Opportunities for neutrino experiments at ISOLDE

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Outline

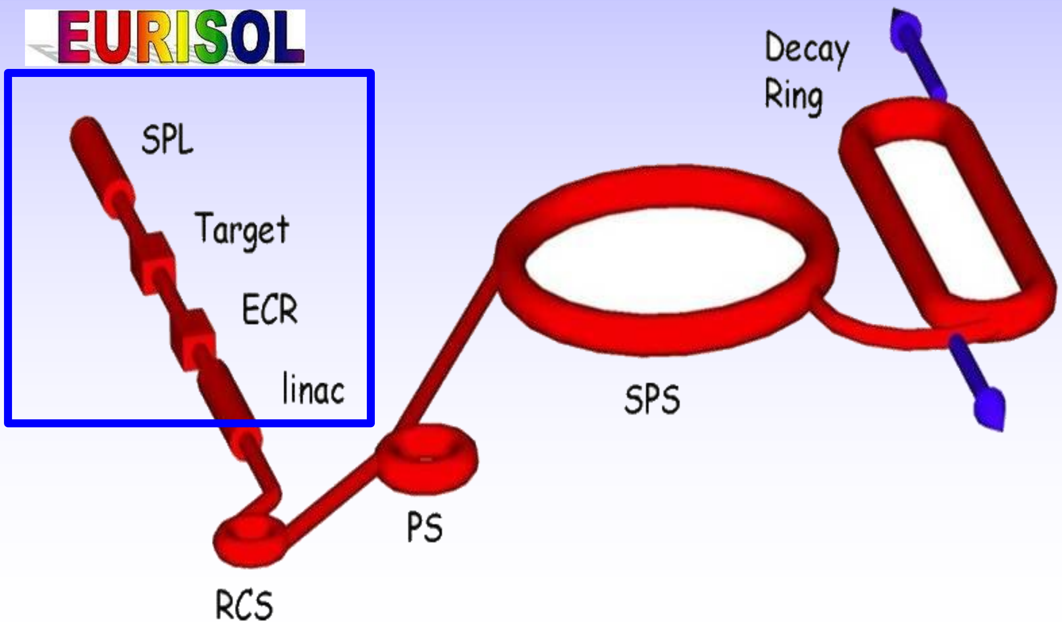
Beta beams within the Eurisol scenario

Production of pure and intense ν_e and anti- ν_e from β decay of radioactive ions circulating in a storage ring based on existing technology and machines

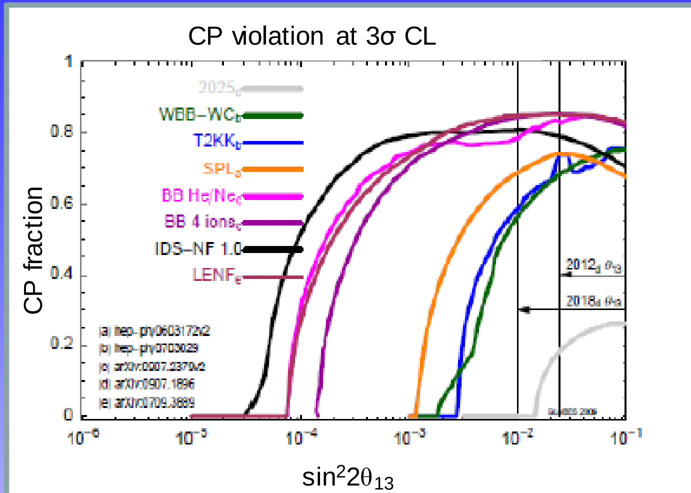
Production of ^{18}Ne

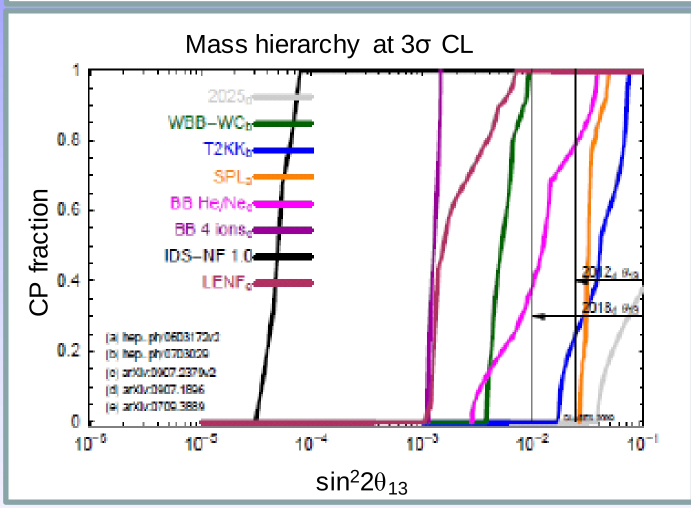
- Oxide targets
- Molten salts targets

Summary

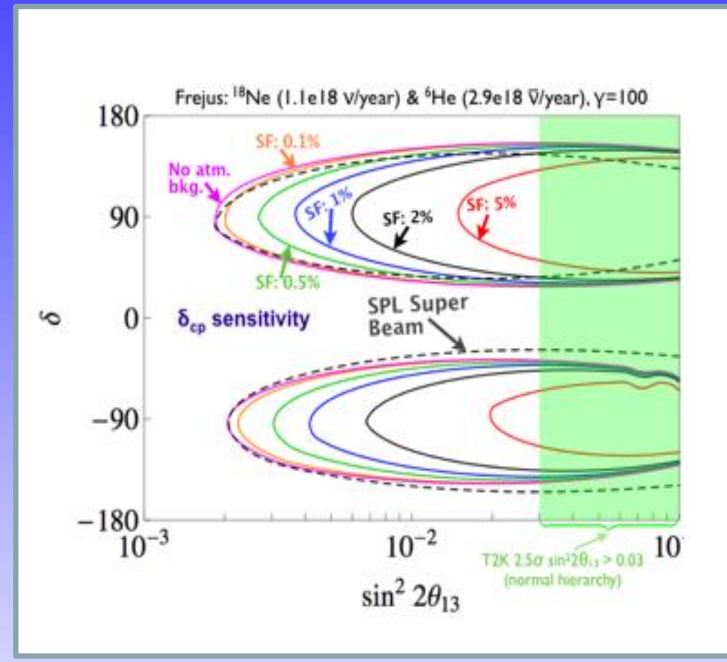


Physics reach of different future facilities

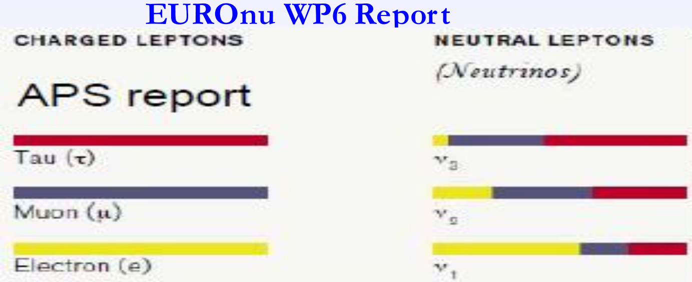


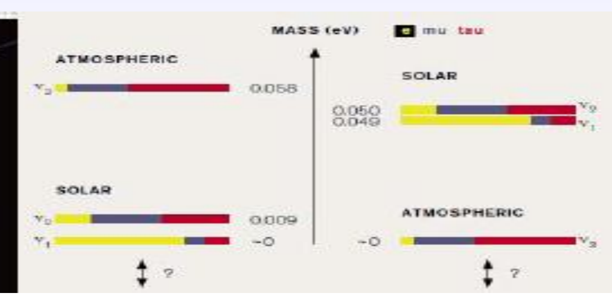


EUROnu WP6 Report



E.F. Martinez, http://arxiv.org/abs/0912.3804
http://arxiv.org/abs/hep-ph/0603261





Eurisol beta beam facility

Production of ν_e and **anti-ν_e from ^{6}He and ^{18}Ne baseline ions:**

- 2.9 x10^{19} antineutrinos/10 yrs from ^{6}He (3(.3) x10^{13} ^{6}He/s)
- 1.1 x10^{19} neutrinos/10 yrs from ^{18}Ne (2(.1) x10^{13} ^{18}Ne/s)

Based on existing technology and machines

-Ion production through ISOL technique

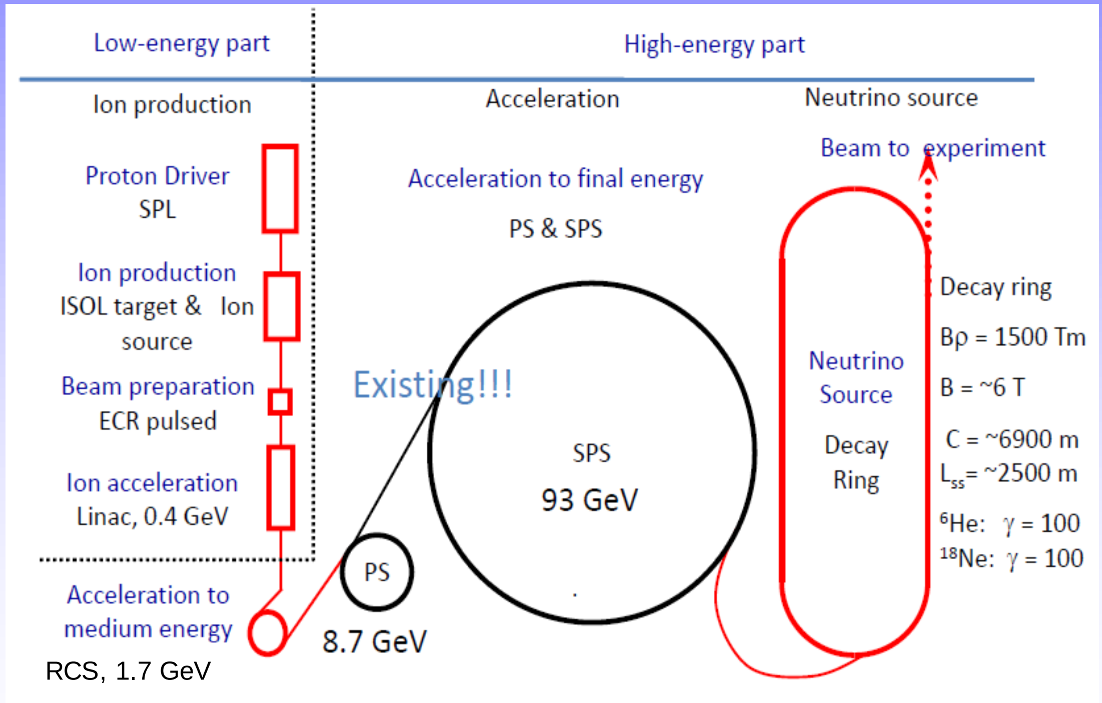
-Bunching and first acceleration: ECR, Linac

- Rapid cycling synchrotron

-Use of existing machines PS and SPS

- Decay ring + detection

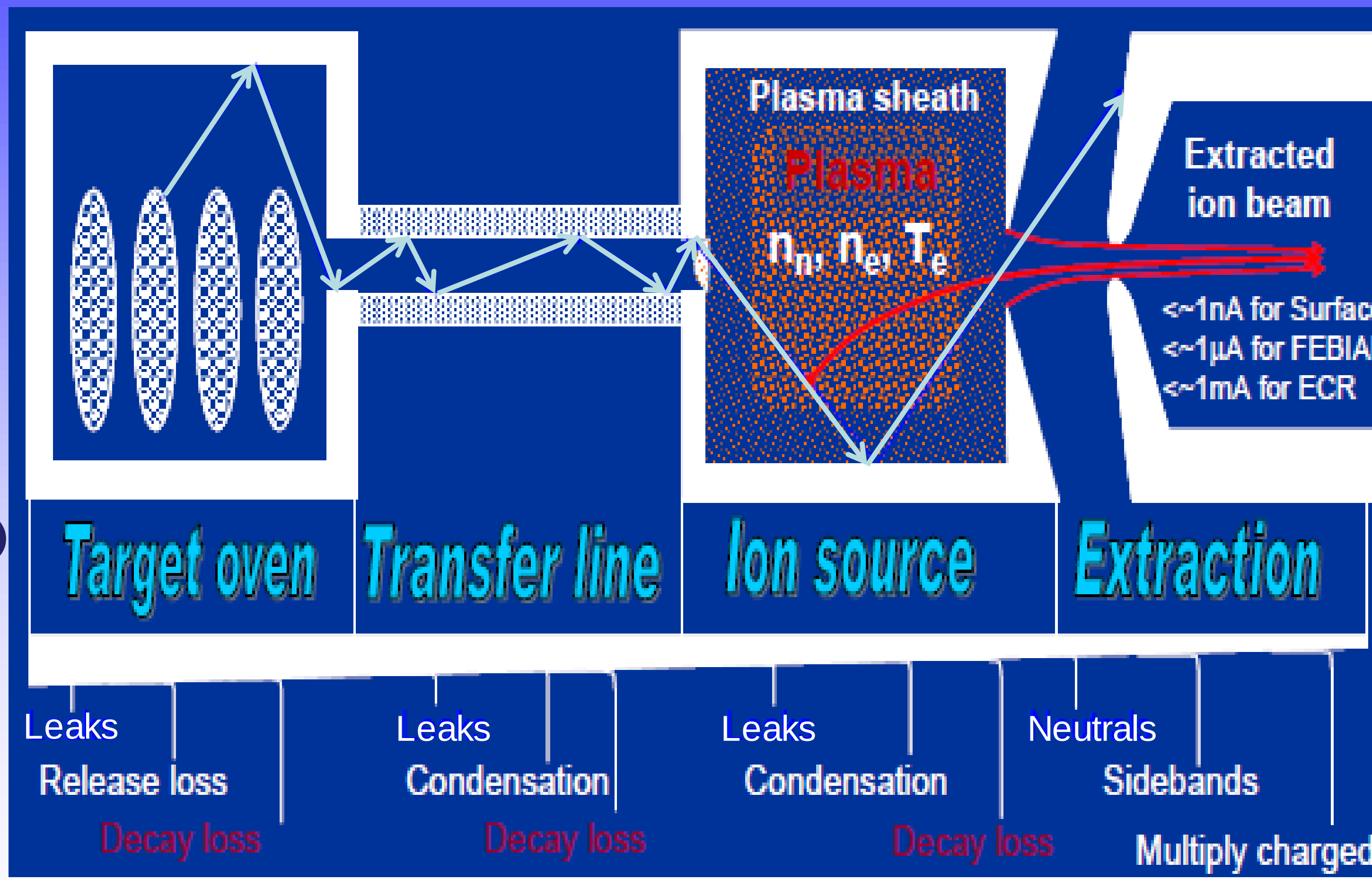
- Storage ring facility at ISOLDE



P. Zuchelli, Phys. Lett. B (2002)

Production of radioactive ion beams based on the ISOL technique

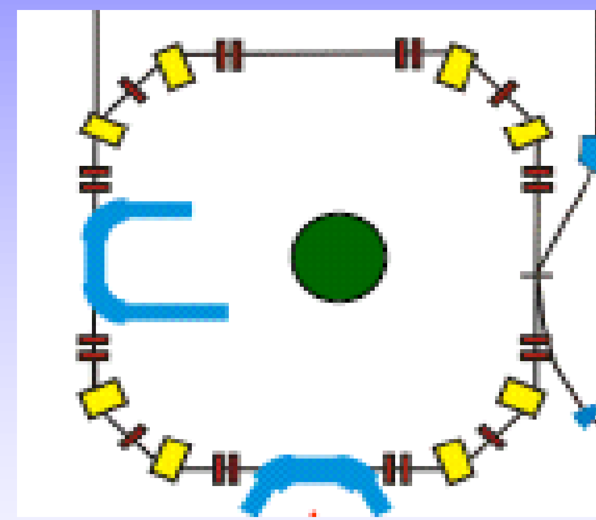
Primary beam
(MeV/u-GeV/u)



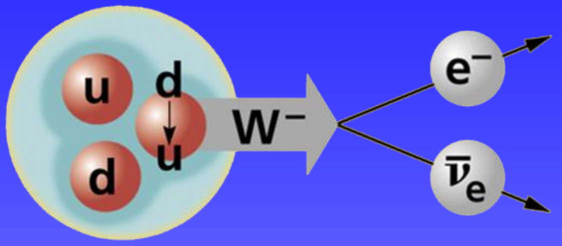
Discussions around implementation of a storage ring for radioactive or stable ions

Source of ν_e and anti-ν_e at CERN?

55m
Gamma ~1.01
(~1-10MeV/u)



Technical choices for isotopes and targets determined by:



- Efficient production channels (high production cross-section σ)
- Isotopes properties ($t_{1/2}$, release properties)
- Side effects (primary beam penetration range, heating, chemistry, …)
- 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)

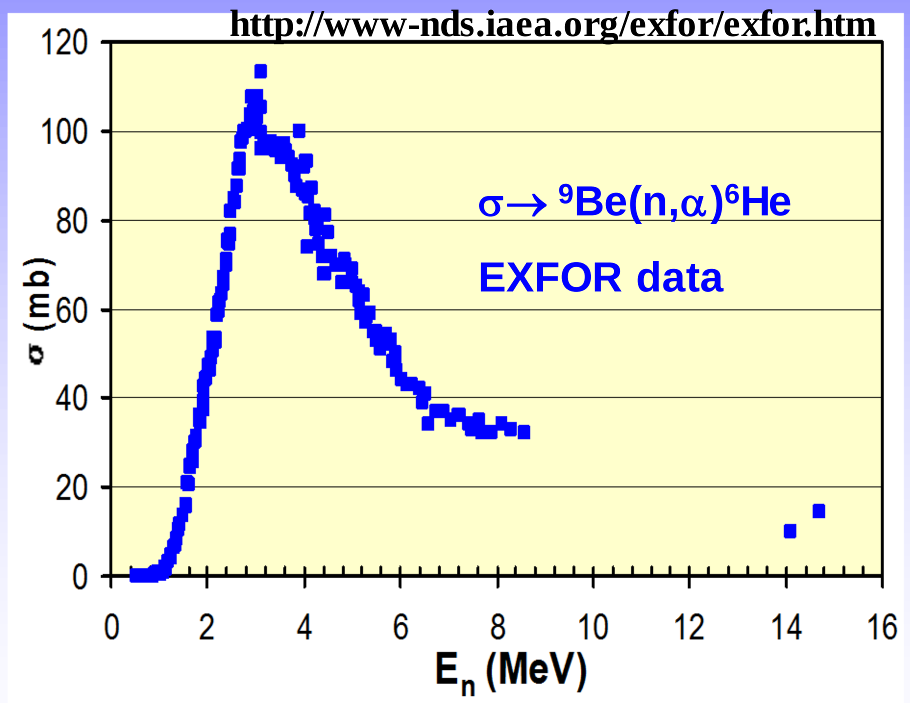
Threshold: **0.6 MeV**

Peak cross-section: **105 mbarn (3MeV)**

$$^6_2He^{2+}(T_{1/2}=0.8s)\rightarrow {}^6_3Li+e^-+\overline{\nu}$$

$$Q_{\beta^-}=3.51\,\text{MeV}$$

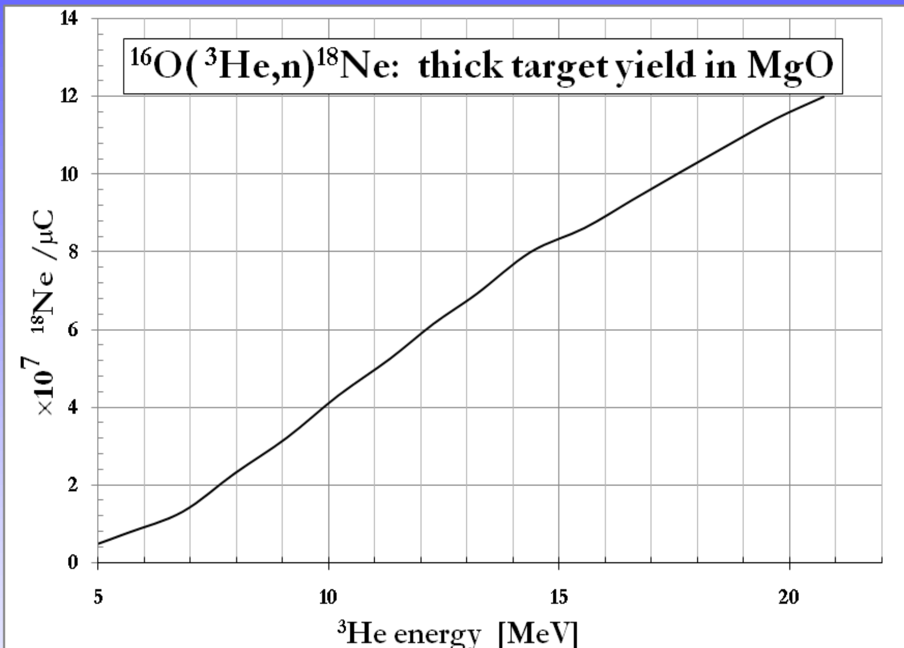
Production of anti-ν_e out of the target ≈ 3 x10^{13} ^{6}He/s



^{6}He production with neutrons on BeO target

Production of ^{18}Ne for ν_e using oxide targets

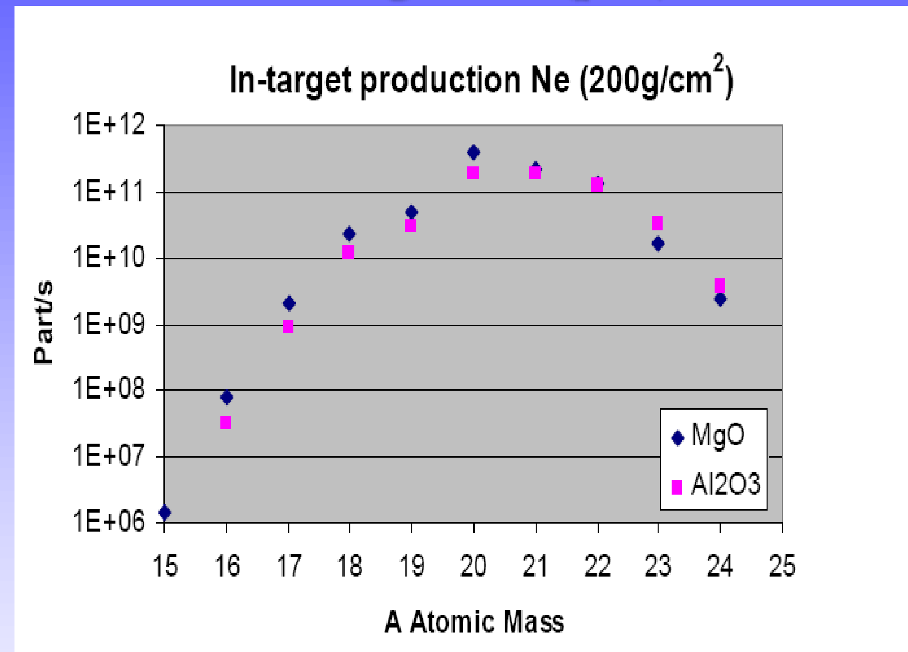
$^{16}O(^3He,n)^{18}Ne$ in thick MgO target



2x10^{13} ^{18}Ne/s for 170 mA and 21 MeV

Intensity reduced for 30 MeV

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



~3x10^{12} ^{18}Ne/s

Further reduction due to extraction losses

M. Loiselet, S. Mitrofanov, Louvain La Neuve

Production of ^{18}Ne for ν_e using molten salts

- Molten salts tested and operated at ISOLDE (CERN 81-09)
- Molten salt targets (LiF): validated at Louvain-la-Neuve using 9 kW, 30 MeV proton beam
- Cross-sections simulations using the TALYS code (in collaboration with Komenius University, Bratislava, Slovakia)

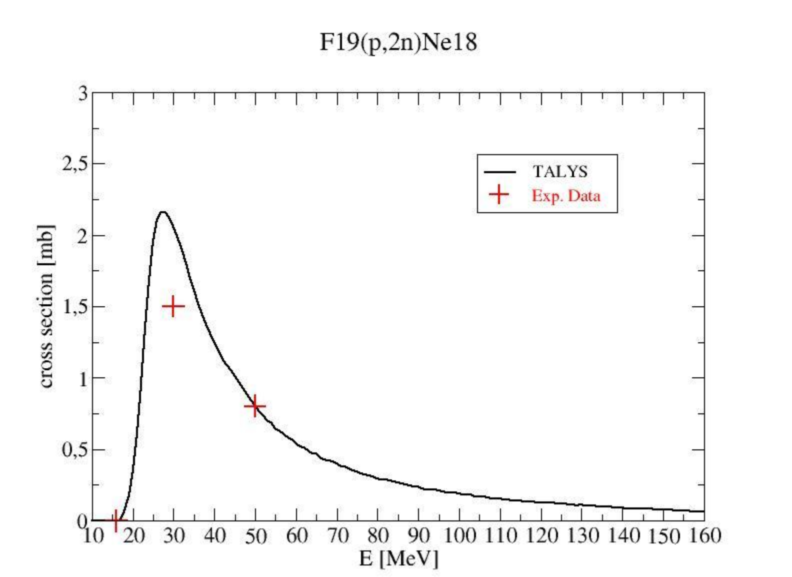
Upcoming activities

Prototype and tests:

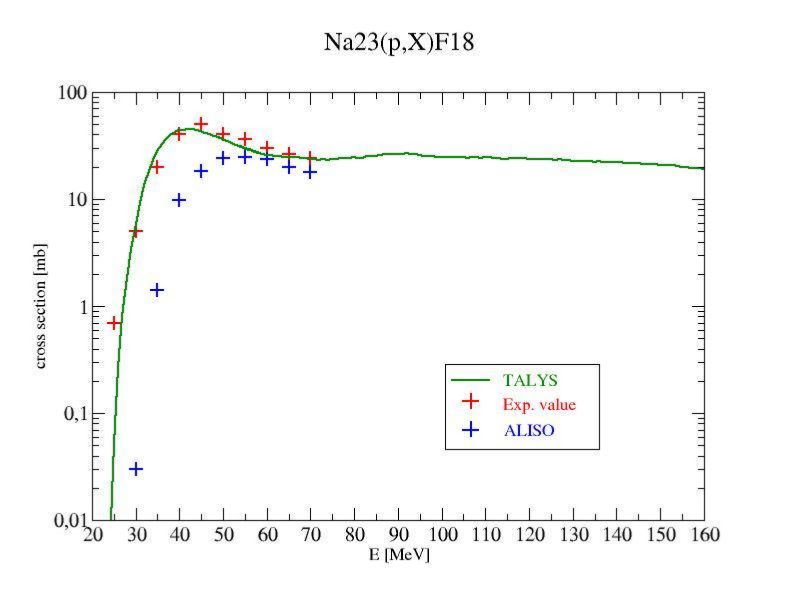
-static sodium molten salt unit at CERN/ISOLDE (IS509, November 2011, collab. R. Hodak, Slovakia)

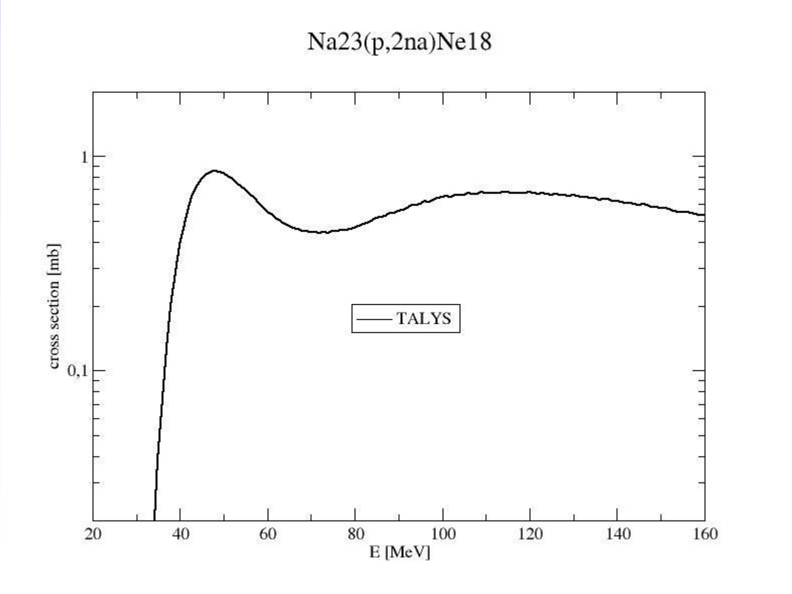
-molten salt loop (in collaboration with LPSC/Grenoble)

TALYS production code benchmarking



M. Loiselet, S. Mitrofanov, Louvain La Neuve



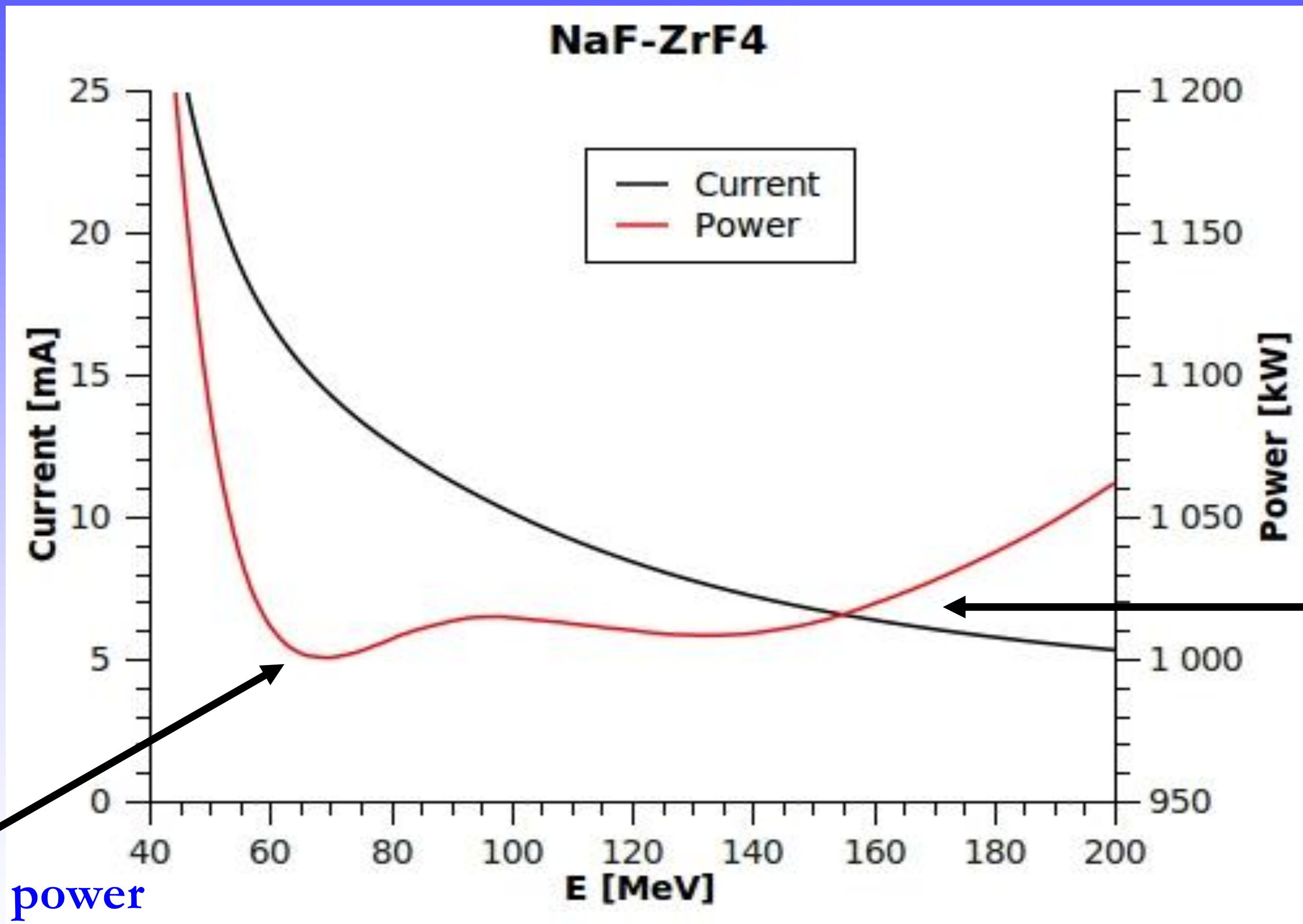


A.J. Koning, S. Hilaire, M.C. Duijvestijn, "TALYS-1.0" Proceedings of the International Conference on Nuclear Data for Science and Technology, April 22-27, 2007, Nice, France, editors O. Bersillon, F. Gunsing, E. Bauge, R. Jacqmin, S. Leray, EDP Sciences, 2008, p. 211-214

M.C. Lagunas-Solar in Proc. of the IAEA consultants' meeting in data requirements for medical radioisotopes production, INDC(NDS)-195/GZ, 1988, p.55

P.Valko

Required beam current and power for a constant yield 10^{13} ^{18}Ne/s



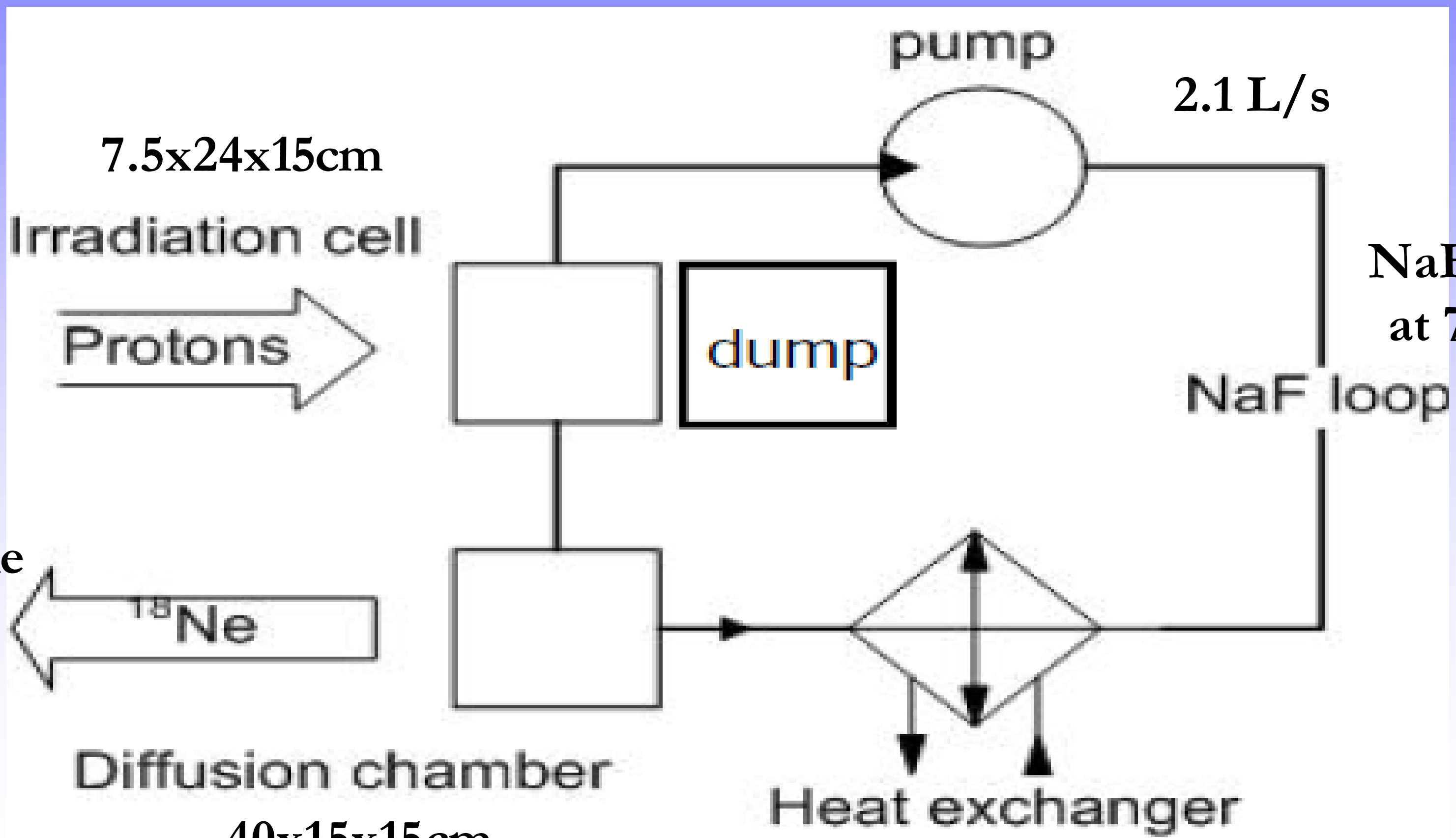
Upgraded LINAC 4

Lowest power

Molten salt MW range ISOL target

Production of ^{18}Ne for ν_e using molten salts

Conceptual Na target loop for ^{18}Ne production
(^{23}Na(p, X)^{18}Ne, ^{19}F(p,2nα)^{18}Ne)



T. Stora, P. Valko

Salt composition selection

Molten salts are well known and characterized concerning physical properties and engineering (ORNL reports)

Selection of a suitable eutectic comprising **Na** and **F** nuclei:

Melting point of **NaF** is cca **1000 °C!** → **mixture** with **Be, Zr, B**

Salt	Composition [mol %]	**Melting point [°C]**	Density [g/cm3] (700 °C)	Viscosity [cP](700°C)	Vapor pressure [mmHg](900°C)	Yield protons 6mA 160MeV	Yield ^{3}He 6mA 160MeV
NaF-BeF_2	57 - 43	340	2.01	7	1.4	8.8E+012	7.1E+012
NaF-$NaBF_4$	8 - 92	385	1.75	0.9	**9500**	8.4E+012	6.9E+012
NaF-ZrF_4	60 - 40	**500**	3.14	5.1	5.1	1.0E+013	8.2E+012

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)

Molten salt loop container selection

Candidate material	Salt corrosion resistance	Air corrosion resistance	Long-term strength at 1000 °C	Highest usage temperature [°C]
Hastelloy N alloy*	**Excellent**	**Good**	**Very good**	**870**
Haynes 242*	**Excellent**	**Good**	**Very good**	**900**
Alloy 800H or HT	Poor-fair	Good	Very good	980
Haynes 214*	**Very good**	**Good**	**Good**	**1000**
MA 956	Very good	Good	Good	?
MA 754	Very good	Good	Good	?
Cast Ni superalloys	Very good	Good	Good	?

* **Nickel** based alloys

O. Benes, el. al., ALISA, Review Report on Liquid Salts for Various Application, version V4

Haynes International, Technical brief

Haynes 242 alloy is a promising candidate for application up to 750°C

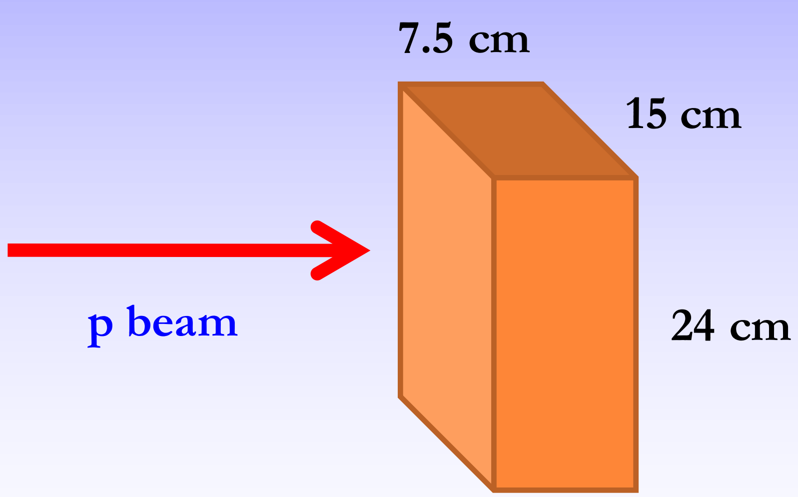
	Ni	Mo	Cr	Fe	Co	Mn	Si	Al	Cu
Haynes 242	65	25	8	2	2.5	0.8	0.8	0.5	0.5

Scaling of the irradiation chamber

For $\Delta T = 100$ °C, $C_p = 1.17$ J.g^{-1}.K^{-1},
flow rate needed ≈ 2.1 L/s

Size of the steel window is ≈ 360 cm^2, e.g. (15x24) cm^2
Projected range in $NaF\text{-}ZrF_4$ is 7.5 cm

Size of the chamber:



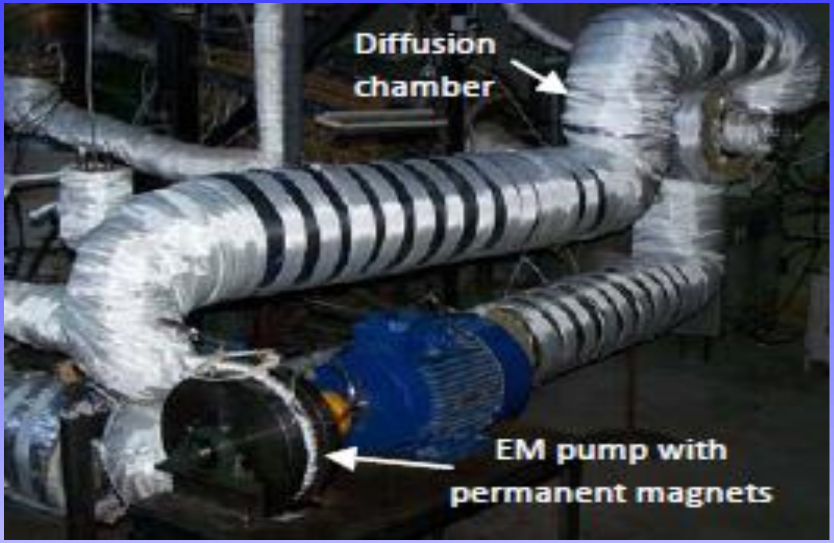
Calculated with SRIM
(The Stopping and Range of Ions in Matter)

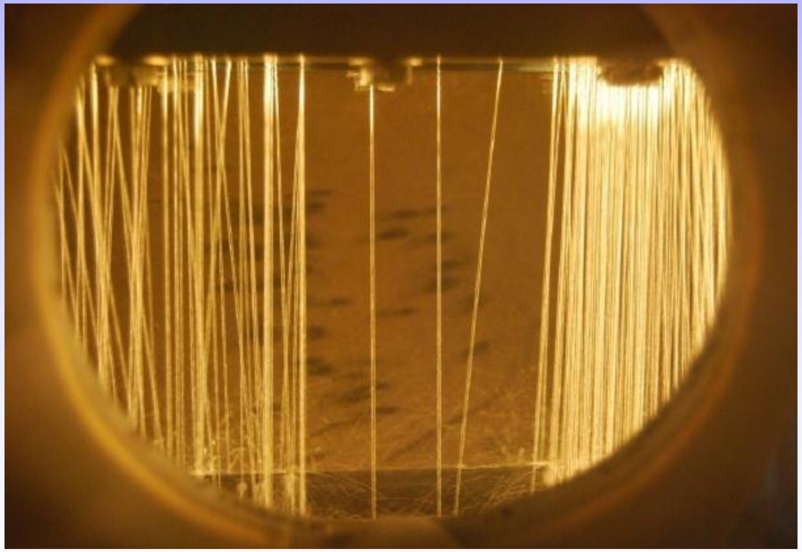
Position on axis [cm]	Stopping power [MeV]	Deposited beam power 6mA, 160MeV [kW]
1	12	74
2	13	78
3	14	83
4	15	90
5	16	99
6	19	111
7	22	133
8	30	178
Total target	126	756
Total dump	31	186
Total window (1 mm thick)	3	18

Cooling of the window (10 kW for 0.5 mm thickness) is done with the circulating molten salt.

J.A. Lane, H.G. MacPherson, F. Maslan, Fluid Fuel Reactor, Chapter 13, Addison-Wesley, Reading, Mass. (1958)

Scaling of the diffusion chamber





E. Noah @ IPUL Latvia
Molten Pb/Bi loop prototype EURISOL DS

Diffusion coefficients

D = (2-4) x10^{-5} cm^2.s^{-1} for **Kr** and **Xe**

D estimate at **(4-8) x10^{-5} cm^2.s^{-1}** for **Ne**

Mean diff. time **0.13 s** for **5 x10^{-5} cm^2.s^{-1}**

Diffusion coefficient [mm^2.s^{-1}]	Hole radius [mm]	Released fraction Cylinder	Released fraction Sphere
1.0E-3	0.25	0.35	0.47
2.5E-3	0.25	0.5	0.63
5.0E-3	0.25	0.64	0.76
1.0E-3	0.1	0.68	0.79
2.5E-3	0.1	0.83	0.9
5.0E-3	**0.1**	0.91	**0.95**

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

R.J. Kedl, A. Houtzeel, ORNL-4069 (1967)

Conclusions

The status of ^{18}Ne production is reviewed

Molten salt targets as good candidates for ^{18}Ne production

Proposed prototype and tests in NaF-ZrF_4 salt:
-Static sodium molten salt unit at CERN/ISOLDE (IS509, November 2011)
-Diffusion chamber (in collaboration with LPSC/Grenoble)
- Physical characterization of molten salt (Ne diffusion, surface tension,…)

Thank you!