SPES project at LNL

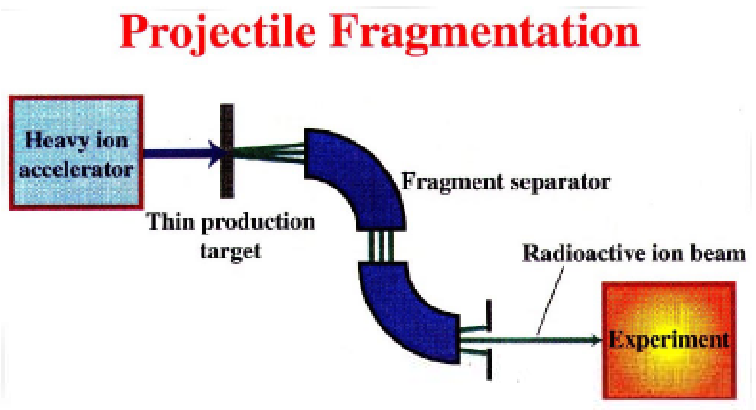
HIAT09

Venezia June 8-12, 2009

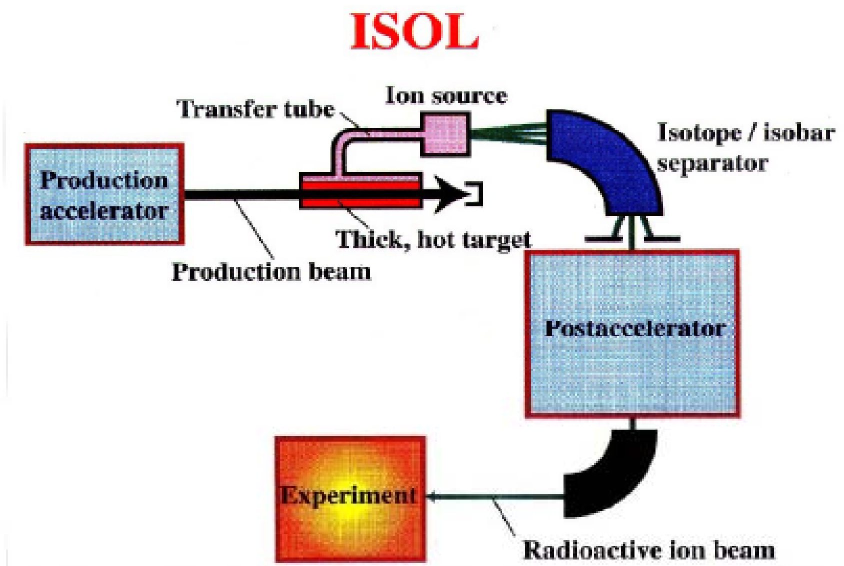
Gianfranco Prete
On behalf of SPES collaboration

Conclusions of the NuPECC Working group on the "Next Generation European Radioactive Ion Beam Facilities" (April 2000)

Next generation of RIB facilities should aim at intensities 1000 times higher than in the facilities presently running or at the commissioning stage. Two truly complementary facilities, based respectively on the « In flight and ISOL» methods are needed to cover the foreseen physics issues.



High energy,
large variety of species



good beam quality,
High flexibility,
High intensity

Conclusions of the NuPECC Working group on the "Next Generation European Radioactive Ion Beam Facilities" (April 2000)

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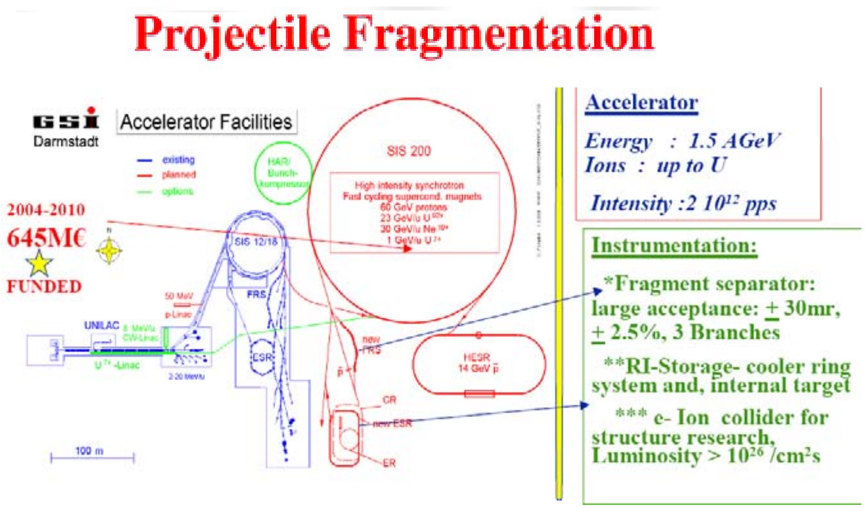
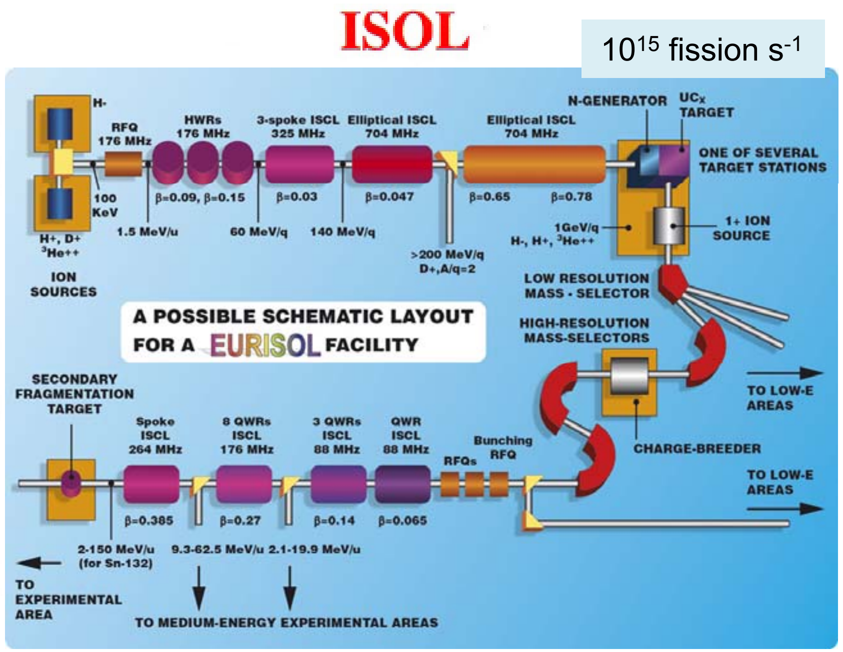


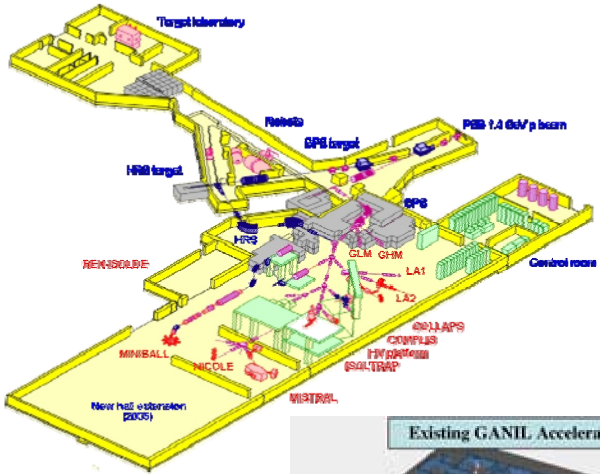
Under construction



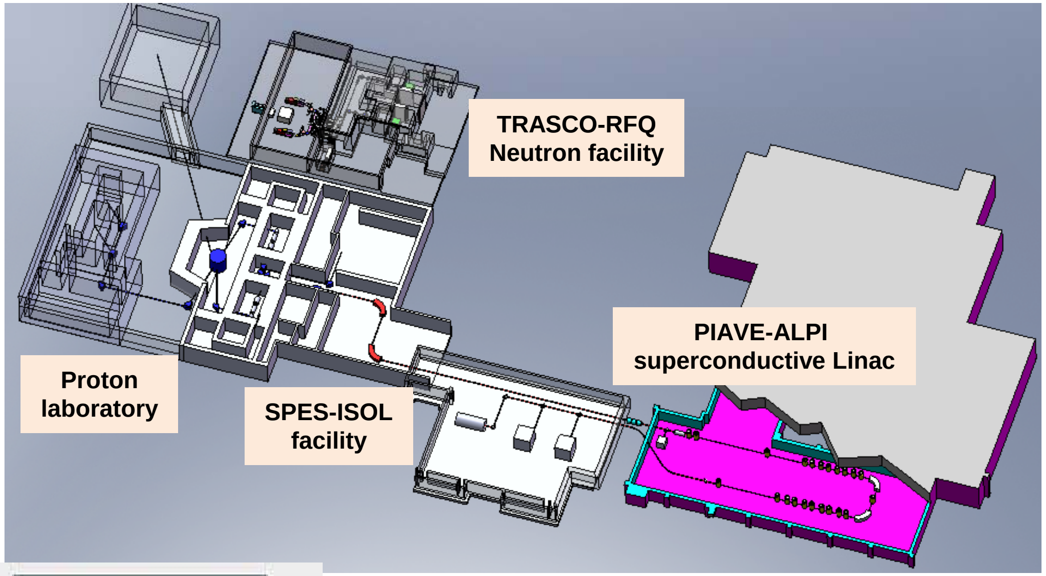
Design study

Second generation ISOL facilities toward EURISOL

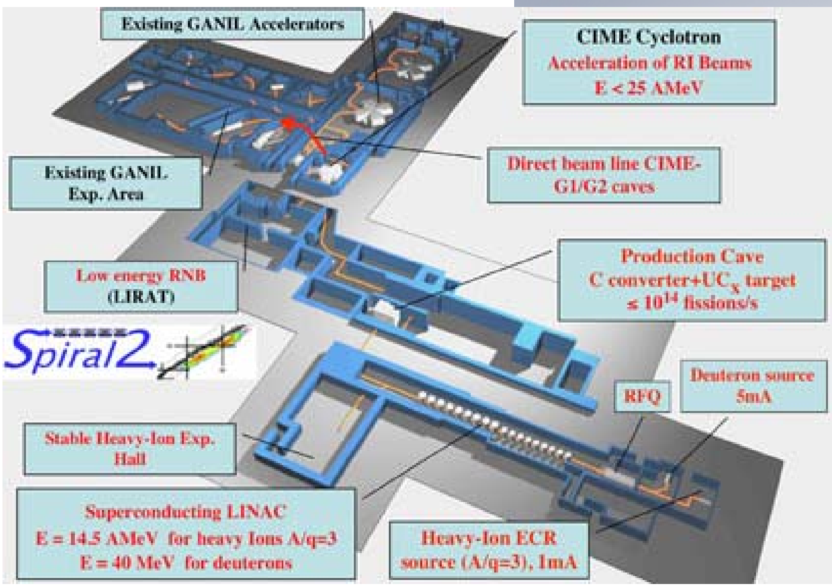
HIE ISOLDE



SPES



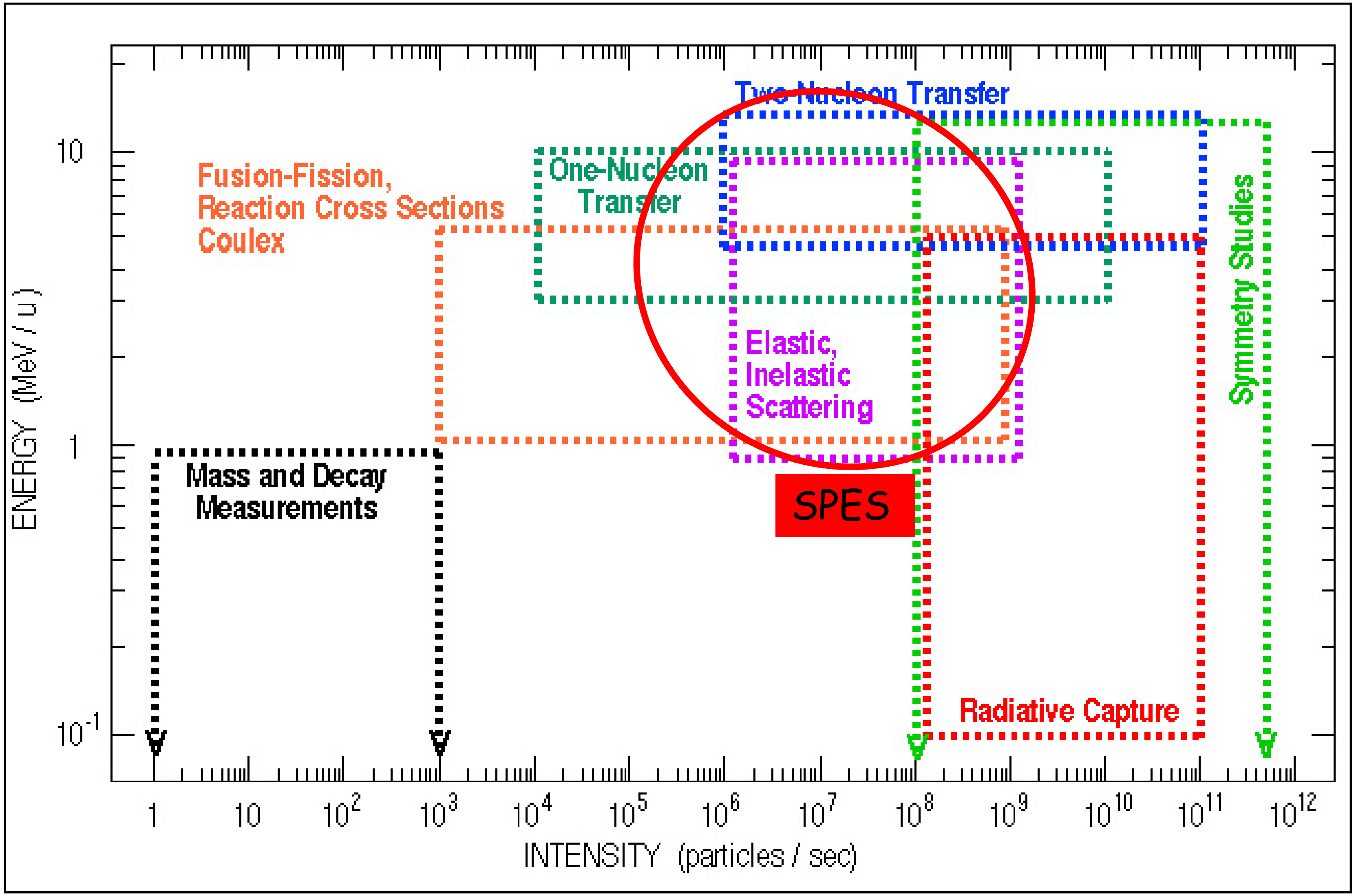
SPIRAL2



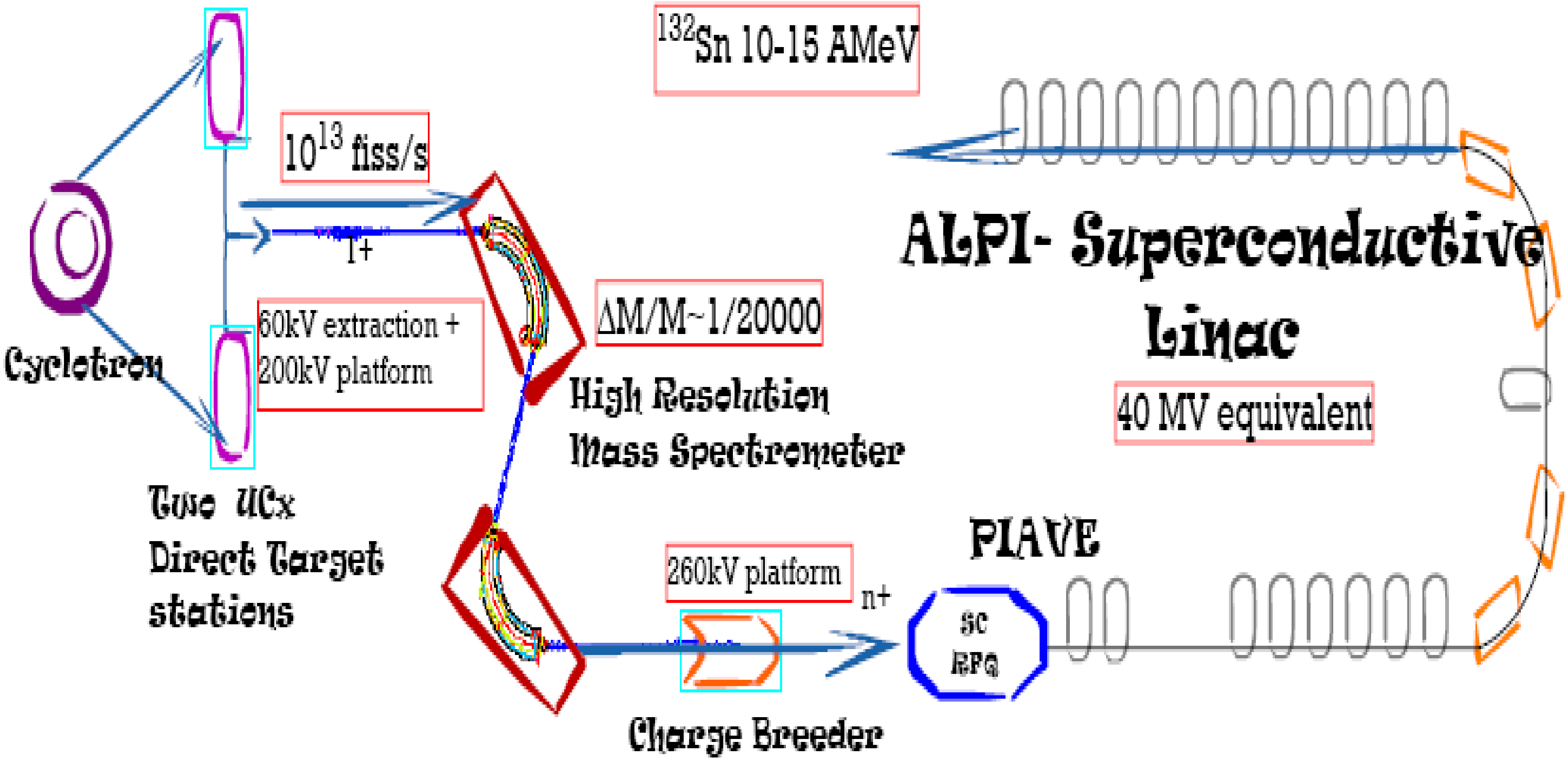
Neutron rich exotic beams
$10^8 – 10^{10}$ pps on target

Production target: UCx
10^{12}-10^{14} fission s^{-1}

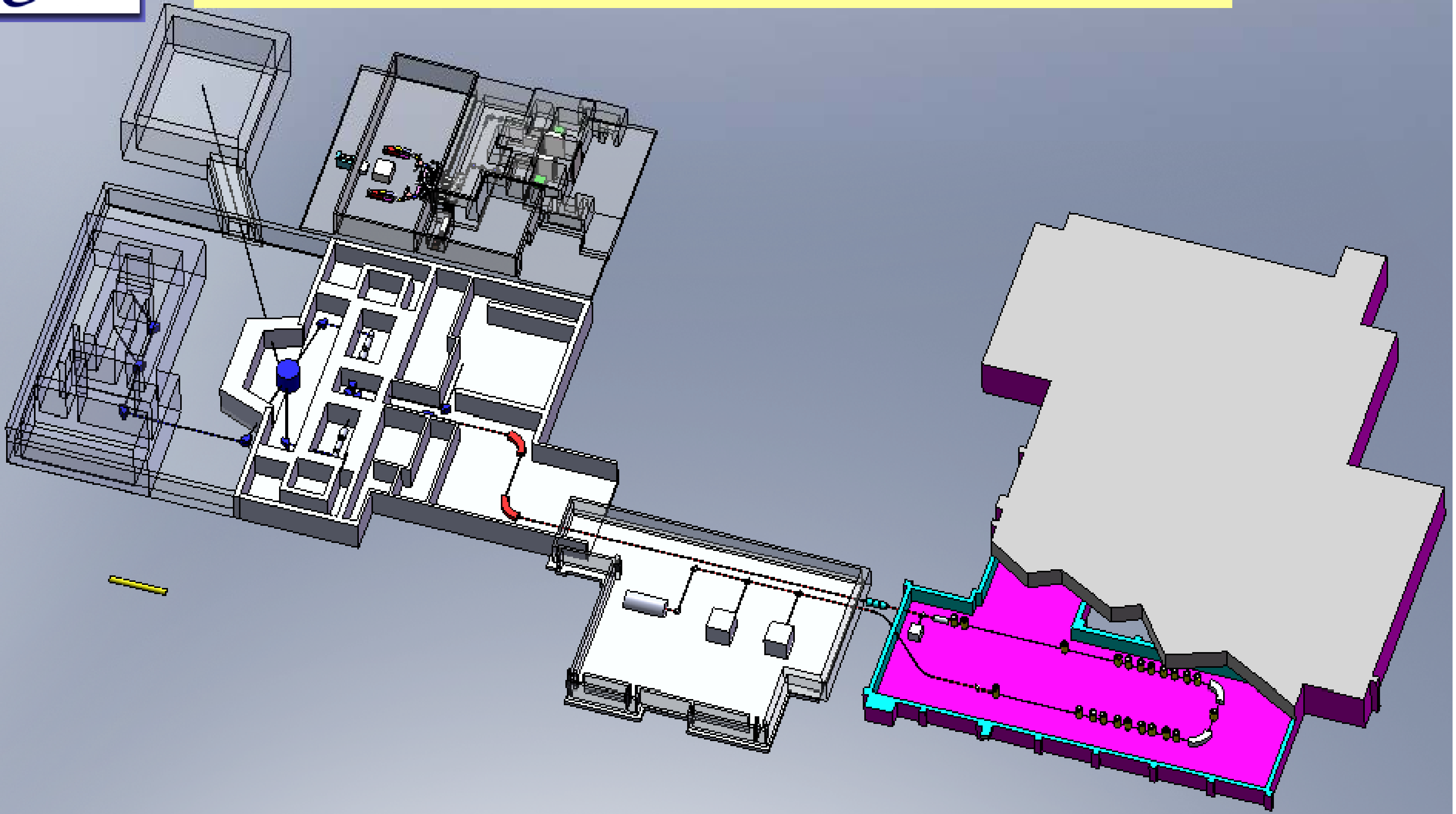
Physics Domain with RIB



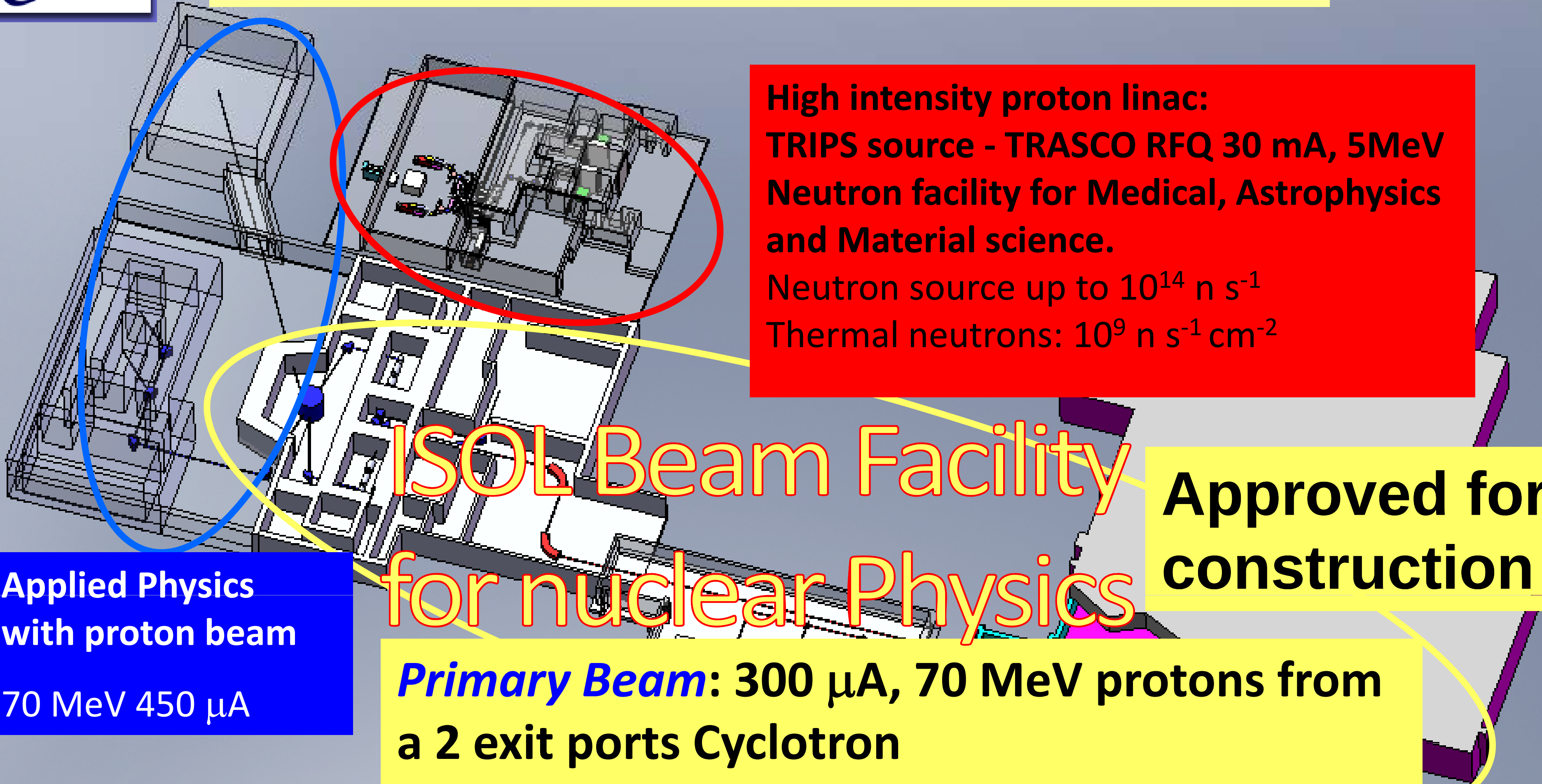
SPES ISOL facility conceptual design



The SPES Project @ LNL: a multi-user project



The SPES Project @ LNL: a multi-user project



High intensity proton linac:
TRIPS source - TRASCO RFQ 30 mA, 5MeV
Neutron facility for Medical, Astrophysics and Material science.
Neutron source up to 10^{14} n s^{-1}
Thermal neutrons: 10^{9} n s^{-1} cm^{-2}

Applied Physics with proton beam

70 MeV 450 μA

ISOL Beam Facility for nuclear Physics

Approved for construction

***Primary Beam*: 300 μA, 70 MeV protons from a 2 exit ports Cyclotron**

***Production Target*: UCx 10^{13} fission s^{-1}**

***Re-accelerator*: ALPI Superconductive Linac up to 11 AMeV for A=130**

The SPES ISOL facility components

1. DRIVER
2. TARGET-ION SOURCE
3. BEAM TRANSPORT-SELECTION
4. CHARGE BREEDER
5. REACCELERATOR

The driver cyclotron

(Commercial solution)

IBA C70 characteristics:

- Diameter < 4m
- Weight > 120t
- Magnetic Gap: 30mm
- Magnetic field: 1.55T
- Extraction Radius: 1.2m
- 2 exit ports
- Particles: **H⁻** / D⁻ / He²⁺/ HH⁺
- **Variable Energy** : 15 MeV → 70 MeV
- extraction Systems:
  - **Stripper → H⁻ / D⁻**
  - Deflector → He²⁺/ HH⁺
- Performances:
  - **750μA H⁻ → 70MeV**
  - 35μA He²⁺ → 70MeV

SPES design

(possible candidates)

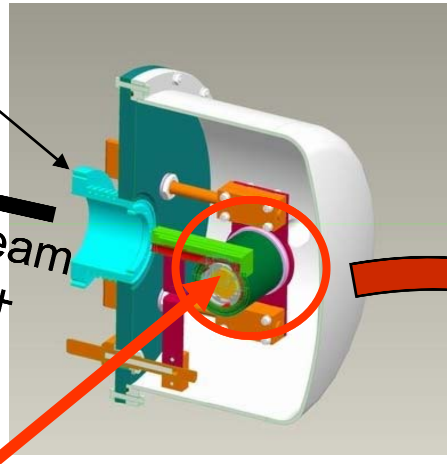
IBA C70 cyclotron

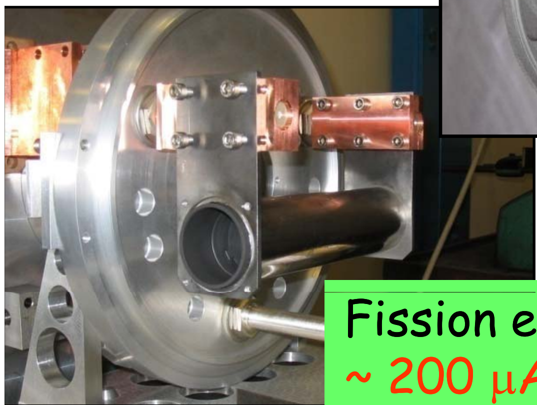
ACSI TR30

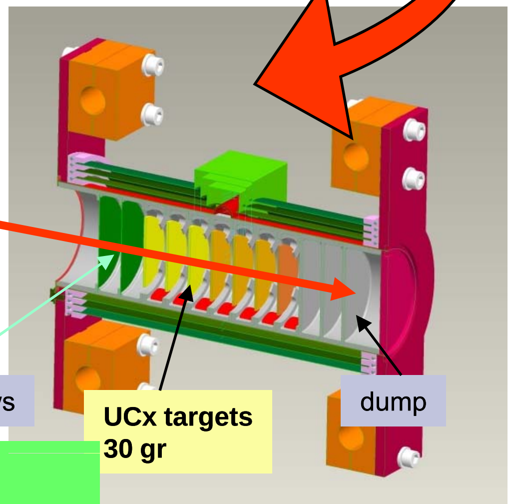
ACSI TR70 cyclotron project

ADVANCED CYCLOTRON SYSTEMS
Outperforming the field

The SPES direct target





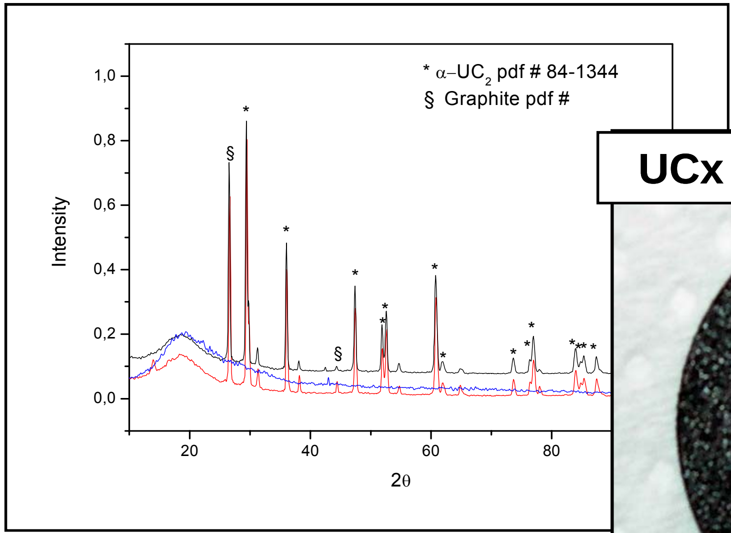


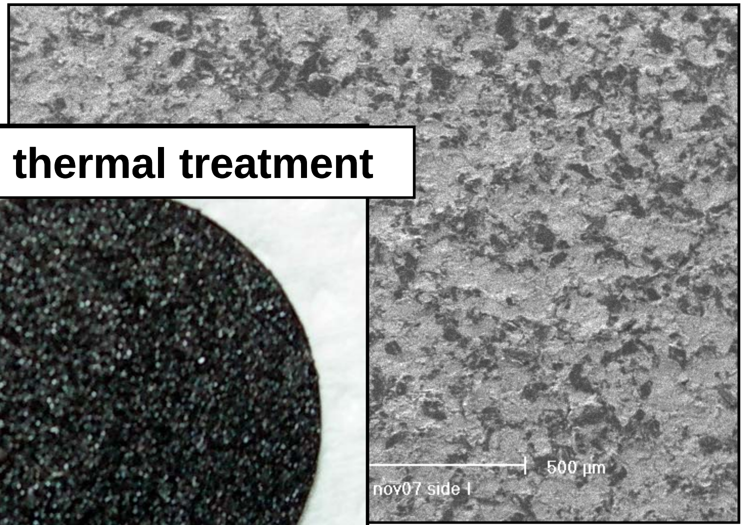
Fission efficiency → 100p per 1.5 FF

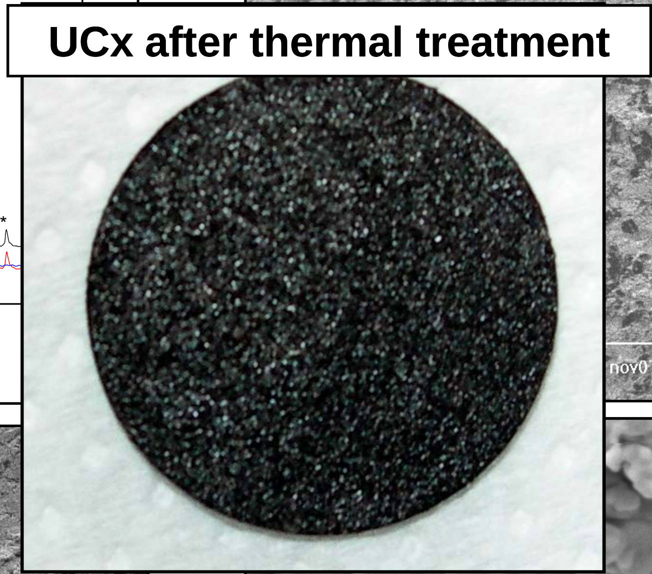
~ 200 μA → 10^{13} fissions/sec

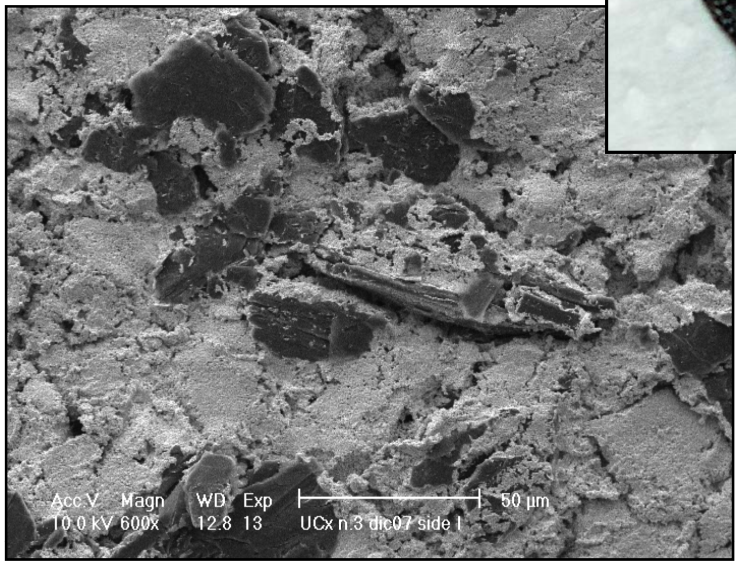
Beam power = 40 MeV p x 200 μA = 8 KW

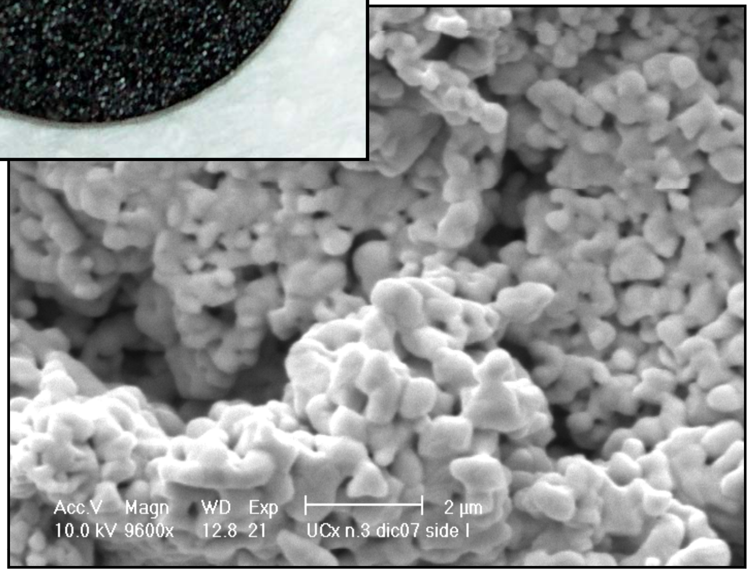
UC_x Characterization: SEM & XRD











SEM = Scanning Electron Microscope

XRD = X Ray Diffraction

SPES beams: Isotopes Release

- GEANT4 toolkit and the RIBO codes.
- Experimental data available from ISOLDE-CERN, ORNL and PNPI Gatchina

T_{diff} Sn= 1sec (ISOLDE UCx material)
T_{eff} = walking time in the container
$T_{Sticking}$ Sn = 10^{-6} sec

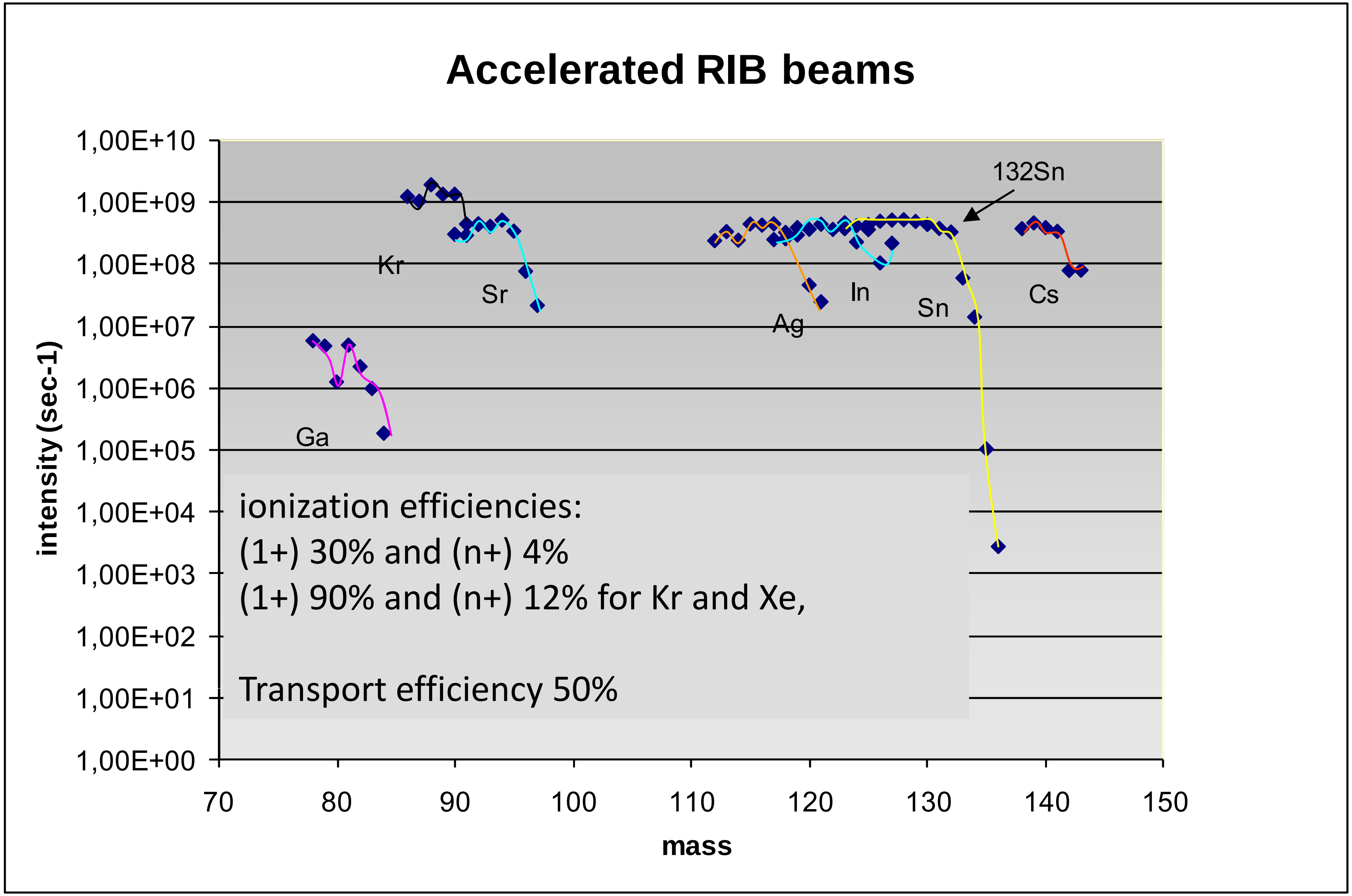
UC_x target 25 gr U

Release time = τ = $T_{diff} + (T_{tof} + N \times T_{sticking})$

Sn τ_{SPES} = 1 + 0.1 + 0.1 = 1.2 s

element	Diffusion time (s)	Nr of collisions	Effusion Time (s)	Release Time (s)	$T_{1/2}$ (s)	Total Release Fraction (%)
^{132}Sn	1	10^5	0.2	1.2	40	98
^{133}Sn	1	10^5	0.2	1.2	1.4	40
^{133}Sn				40	1.4	1

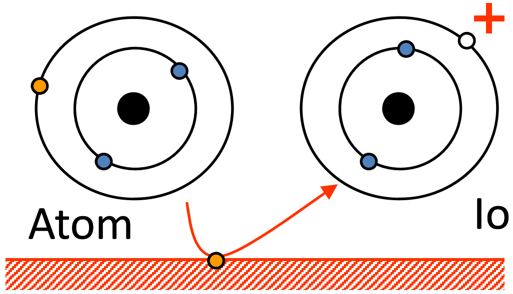
Some expected Beams at SPES

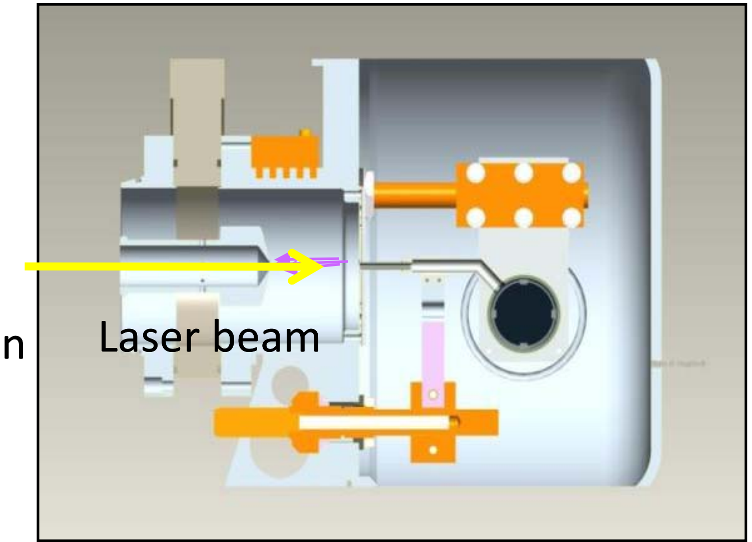


The SPES Ion Sources

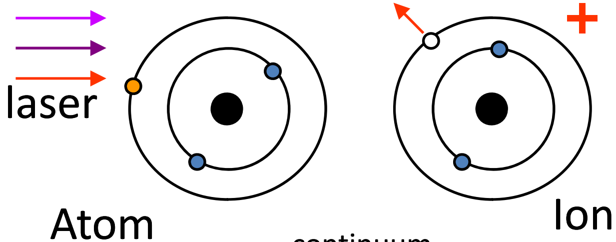
Ionization schema with a Surface ionizer coupled to a Laser beam

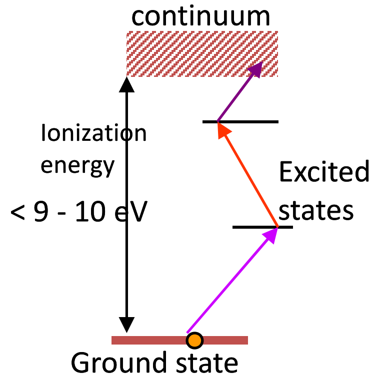
Surface ionization

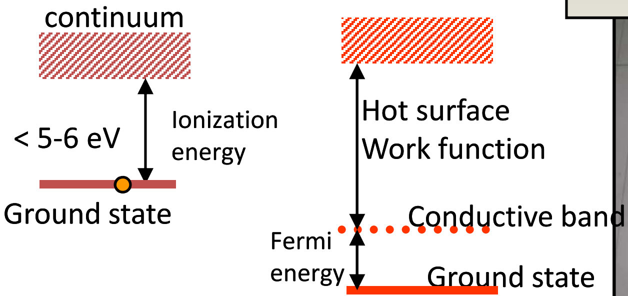


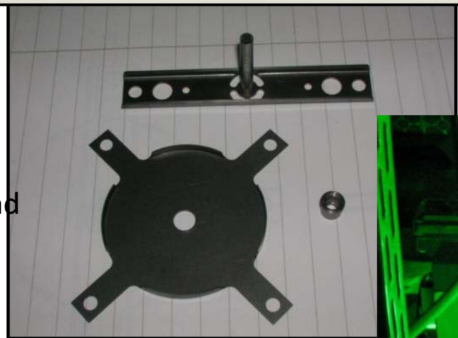


Laser ionization

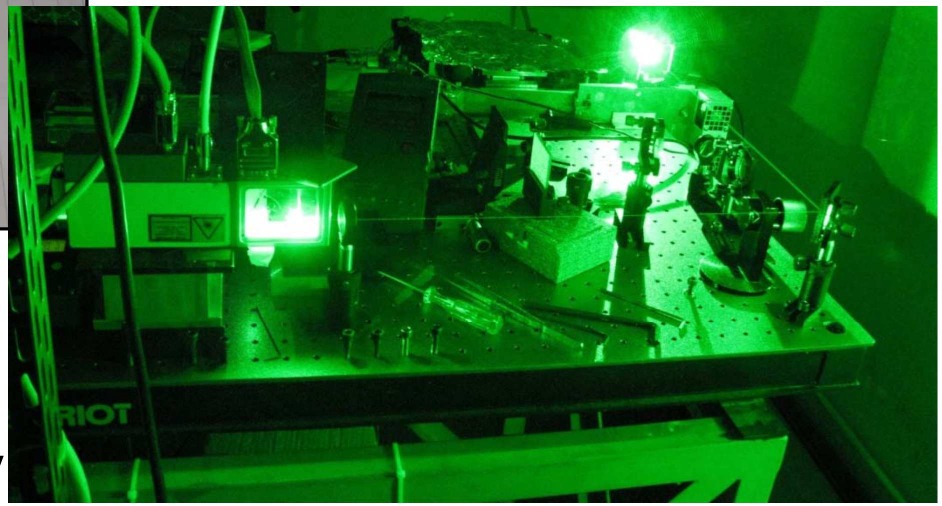








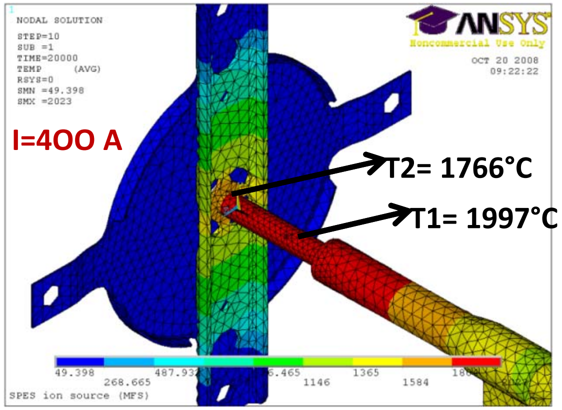
INFN-Pavia
SPES Laser Laboratory



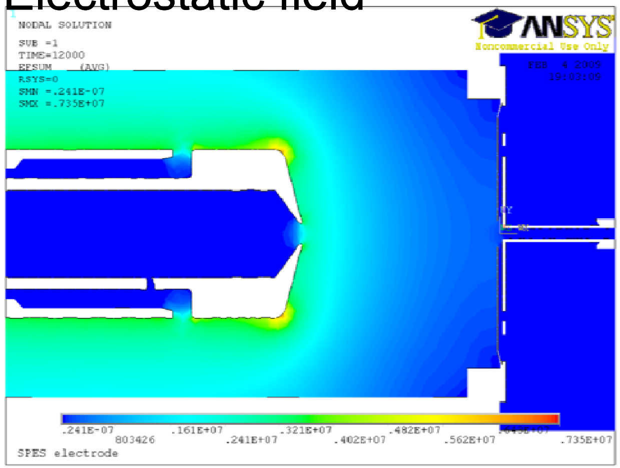
Surface Ionization Source

ANSYS simulation

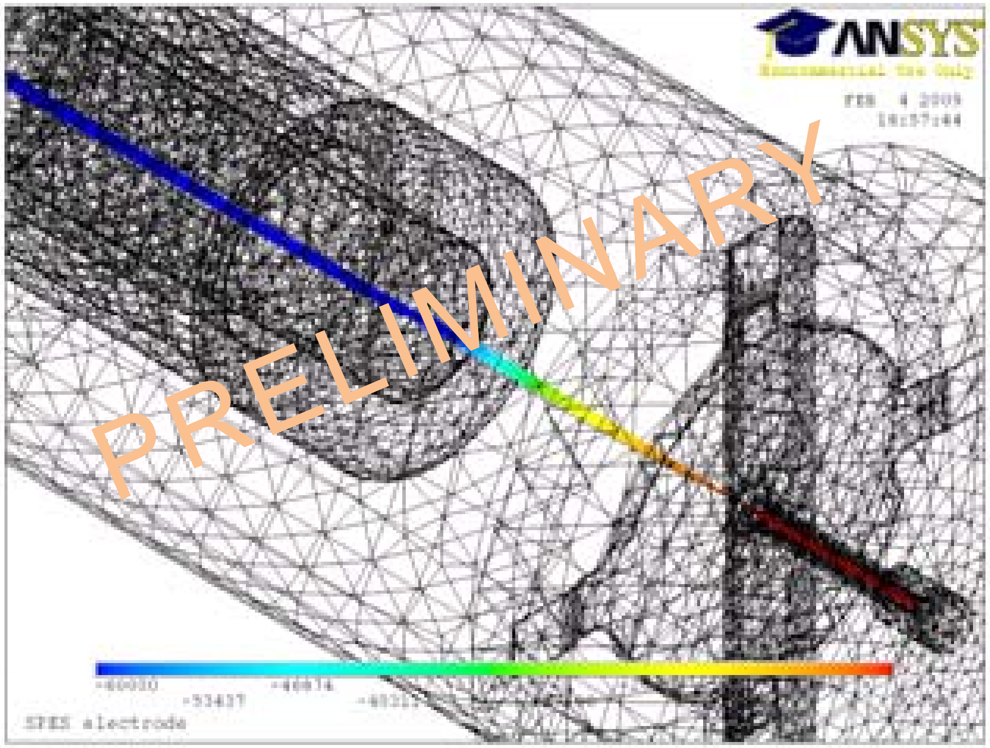
Thermo-mechanical simulation



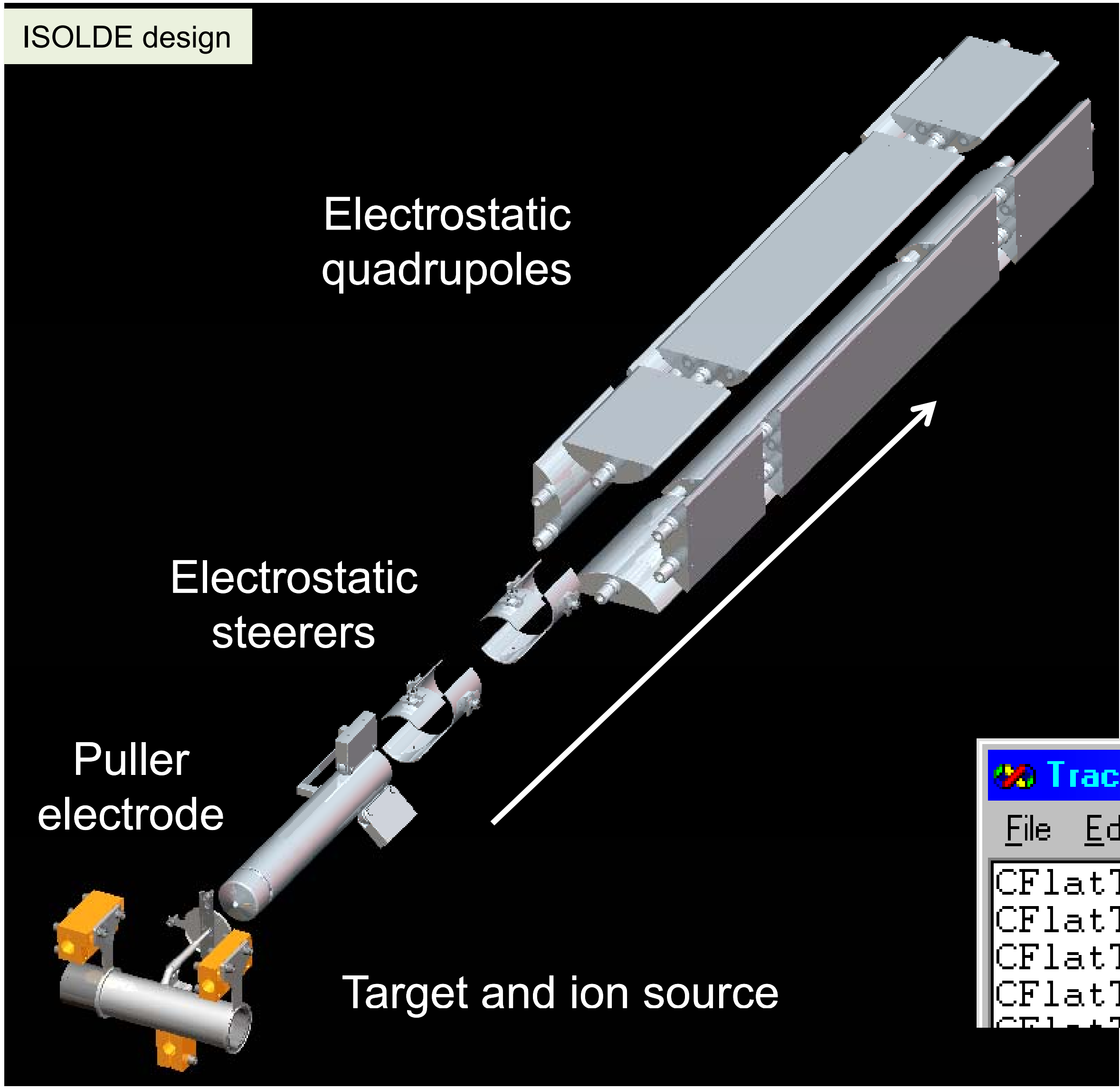
Electrostatic field



Ions trajectory

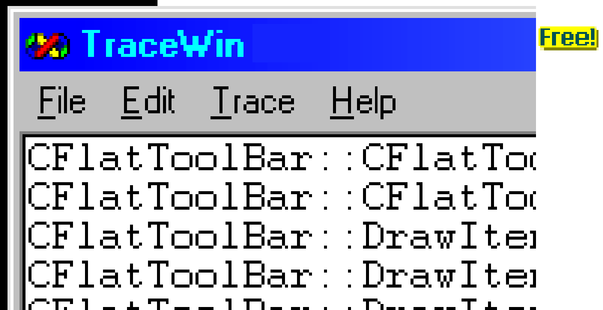


Beam transfer in the Front End



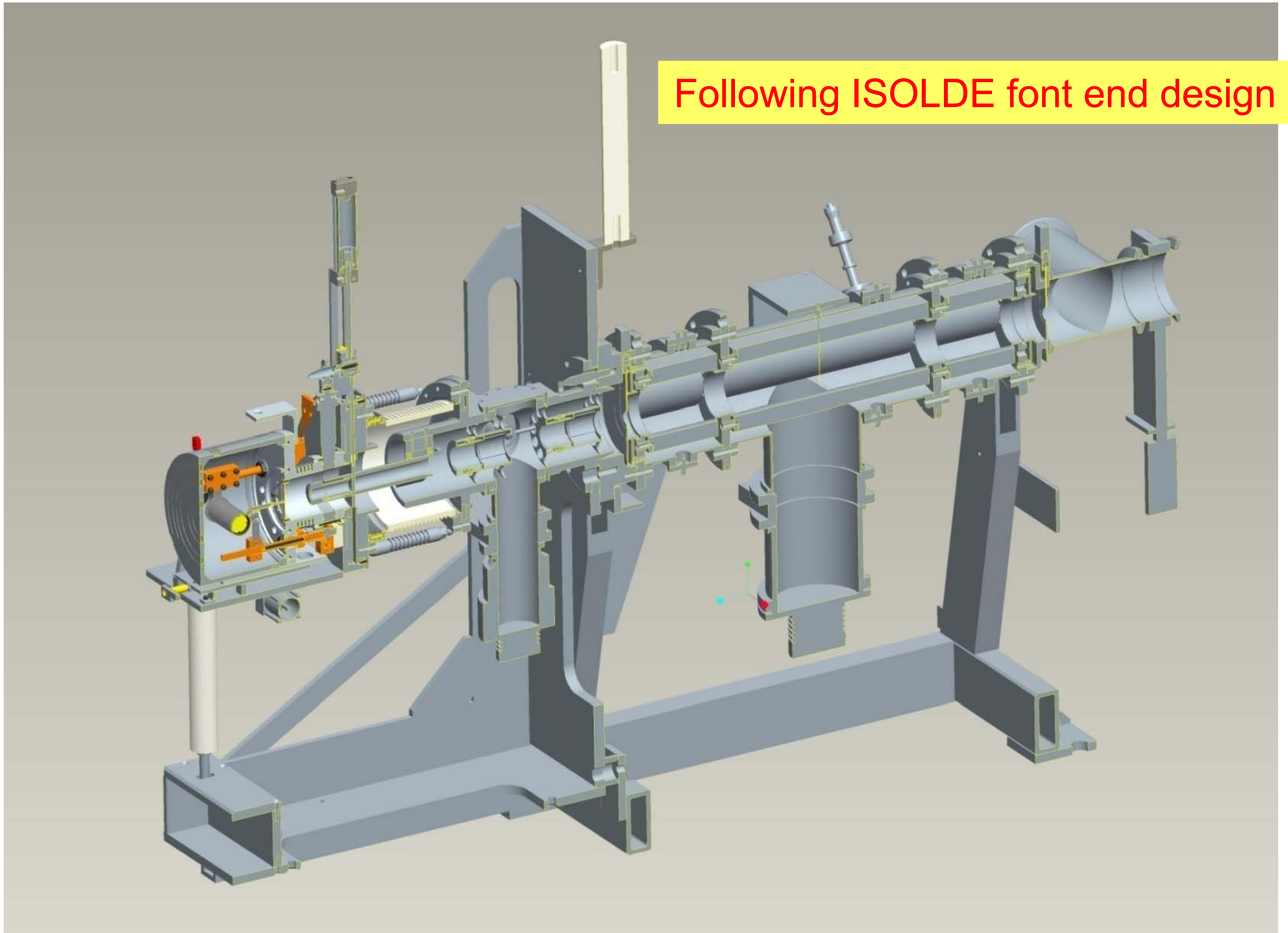
The beam is accelerated to 60KeV by the puller and shaped by electrostatic devices.

TraceWin will be used for beam calculation.



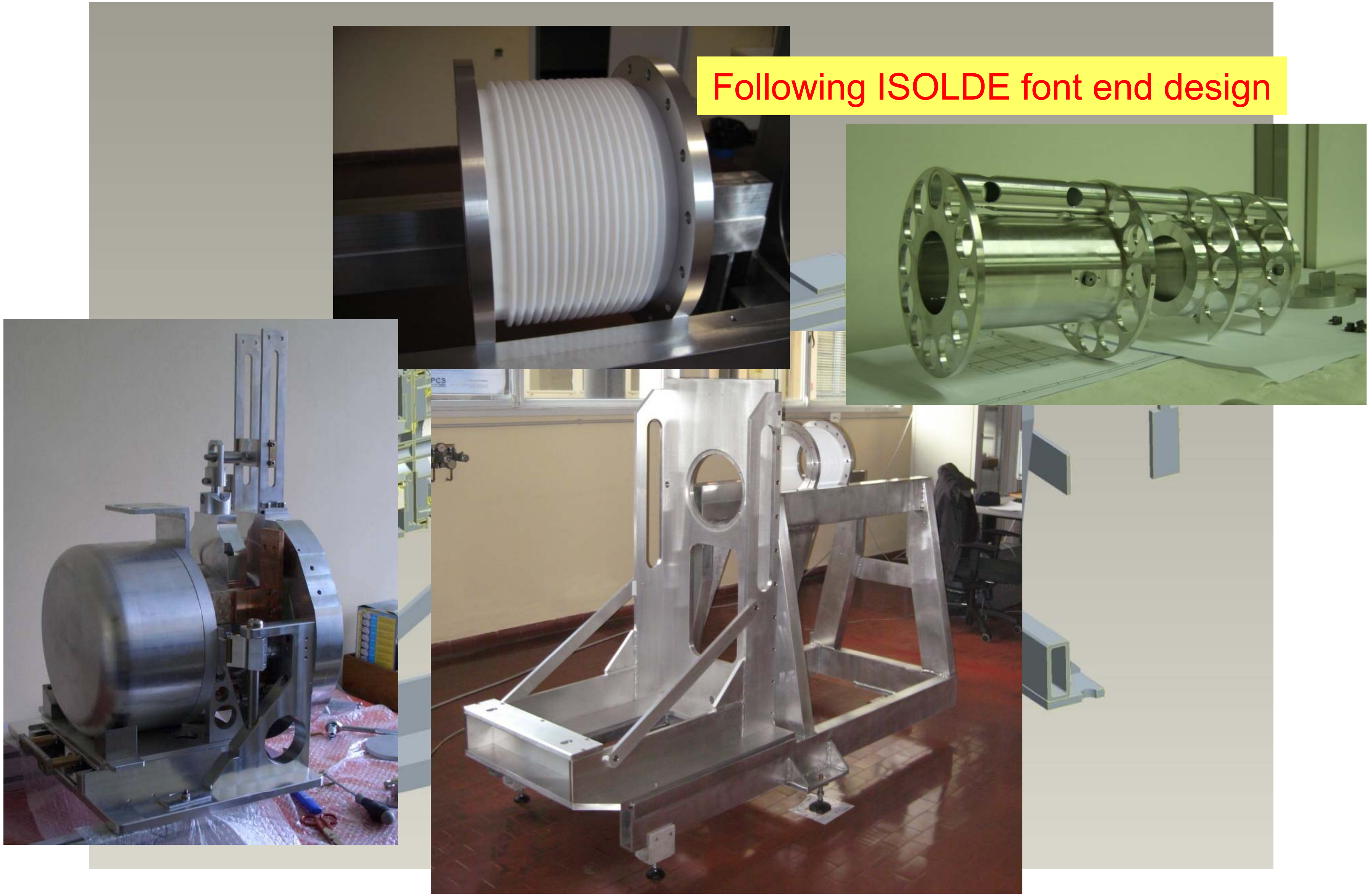
RIB Front end construction

In collaboration with INFN Milano & INFN Pavia



RIB Front end construction

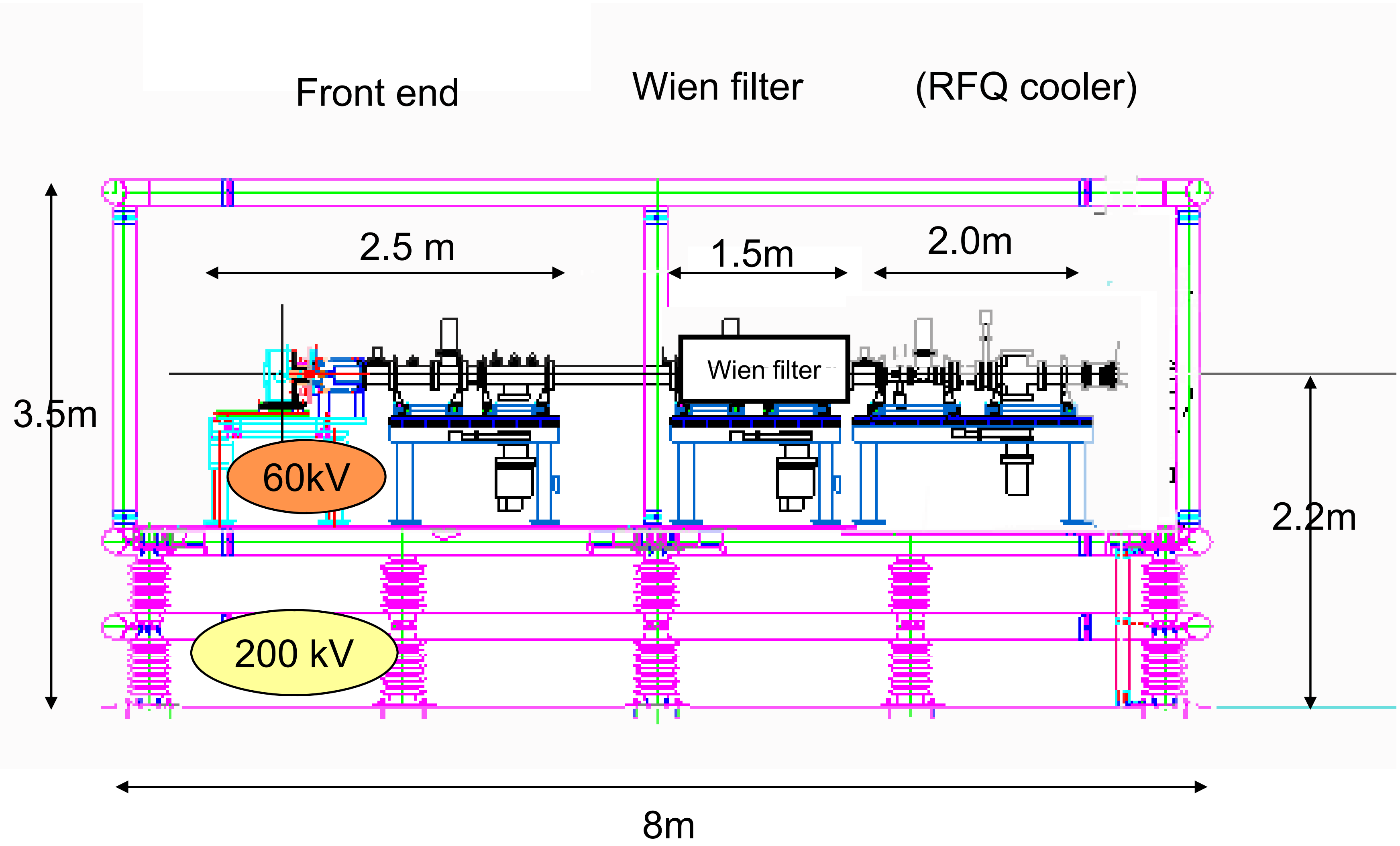
In collaboration with INFN Milano & INFN Pavia



RIB Front end

(status at May ‘09)

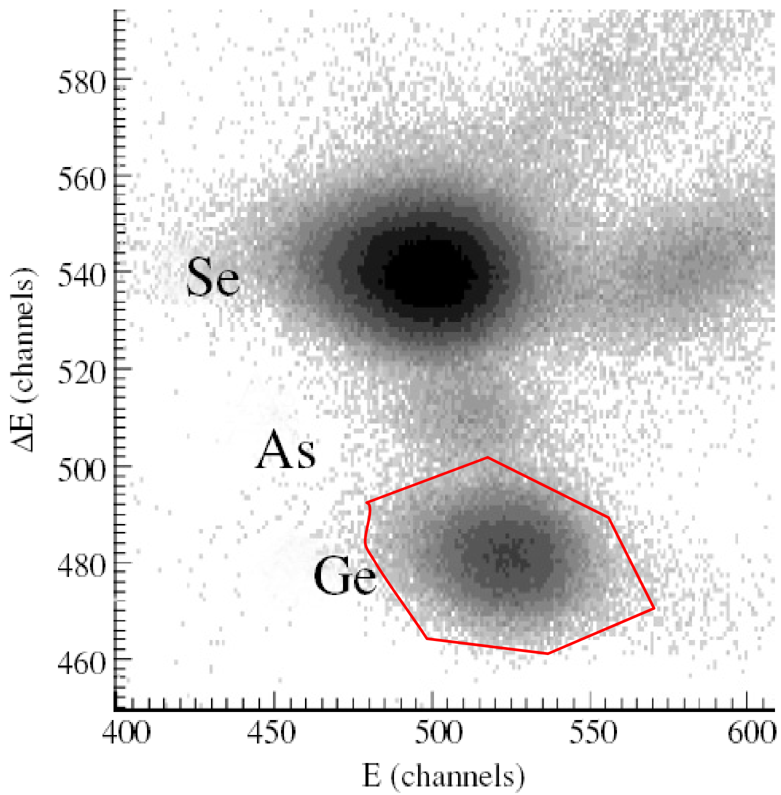
SPES High Voltage platform



HV platform: EXCYT – HRIBF design

Beam selection and identification

Beam: Isobaric mixed Beam: A=82

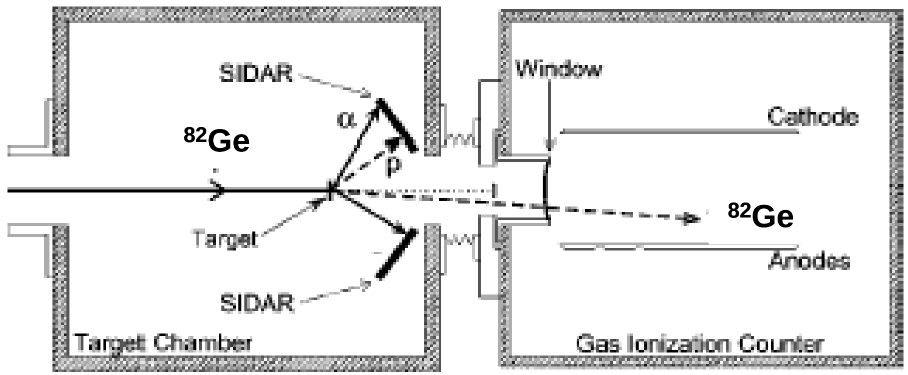


First study of the level structure of the *r*-process nucleus ^{83}Ge

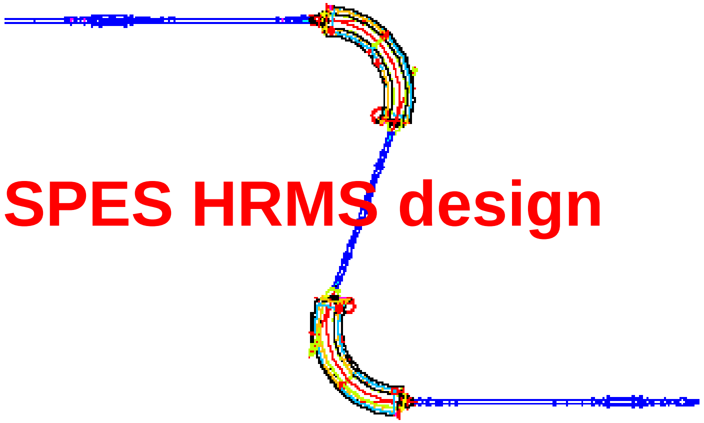
ORNL-HRIBF J. S. Thomas et al. PHYSICAL REVIEW C **71**, 021302 (2005)

- Identification of beam and beam-like particles by Ionization Chamber, total rates up to 10^5 particles per second.
- *A* = 82 beam was composed of several isotopes: stable ^{82}Se (85%), **^{82}Ge (15%)** and a trace of ^{82}As (<1%).
- **HRIBF: $5x10^{11}$ f/s**

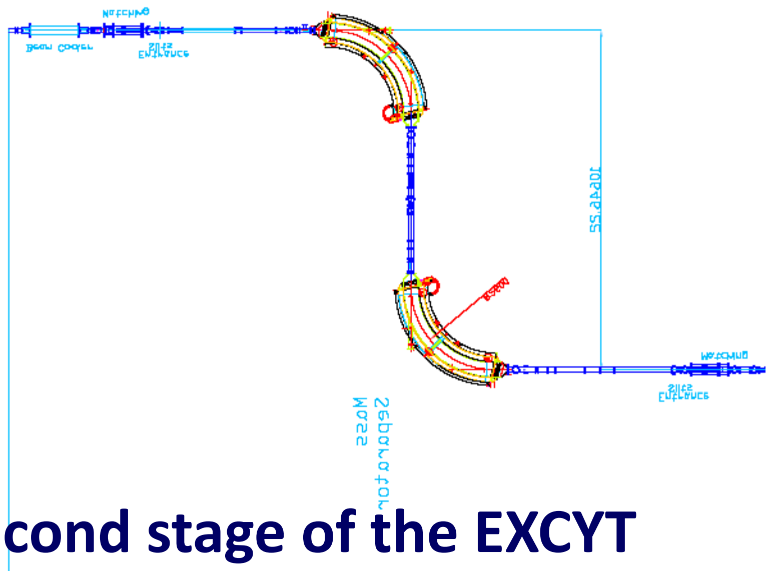
Reaction: $^2H(^{82}Ge,p)^{83}Ge$
Direct reaction in inverse kinematic



High Resolution Mass Separator



SPES HRMS design

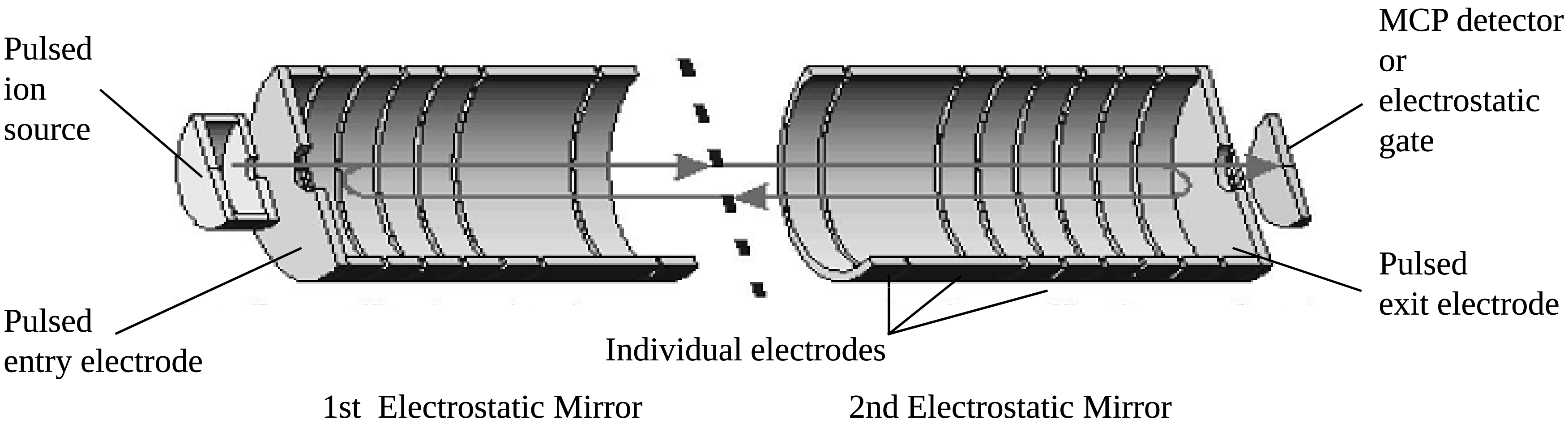


Second stage of the EXCYT isobaric mass separator

Comparison of the main parameters of the EXCYT and the SPES mass spectrometer.

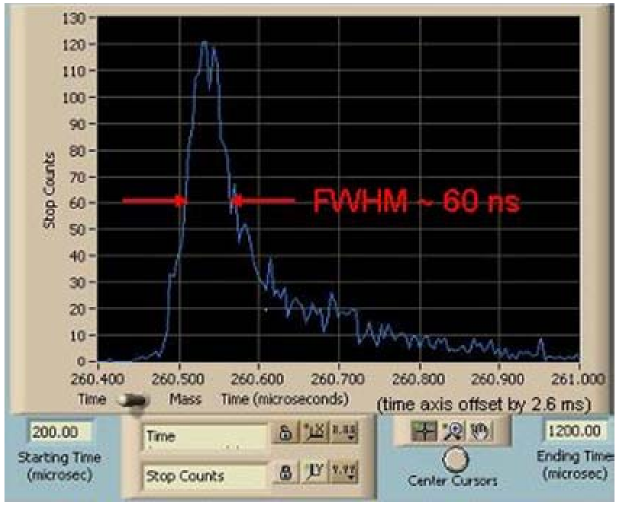
Project name	EXCYT	SPES
Number of dipoles	2	2
Bending Angle	90°	110°
Bending radius	2.6 m	2.6 m
Entrance/exit angle	12.8°	32°
Magnetic field range	0.6 - 4.4 kGauss	1.0 - 4.4 kGauss
beam size at analysis slits	0.4 mm	0.4 mm
Teta acceptance	40 mrad	40 mrad
(x,x’) emittance	4 π mm.mrad	4 π mm.mrad
Y beam size	2 mm	2 mm
Phi acceptance	10 mrad	10 mrad
(y,y’) emittance	4 π mm.mrad	5 π mm.mrad
Resolving power	>15.000	>20.000
Dispersion	16 m	28 m

Multi-pass Time-of-Flight system: concept



MTOF Spectrometer: Spectrum taken with MCP

MTOF Separator: Physical separation using fast electrostatic gate



N_2 time spectrum, ToF = 2.6ms
FWHM ~ 60ns
→ m/Δm(FWHM) = 22,000

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ScienceDirect
Nuclear Instruments and Methods in Physics Research B xxx (2008) xxx–xxx
NIM B Beam Interactions with Materials & Atoms
www.elsevier.com/locate/nimb
2008

Development of a high resolution isobar separator for study of exotic decays

A. Piechaczek[a], V. Shchepunov[b], H.K. Carter[b,*], J.C. Batchelder[b], E.F. Zganjar[a], S.N. Liddick[b], H. Wollnik[c], Y. Hu[d,e], B.O. Griffith[b]

[a] Louisiana State University, Baton Rouge, LA, USA
[b] UNIRIB, Oak Ridge Associated Universities, Oak Ridge, TN, USA
[c] Iontech, Santa Fe, NM, USA
[d] Grinnell College, Grinnell, IA, USA
[e] Oak Ridge Associated Universities, Oak Ridge, TN, USA

Available online

CB For the SPES Progect

CHOICE of the Charge BOOSTER

ECR-Charge Breeder

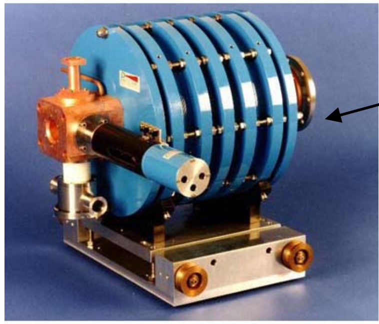
ROBUST

SIMPLE

IDEAL FOR INJECTION INTO ALPI
(Sit on a HV platform)

CB For the SPES Progect

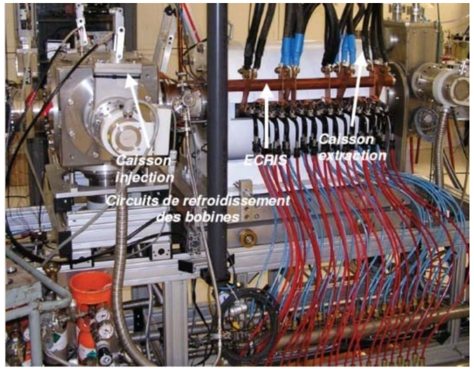
ECR ION SOURCE



SUPERNANOGAN BY PANTECHNIK

•**FULLY PERMANENT MAGNET @ 14 GHz**

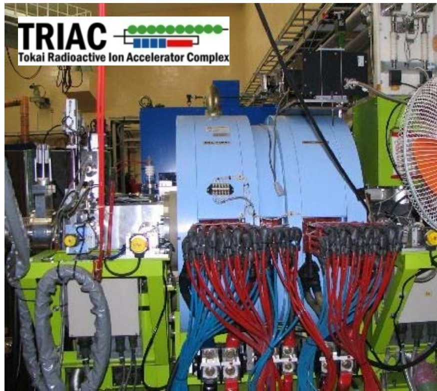
FPMS



LPSC Booster

•**ROOM TEMPERATURE @ 14-18GHz**

RTS



KEKCB @ TRIAC

•**HT SUPERCONDUCTING @ 18 GHz**

HTS

•**FULLY SUPERCONDUCTING @ >18 GHZ**

FSS

PHDelis

BY

PANTECHNIK

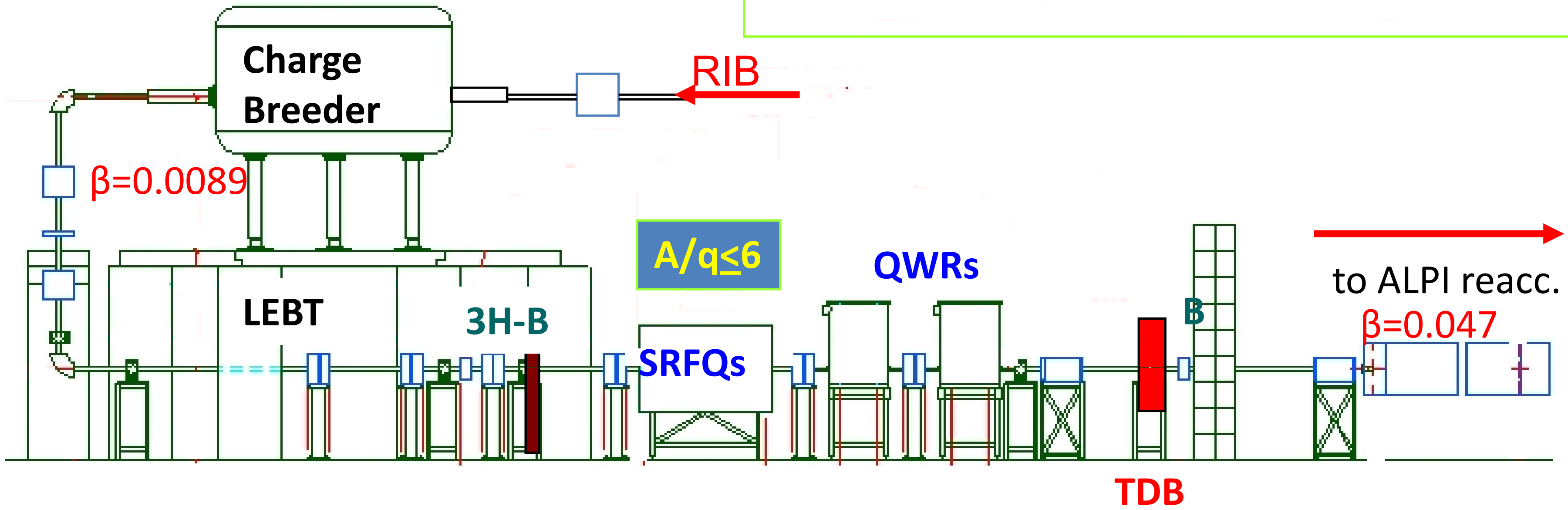
CB For the SPES Progect

REQUIREMENTS

- PRODUCTION OF HIGH CHARGE STATE WITH GOOD EFFICIENCY: $^{132}Sn^{26+}$
- INJECTION INTO RFQ PIAVE AT FIXED β

POSSIBLE DEVELOPMENTS

- OPTICS AND BEAM INJECTION
- USE OF UHV MATERIALS
- EXPLORE COMBINATION OF MAGNETIC AND ELECTROSTATIC SELECTION
- EXPLORE COMPATIBILITY WITH HV PLATFORM

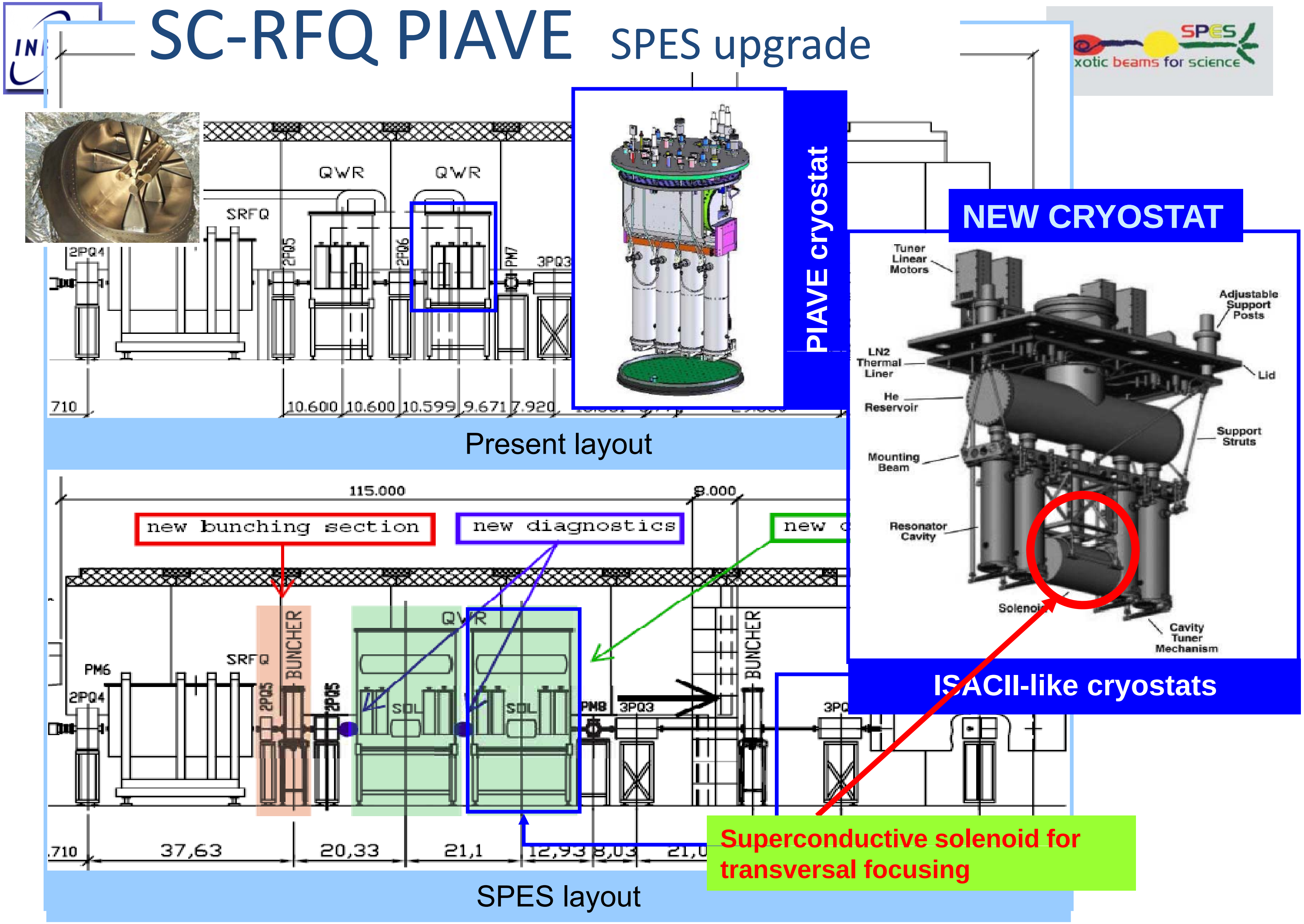


Reacceleration

PIAVE up-grade:
- new cryostat
- improved diagnostic
- new bunching section

ALPI up grade:
- Low Beta cavities
- Stronger Magnetic lenses

SC-RFQ PIAVE SPES upgrade



The ALPI post accelerator

Superconductive linac based on QW resonators.

2003: Up graded to Veq ~ 40 MV

Original Pb/Cu cavities substituted with

Nb/ Cu spattered cavities
or bulk Nb cavities

Upgrading of ALPImedium β QWRs

The possibility of an effective improvement of medium β resonators by Nb/Pb replacement was shown in 1998; 44 upgraded QWRs were installed by 2004; they are working now at an average field of **4.7 MV/m @7 Watt**

- ❑ Brazed joints
- ❑ Flat shorting plate
- ❑ Beam ports shape
- ❑ Inductive coupler (hole in high current region)

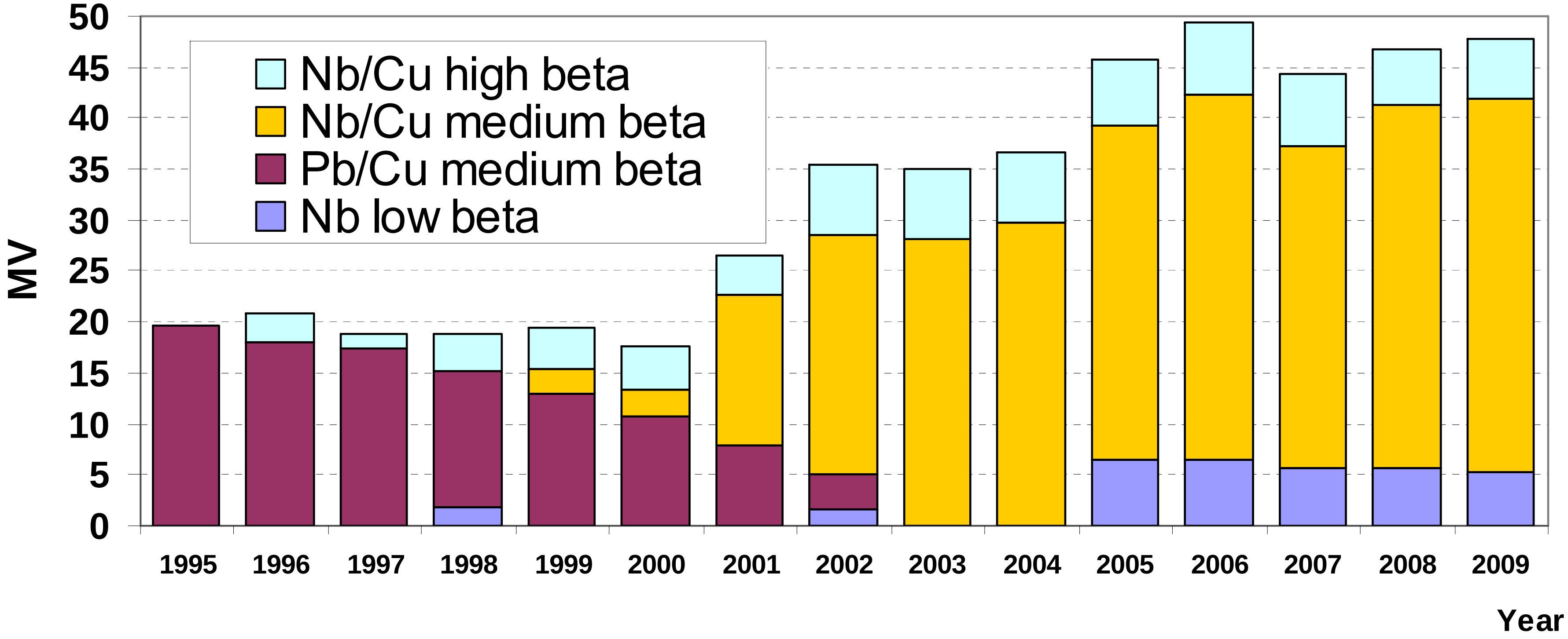
Limited the reached performance to 4.7MV/m @7W, a factor 2 higher than when Pb plated, but lower than the high β resonators performance

In 2005 we had the possibility to build 4 new substrates having:

- ❑ New beam port design
- ❑ A rounded shorting plate
- ❑ A capacitive coupler
- ❑ No holes in high current regions
- ❑ No brazing in the outer resonator body

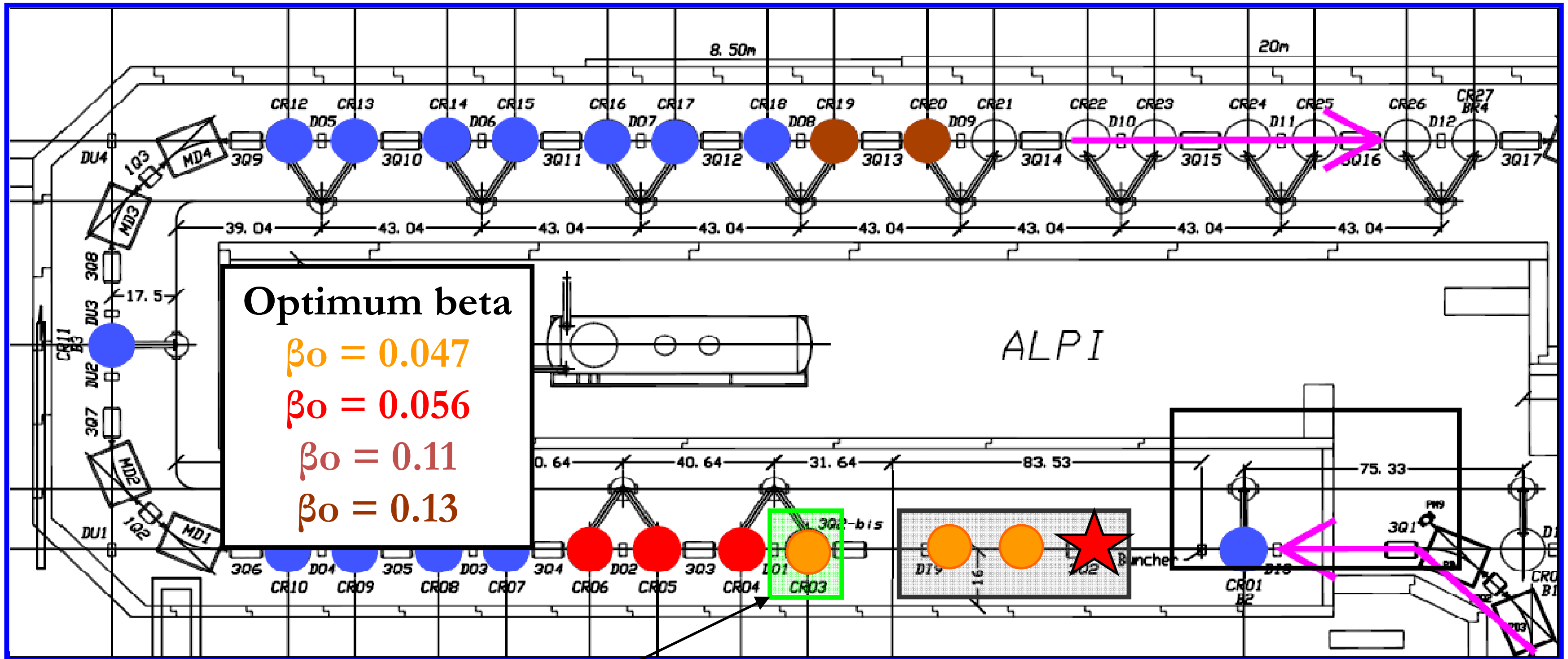
They are now ready to be installed; **6 MV/m expected on line**

Evolution in ALPI Performance



The substitution of Pb with Nb increased substantially the ALPI available equivalent voltage ($V_{eq} = \sum E_a l$) where l is the resonator active lenght and Ea is the accerating field of the operating resonators. An improvement is aspected soon by installation of the new ready medium beta cavities. A further increased in performance is foreseen in future (next slides)

ALPI upgrade for SPES



ALPI layout

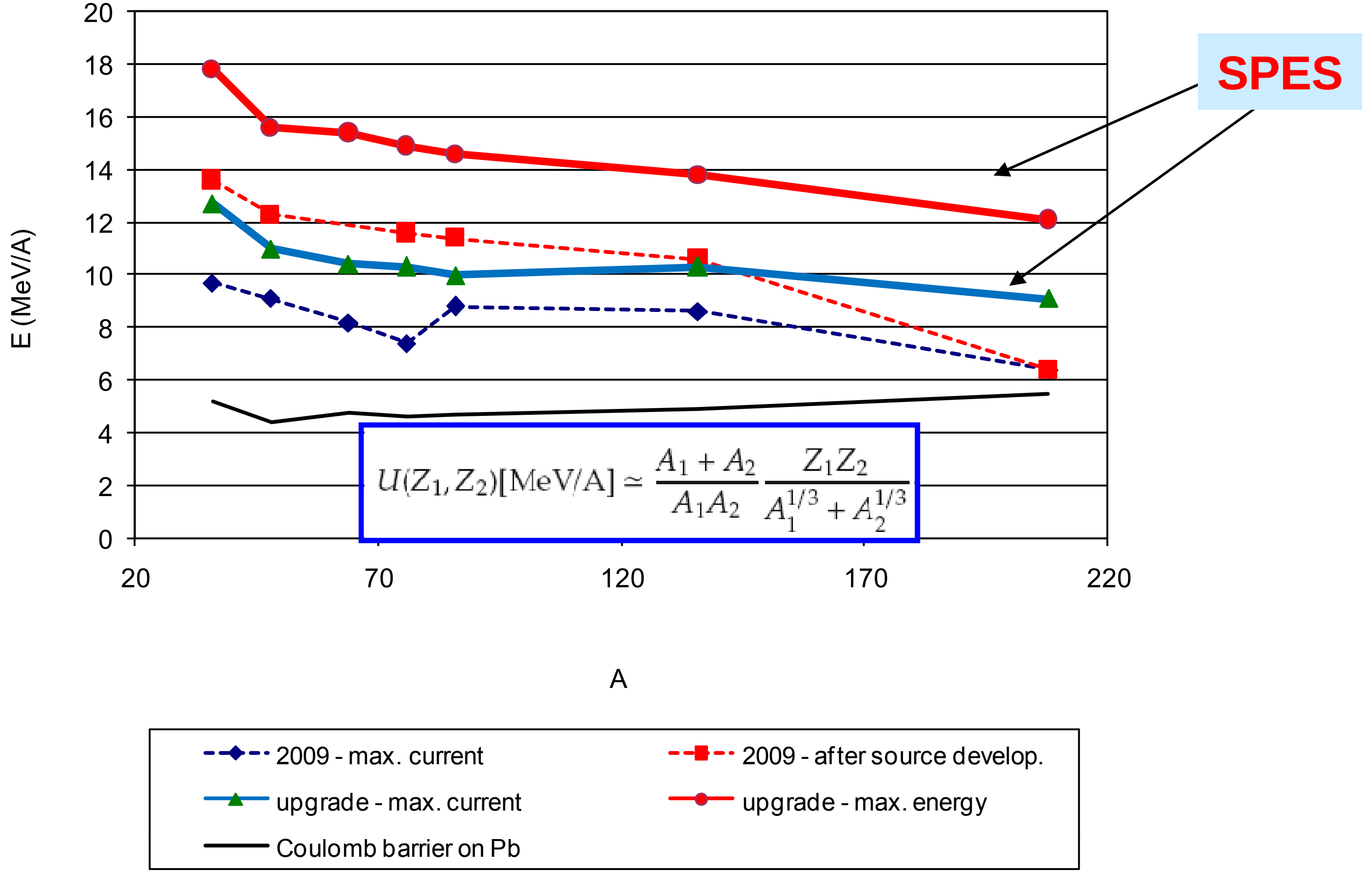
Funded upgrade (2009)
LowBeta CR3, new couplers

To be funded:

2 additional LowBeta Cryostats (CR1, CR2) a New buncher

New magnetic lenses (upgrade from 20 to 30 T/m)

Final performance for stable beams: 2009 and SPES scenarios



SPES SCHEDULE

	2008	2009	2010	2011	2012	2013	2014
Facility design							
First Target and ion source							
Second target and ion source							
Authorization to operate							
Building construction							
Target installation and commissioning							
Completion of RFQ for Neutron Facility							
Installation and commissioning Neutron Facility							
Cyclotron construction							
Cyclotron Installation and commissioning							
Alpi preparation for post acceleration							
Installation of RIBs transfer lines and spectrometer							
Complete commissioning							

The INFN Legnaro Laboratory

SPES Collaborations

Laboratori Nazionali di Legnaro – Laboratori Nazionali del Sud

Sez INFN: Padova, Milano, Bologna, Catania, Firenze, Napoli, Bari

Ingegneria Meccanica (Sezione Materiali) – Univ. di Padova

Dipartimento Scienze Chimiche – Univ. di Padova

Ingegneria Meccanica (Sezione Progettazione) – Univ. di Padova

Target development

Ingegneria Meccanica (Sezione Meccatronica) – Univ. di Trento

Ingegneria Informatica – Univ. di Padova

ENEA Bologna ENEA Faenza

Nuclear safety

Ingegneria Nucleare-Univ. di Palermo

(Ing. Energetica Politecnico di Torino)

International collaborations:

ISOLDE-CERN, HRIBF-ORNL

SPIRAL2-(LEA), ISAC-TRIUMF , TRIAC-KEK

EURISOL

Design Study