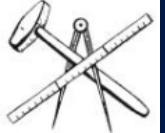


Baseline ${}^6\text{He}$ & ${}^{18}\text{Ne}$ ion production for β beams

Thierry.Stora@cern.ch

Target and Ion Source Development
(EN-STI) - ISOLDE



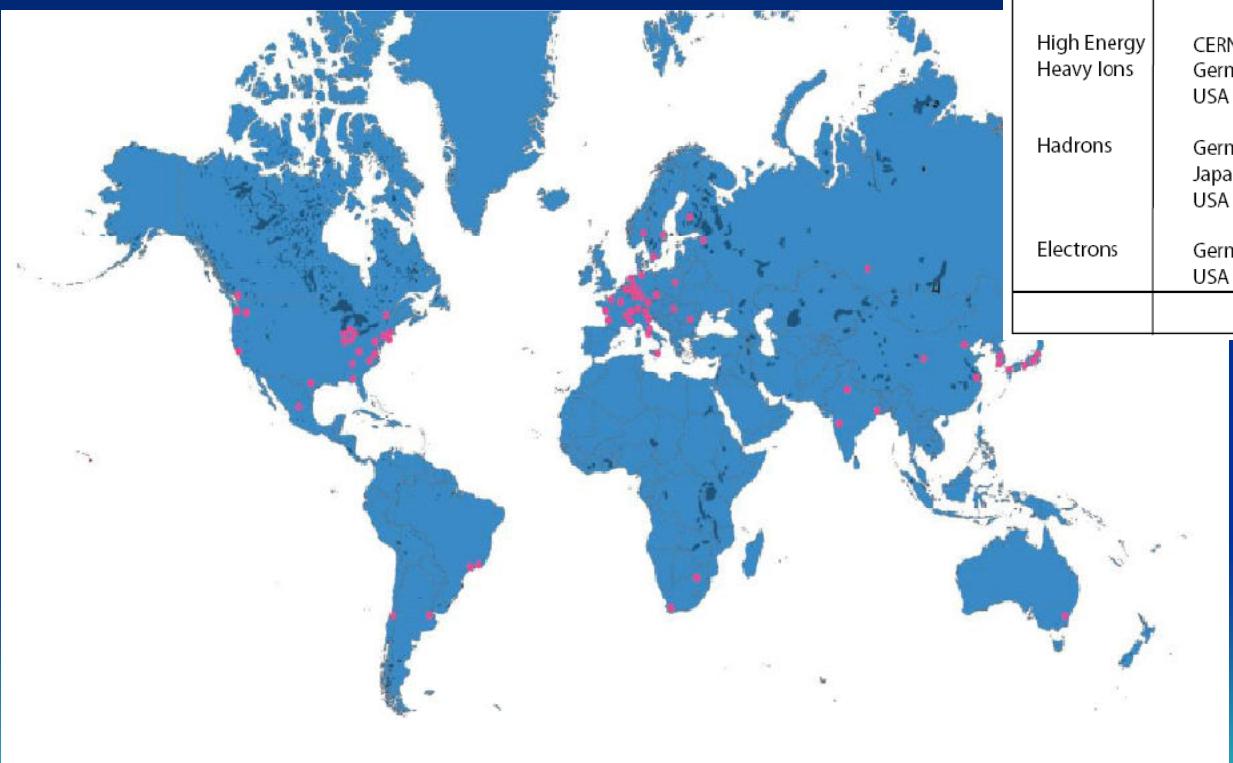


(Radioactive) Ion Beam Facilities

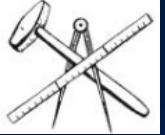
OECD Global Science Forum

Report of the
Working Group on Nuclear Physics

MAY 2008

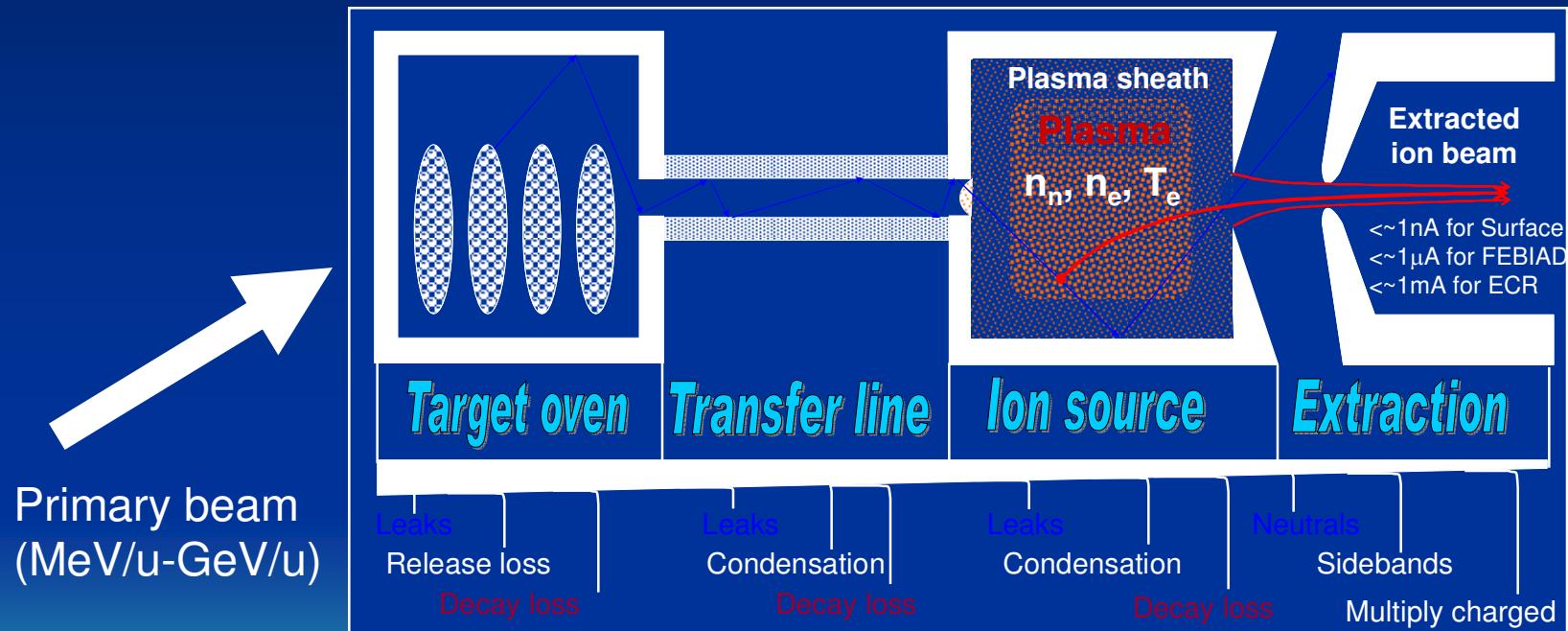


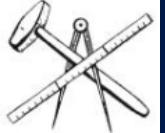
TYPE	Country	2000	2005	2010	2015	2020
Rare Isotope Beams	Canada	ISAC I			ISAC II	
	CERN	ISOLDE				
	France	GANIL/SPIRAL			SPIRAL II	
	Germany	SIS			FAIR	
	Japan	RARF			RIBF	
	USA	NSCL, HRIBF			FRIB	
High Energy Heavy Ions	CERN			LHC		
	Germany			FAIR		
	USA	RHIC		RHIC II		
Hadrons	Germany				FAIR	
	Japan	KEK-PS			J-PARC	
	USA	AGS				
Electrons	Germany	MAMI		MAMI C		
	USA	CEBAF		CEBAF-12 GeV		
		2000	2005	2010	2015	2020



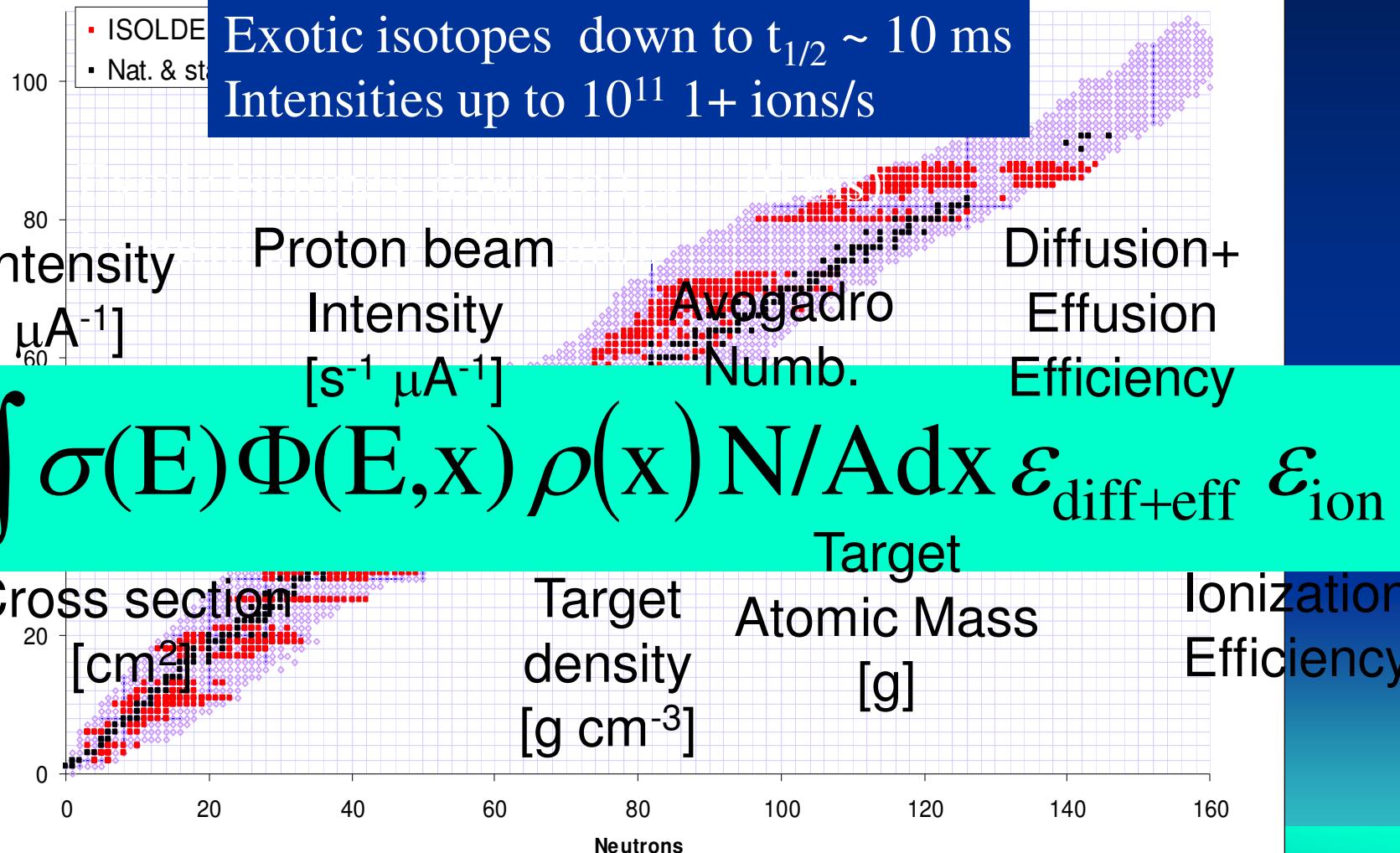
How to produce a radioactive ion beam based on the “ISOL” technique

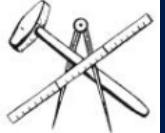
Thick target ($1\text{-}200\text{g/cm}^2$)





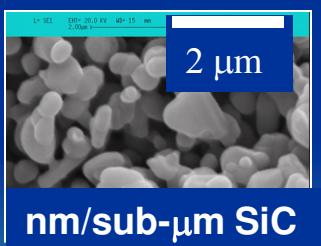
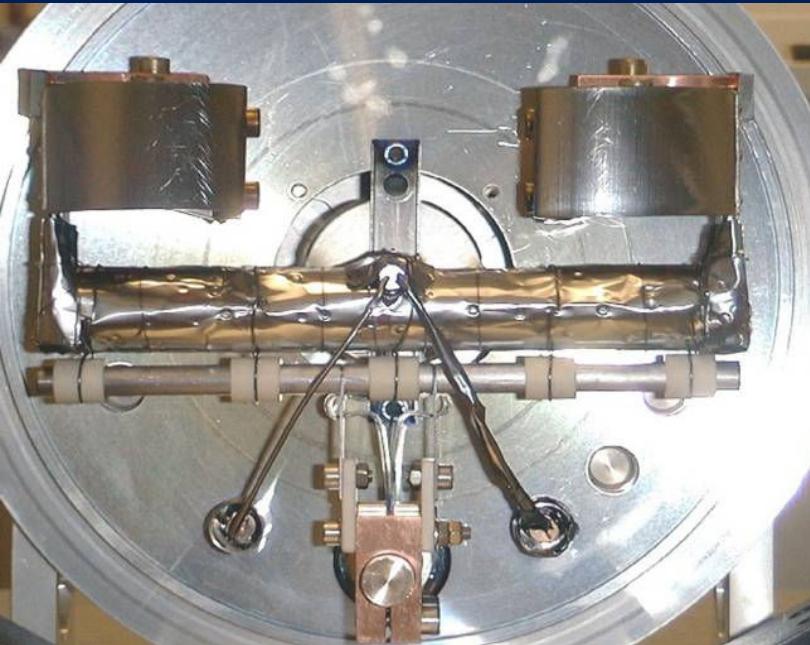
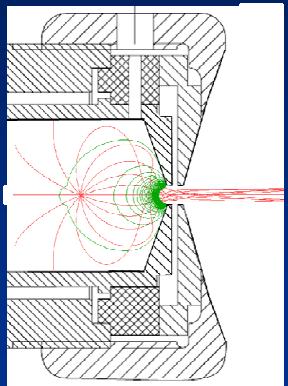
800 isotope beams (70 chemical elements)



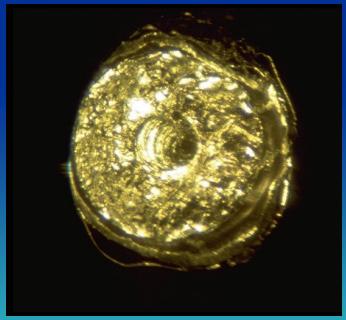


Recent ISOL(DE) Technologies

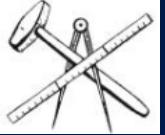
Arc discharge
VADIS ion source
(CERN Courier Apr 09)



Nanograined Target



Aged metal foils



“CERN based” Layout

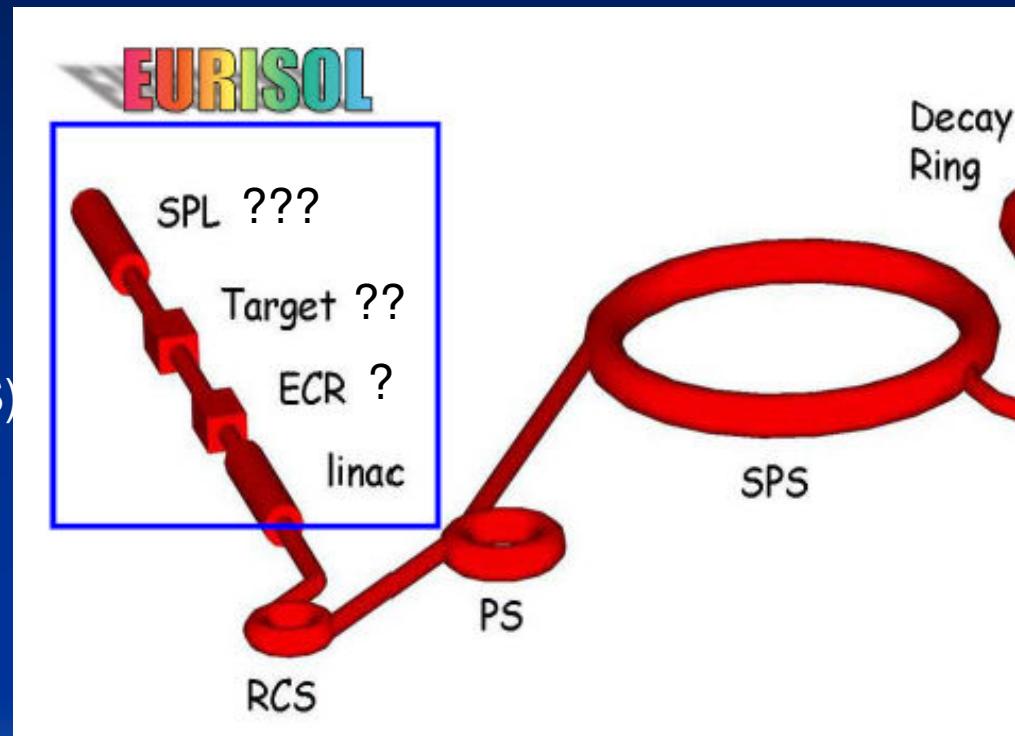
Production of $\bar{\nu}_e$ & ν_e :

$3(.3) \cdot 10^{13} \text{ } ^6\text{He}/\text{s}$

$2(.1) \cdot 10^{13} \text{ } ^{18}\text{Ne}/\text{s}$

out of the primary target

(Final report, FP6 EURISOL-DS)



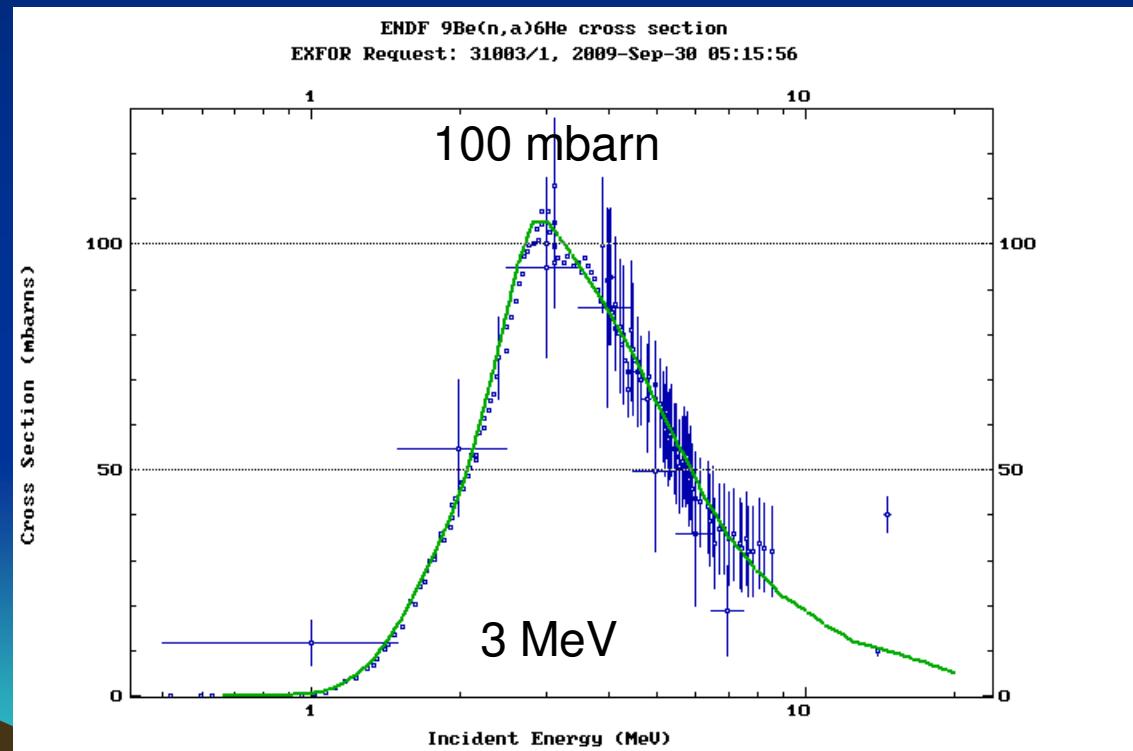


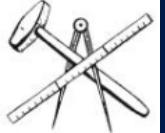
Production of ${}^6\text{He}$ ions for $\bar{\nu}_e$

Elements driving the technical choices for isotopes and targets:

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

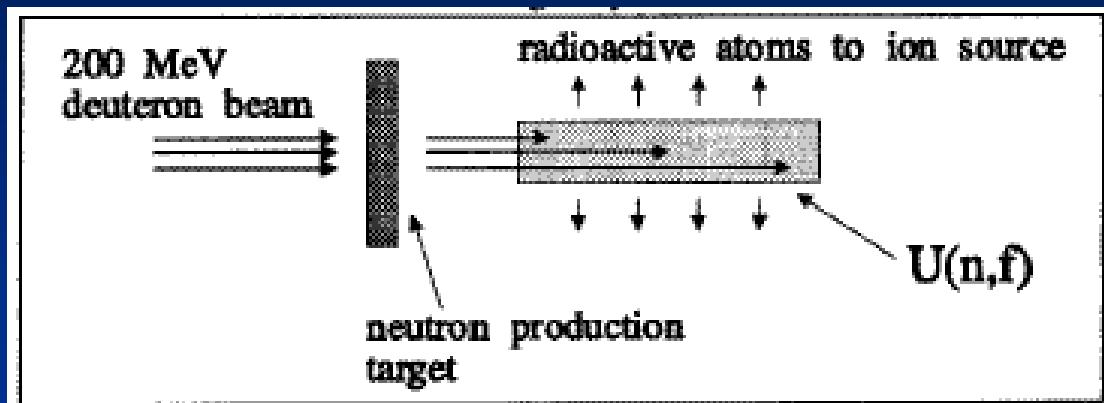
Production of $\bar{\nu}_e$
Out of the target
 $3 \cdot 10^{13} {}^6\text{He}/\text{s}$



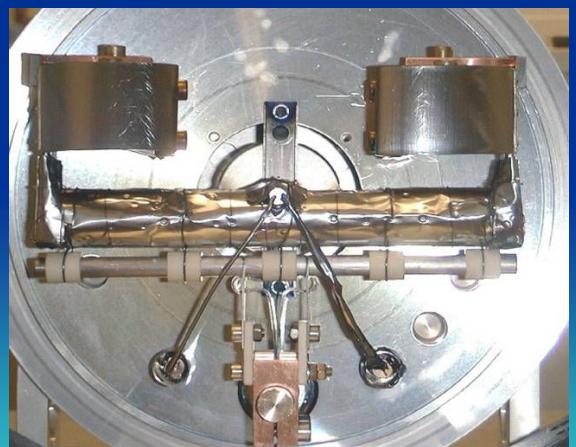


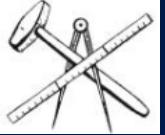
Production of 1-10MeV neutrons

Original idea: J. Nolen, Report to Users of ATLAS, ANL, USA, 1995

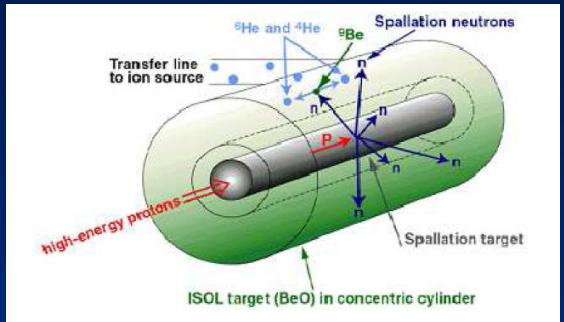
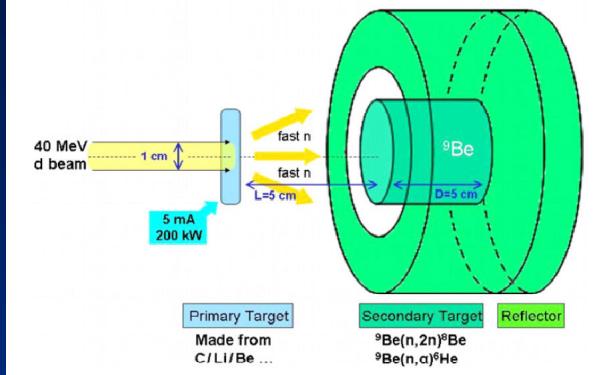


Has been used routinely at CERN ISOLDE
with High Z converter (W) 3kW 1.4 GeV p
for ~ 10 years

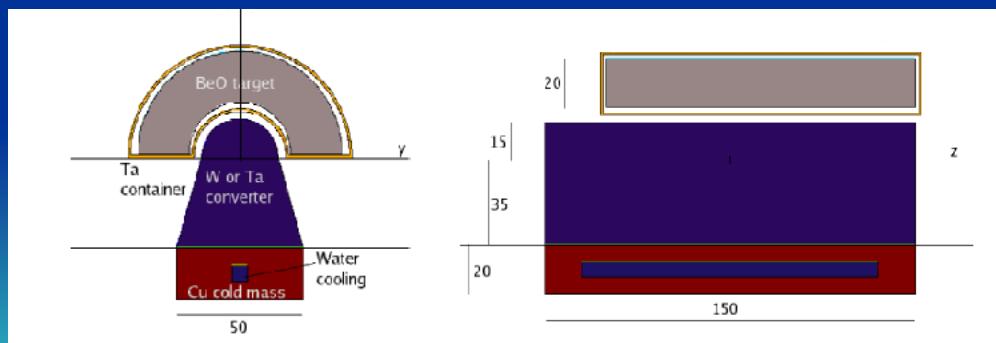




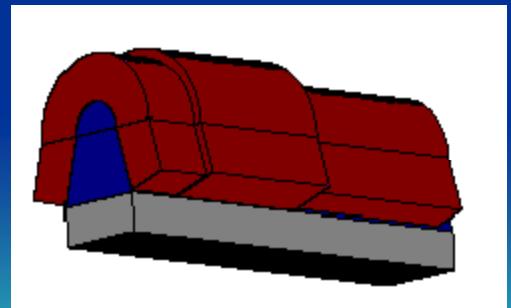
Production of ${}^6\text{He}$



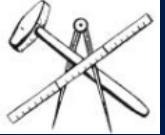
- $1.3 \times 10^{13} {}^6\text{He}/\text{s}$ 100kW, 40 MeV deuton beam
- $2 \times 10^{13} {}^6\text{He}/\text{s}$ 100kW, 1 GeV proton beam
- $10^{14} {}^6\text{He}/\text{s}$ 200kW, 2 GeV proton beam



$\varnothing 3\text{cm}$, 15cm

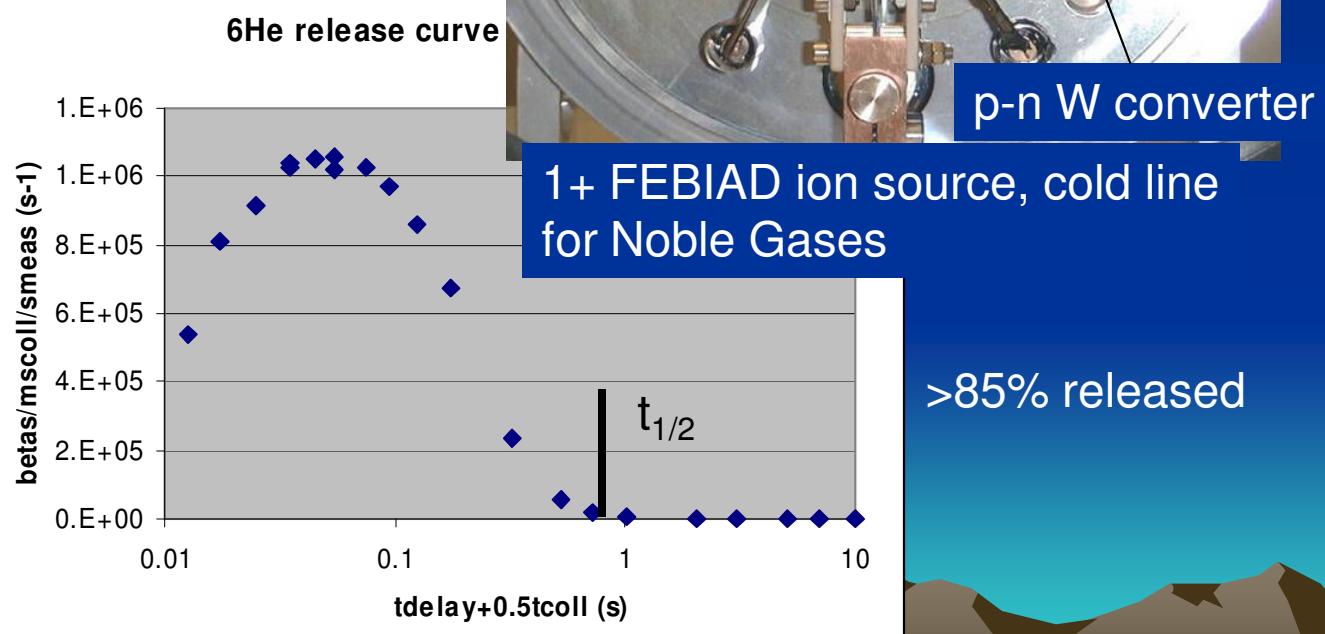
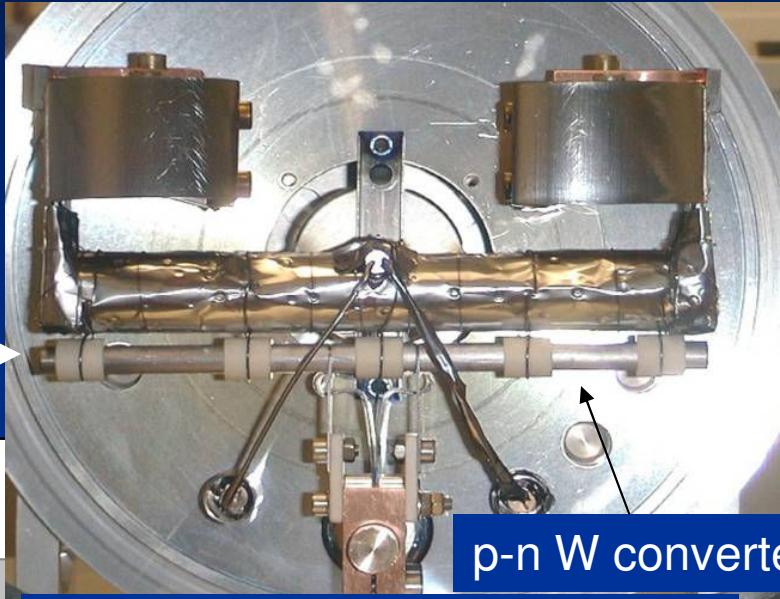


$\varnothing 3\text{cm}$, 24cm



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

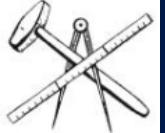
1.4 GeV from PSB



80 porous BeO pellets



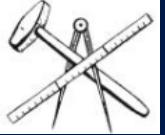
Release efficiency
operation temperature
outgassing
materials compatibility
ageing, etc...



100-200kW operating range

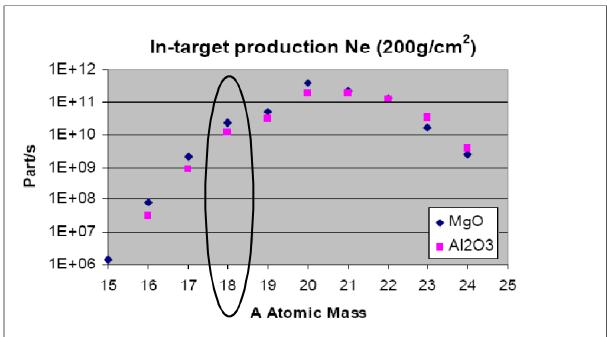
TRIUMF (Canada) operates ISOL Radioisotope beams
at 0.5GeV, 40kW, cw protons
with 1 target / month

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



Production of ^{18}Ne ions for ν_e

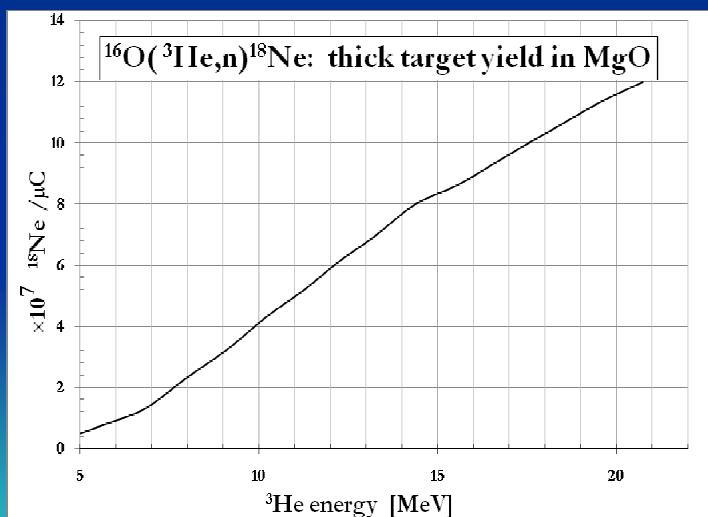
- Direct spallation of 1 GeV protons onto thick oxide targets $\text{Al} (\text{p},\text{X}) ^{18}\text{Ne}$



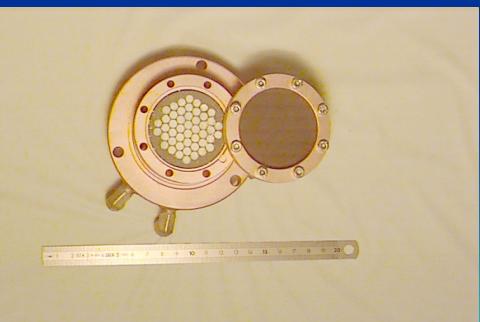
Silberberg-Tsao,
Thin target approx.

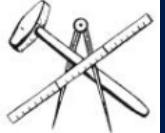
Nominal parameters:
 $3 \cdot 10^{10}$ part/s (Fluka)

Production of ν_e
Out of the target
 $2 \cdot 10^{13} ^{18}\text{Ne}/\text{s}$



Validated at 9kW at LLN.
Needs $\sim 200\text{mA}$, ^3He 21MeV, $\varnothing 86\text{cm}$ target





Production of ^{18}Ne ions for ν_e

Other reactions (mainly coming from ^{18}F production for PET imaging):

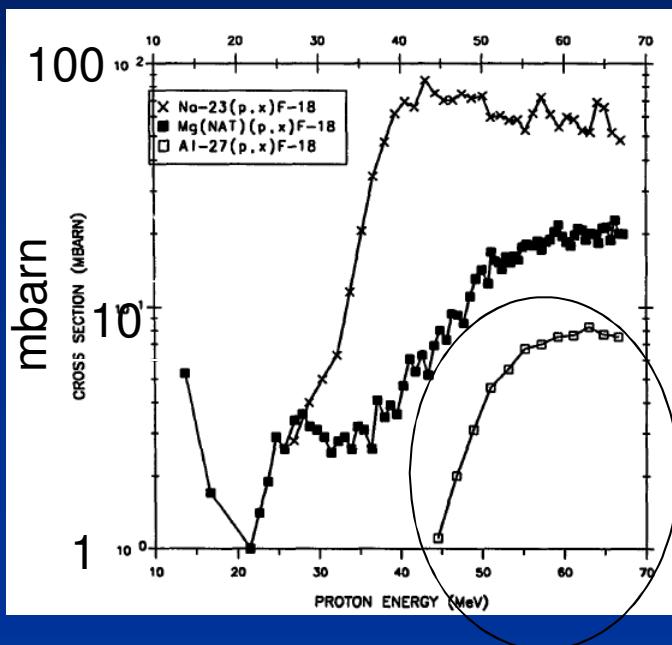
$^{19}\text{F}(\text{p},2\text{n})^{18}\text{Ne}$: threshold 16 MeV, peak at 1.6 mbarn @ 30 MeV (M. Loiselet, S. Mitrofanof)

$^{24}\text{Mg}(\text{p},\alpha p2\text{n})^{18}\text{Ne}$: threshold 39 MeV, cross-sections ?

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

We need ~ 30mA, 70MeV p, and target R&D (~ 600kW to be dissipated) for $2 \cdot 10^{13} \text{ }^{18}\text{Ne}/\text{s}$

Production of ν_e
 $2 \cdot 10^{13} \text{ }^{18}\text{Ne}/\text{s}$



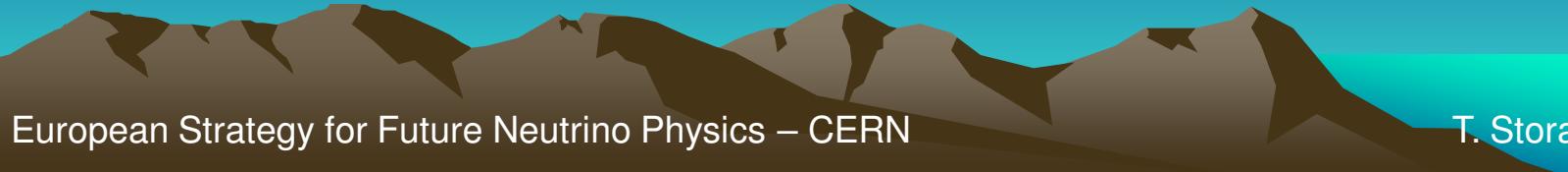


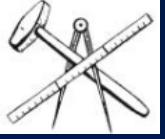
The Transfer line between the target and the ion source

Closing valves for the ion source operation

Appropriate length:

- prevent important isotope decay losses
- trap eventual residual gases
- accommodate shielding



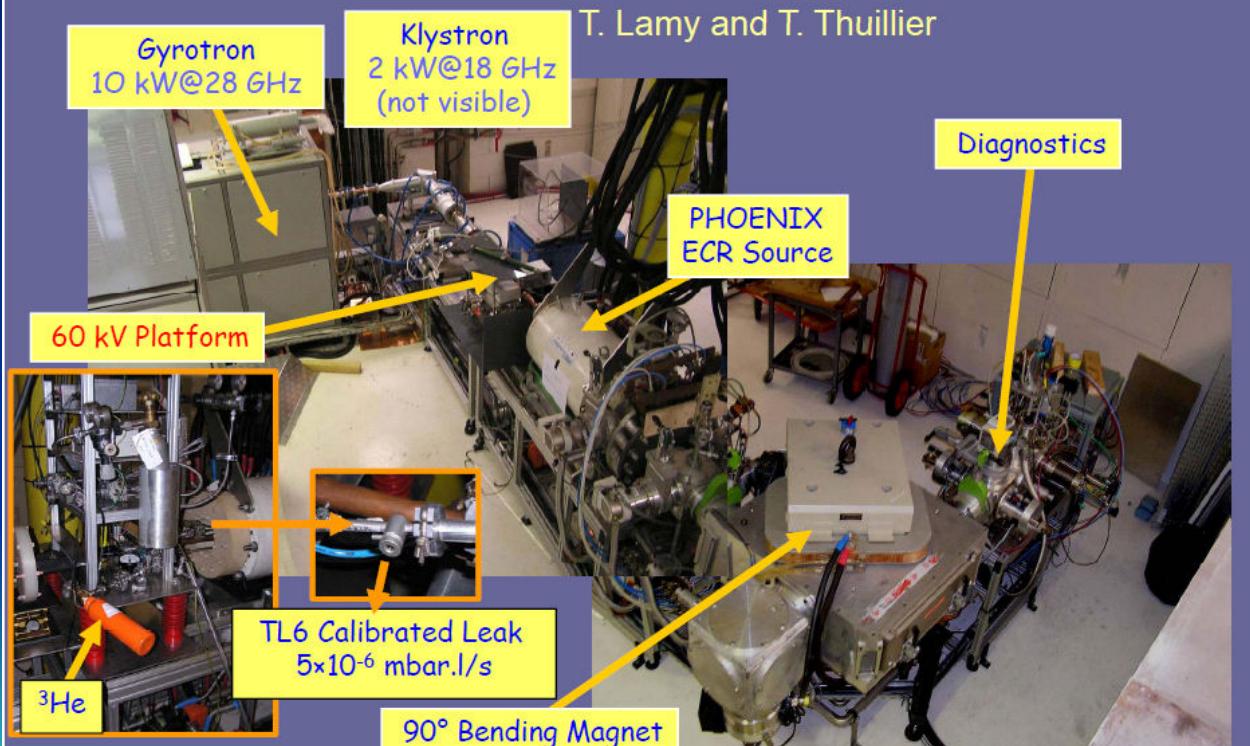


The ion source

Operation of a 60GHz ECR ion source in a bunching mode (“preglow”)

Tests were performed on 18 and 28GHz ECRIS available at LPSC

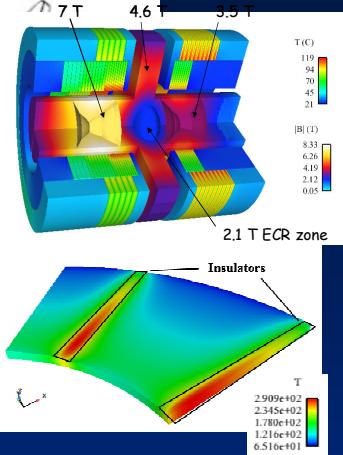
Experiments at LPSC Grenoble



P. Delahaye, beta-beam meeting, Stockholm 3-4/05/2007



LPSC - 60 GHz ACTIVITIES



Prototype - End of the thermal simulations in helices

24 to 32 insulating areas are necessary to:

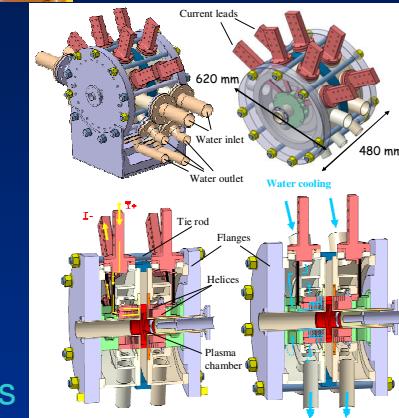
- Handle the repel forces generated by the magnetic field
- Avoid the contact of 2 windings between two insulating areas



Max coil temperature: $T_{\text{Max loc.}} \sim 290^\circ\text{C}$, $T_{\text{mean}} \sim 180^\circ\text{C}$

Prototype - End of the mechanical design

Beginning of the construction

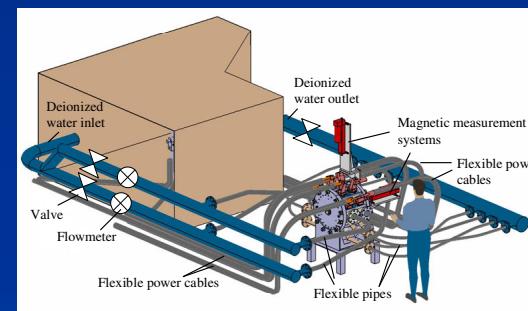


Magnet time proposal to EUROmagnetII accepted (group A, 15 days)
Modification of the LNCMI environment for magnetic field measurements



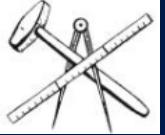
schematic view of the temporary on-site setup for the half-magnetic field test

- Electrical parameters
 - $I = 15000 \text{ A}$
 - $P = 1.5 \text{ MW}$
- Max coil temperature
 - $T_{\text{mean}} = 50^\circ\text{C}$
 - $T_{\text{Max loc.}} = 70^\circ\text{C}$



- Source Assembly for October 2009
 Magnetic field measurements at half intensity
- Tests of the source at 28 GHZ expected in 2010
- Scientific collaboration ISTC (IAP NN, LPSC, LNCMI, CERN, Istituto di Fisica del Plasma) accepted July 2009 (490 k€ EU + 225 k€ LPSC)
 Objectives: Gyrotron manufacturing, 60 GHz plasma and beams developments





Overview

^6He $3\text{e}13/\text{s}$ out of the target can be achieved:

simulations done : 1-2GeV p, 40MeV d

1-2 GeV 100-200kW converter : in operation RAL

40MeV d converter : under development SPIRAL 2, GANIL
isotope production with suitable thick target tested ISOLDE

^{18}Ne $2\text{e}13/\text{s}$ out of target:

^3He , 30MeV, 200mA on oxide target, but MW beam required

1-2GeV p no

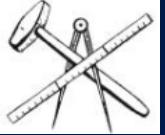
p, 70MeV, 30mA on Al_2O_3 target, but 100kWs solid target R&D

60GHz ECRIS in bunched mode:

characterized for 18 and 28GHz ECRIS

Need to confirm 90 and 30% efficiency, 50 μs bunch length

Need to confirm gas load and beam extraction



Additional remarks

Ongoing developments of low energy, high intensity Linac (IFMIF-EVEDA, SPIRAL 2, SOREQ)

Ongoing developments of n converters (IFMIF-EVEDA, SPIRAL 2, ESS)

Linac 4 – SPL program at CERN : 70MeV, 1-2 GeV p delivery

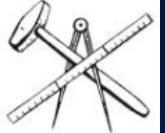
Ongoing R&D on 60GHz ECRIS.

Will need to be tested with full target, and under beam irradiation

High power target R&D for ^{18}Ne production needs to start + σ p 70 MeV

Full converter-BeO target for ^6He needs to be tested

Clear synergies with Radioactive Ion Beam facilities :
SPIRAL2, HIE-ISOLDE phase 2 (100kW), EURISOL



References and Acknowledgement

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- P. Delahaye, T. Thuillier, T. Lamy, E. Noah, E. Wildner, M. Marie Jeanne, M. Loiselet, M. Hass, R. Garoby for fruitful inputs