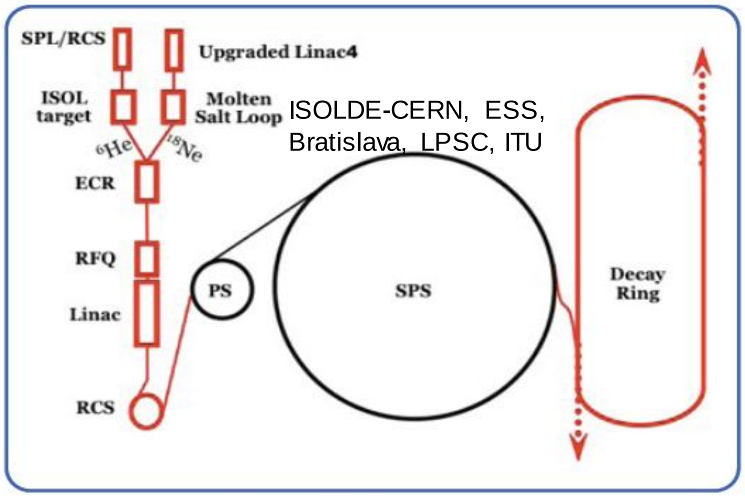
Two Baselines

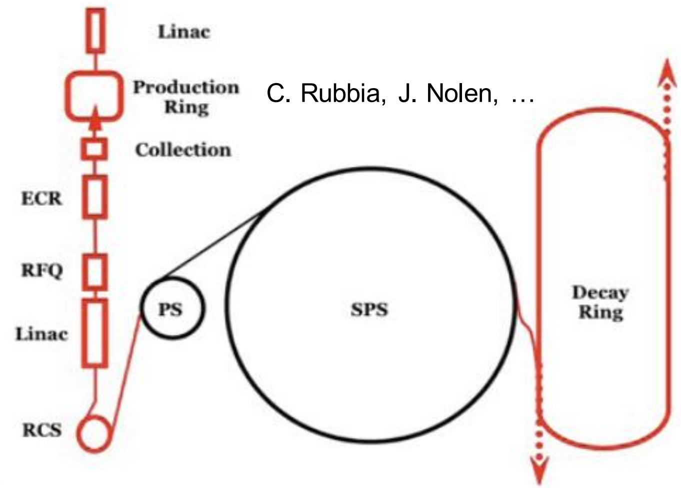
BB OVERVIEW

- **Currently two different baselines** (both with γ=100) **are under investigation**
- **^{6}He & ^{18}Ne: L ≈ 130 km**
- **^{8}Li & ^{8}B: L ≈ 650 km**

ISOLDE-CERN, GANIL, Bratislava, Weizman

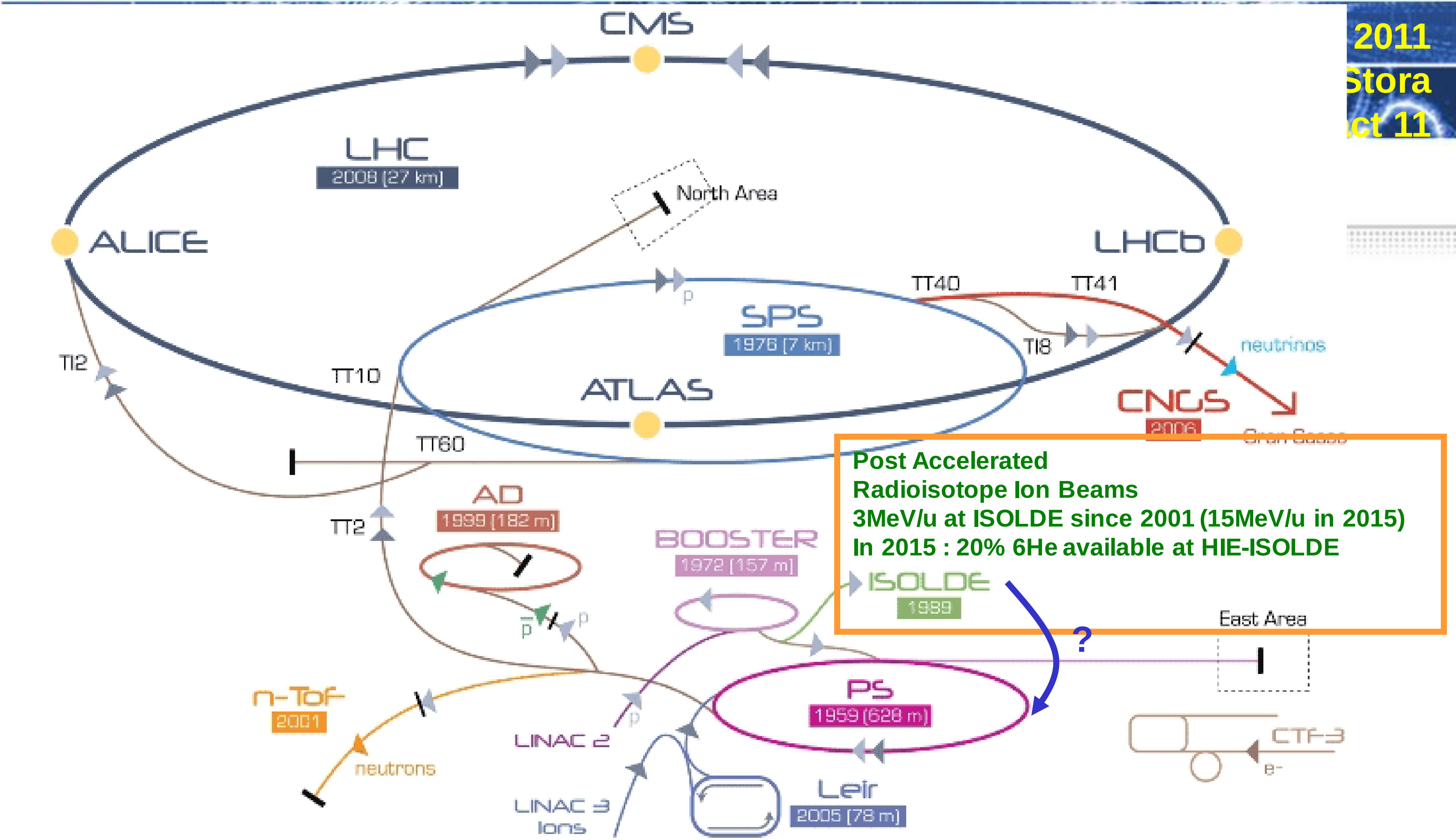
LPSC/LNCMI, PAH, Jyvaskyla, LBNL





Chosen as EURONu's baseline

50 μs ago ! (and was still true 1-3 ns ago !!)



Do you believe this Laboratory could accelerate and let decay stored relativistic radioactive ions ?

p (proton) ▸ ion ▸ neutrons ▸ p̄ (antiproton) —+|— proton/antiproton conversion ▸ neutrinos ▸ electron

Radioisotope

LHC Large Hadron Collider SPS Super Proton Synchrotron PS Proton Synchrotron

AD Antiproton Decelerator CTF3 Clic Test Facility CNGS Cern Neutrinos to Gran Sasso ISOLDE Isotope Separator OnLine DEvice

LEIR Low Energy Ion Ring LINAC LINear ACcelerator n-ToF Neutrons Time Of Flight