An R&D program to Address Irradiation Effects in Superconductors for LHC Upgrade

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EuCARD workshop on insulator irradiation
CERN, December 2, 2009

Remember : LHC Upgrade
2.5 X « present » values (Phase I)
10 X « present » values (Phase II)

Data from FLUKA simulations, F. Cerutti, collected by R. Flukiger

Peak fluence - Phase I (2.5 x 10^{34} 1/cm^2s)

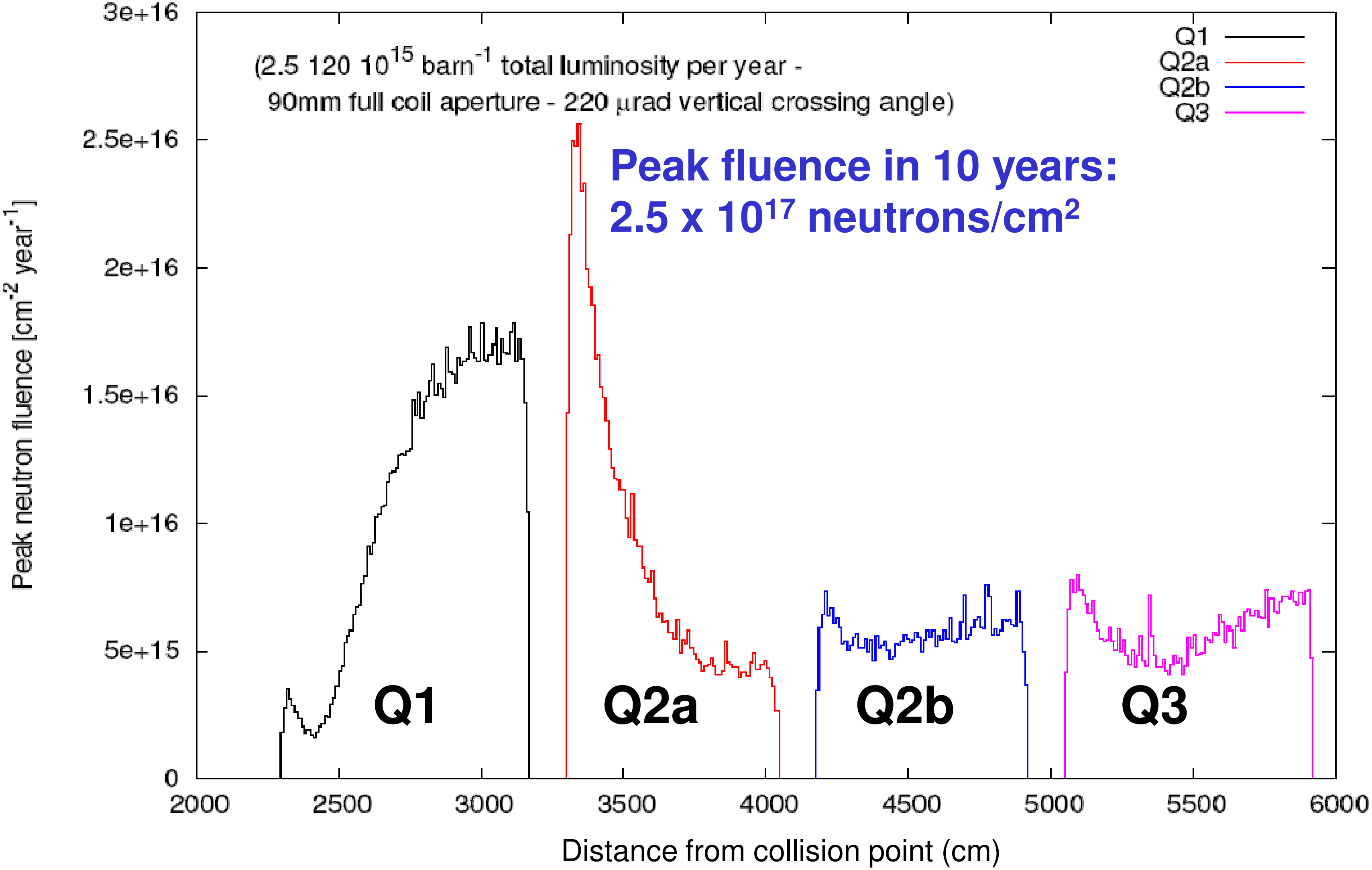
- Radiation spectrum at the IR quads (Q1-Q3)

Neutrons	6%	SC and Cu
Protons	0.15 %	SC and Cu
Photons	87 %	Insulation
Electrons	3.5 %	*negligible effect*
Positrons	2.5 %	
Pions	0.4 %	

- Total fluence in 10 years (200 d/year):
  - neutrons: 2.5 x 10^{17} n/cm^2
  - protons: 6.2 x 10^{15} p/cm^2

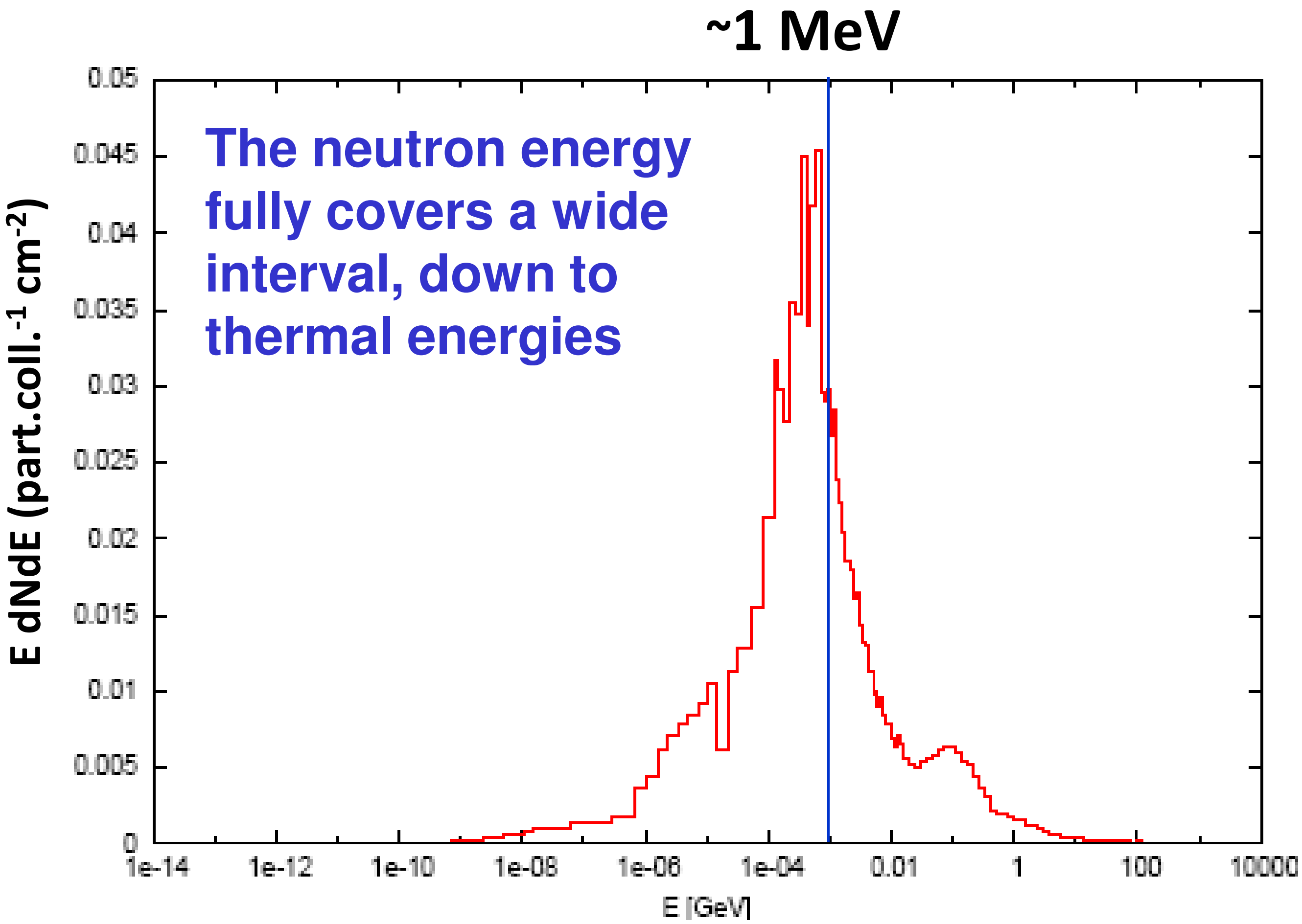
Data from FLUKA simulations, F. Cerutti and A. Mereghetti

Radiation map for the IR quads



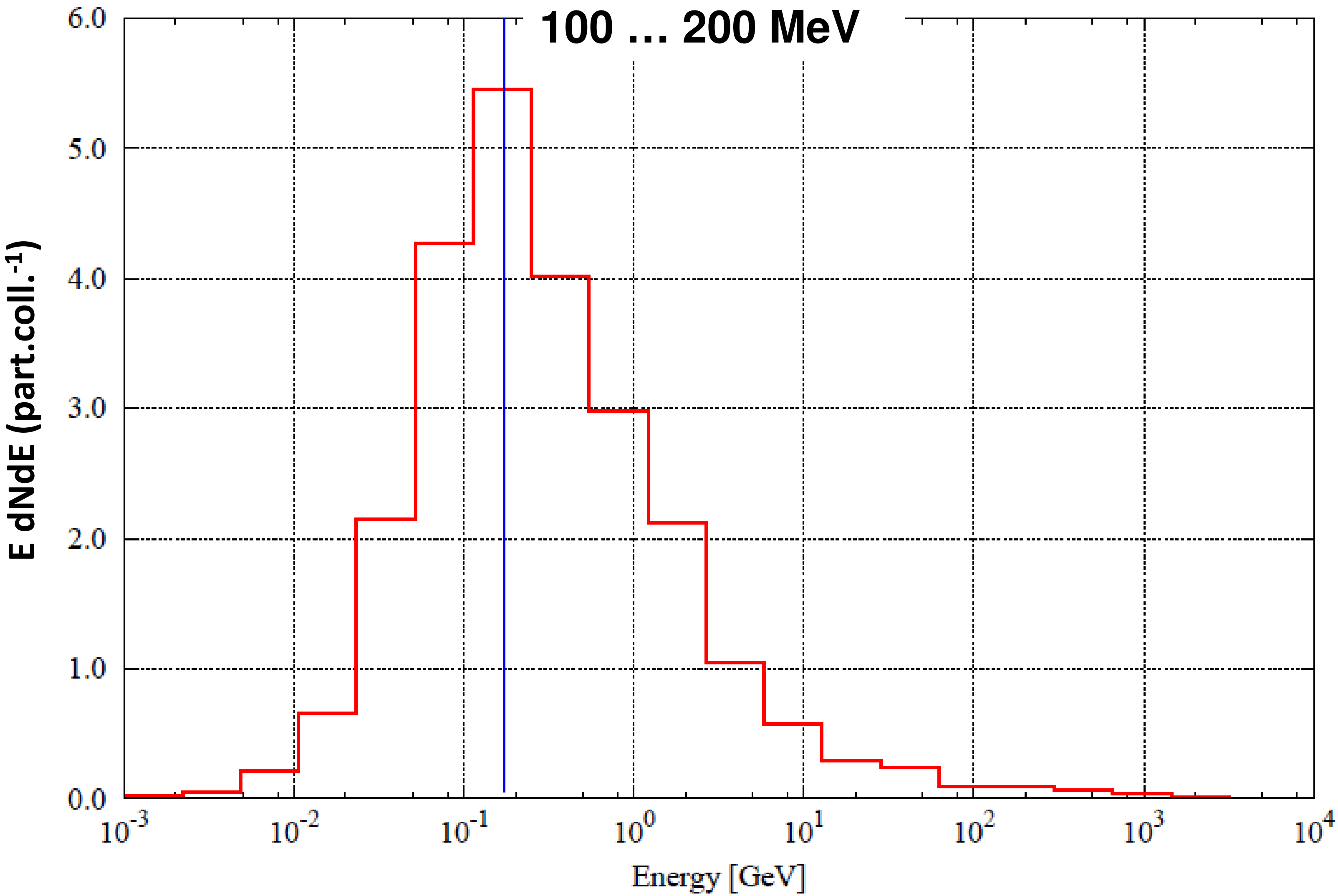
Data from FLUKA simulations, F. Cerutti and A. Mereghetti

Neutron spectrum in the Q2

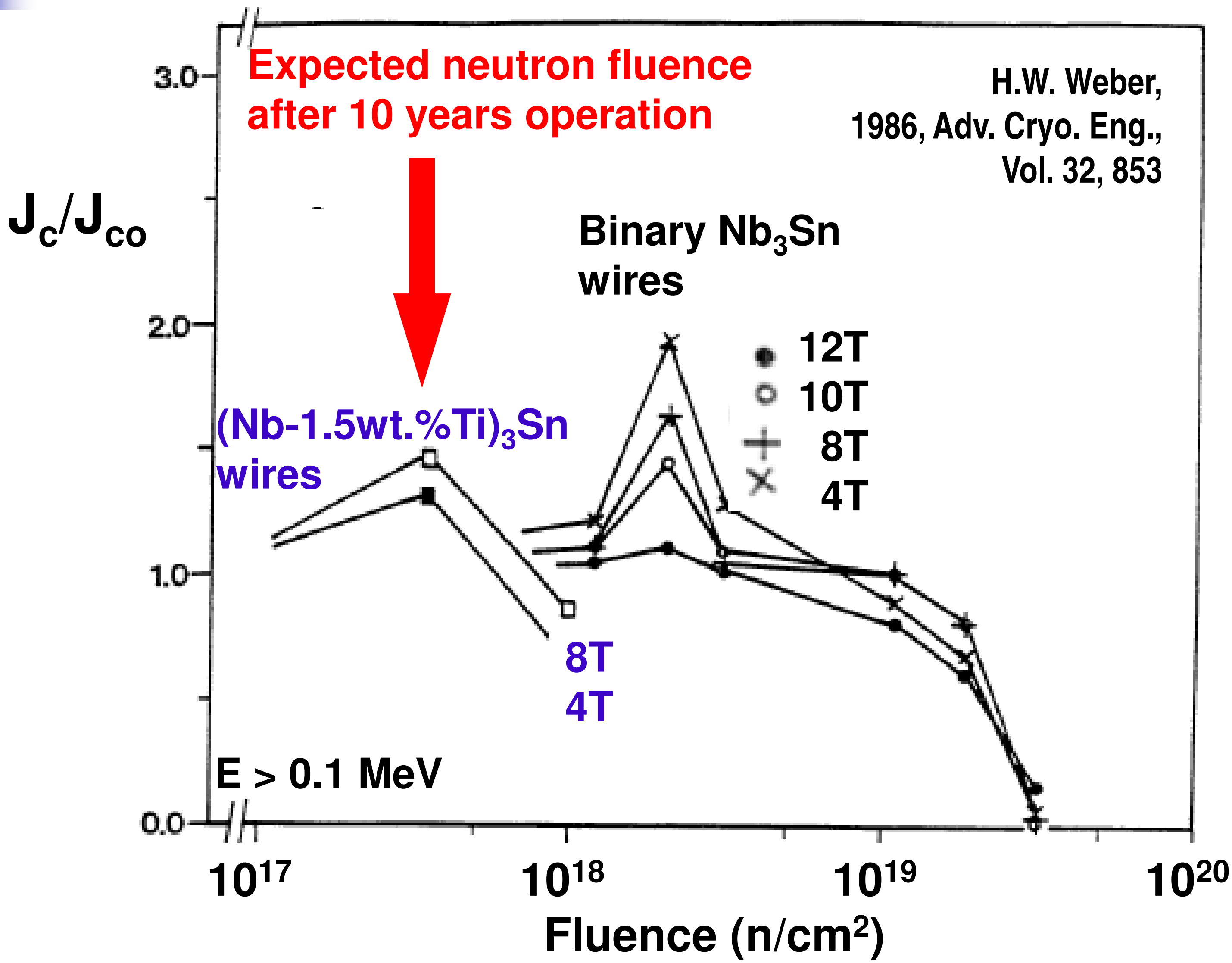


Data from FLUKA simulations, F. Cerutti and A. Mereghetti

Proton spectrum in the Q2



Effect of radiation on J_C



Motivation for an R&D - 1/2

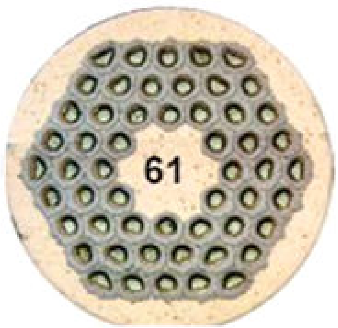
- Last data available on LTS materials dates back to the 80's, typically binary and non-optimized ternary Nb_3Sn (500 A/mm^2 at 12 T, 4.2 K).
- Recent materials, especially highly optimized ternary Nb_3Sn (3000 A/mm^2 at 12 T, 4.2 K) may respond in a different manner.
- Will J_C increase/decrease significantly ?
- Will the strands remain magneto-thermally stable, or become unstable (excess J_C and reduced RRR) ?

Open a parenthesis…

(…

Courtesy of B. Bordini, M. de Rapper, G. Willering

Magneto-thermal stability - 1/2

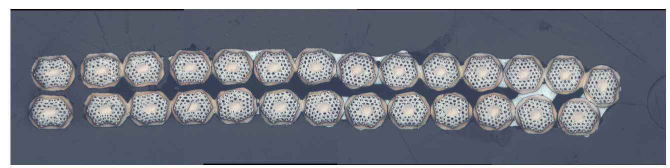


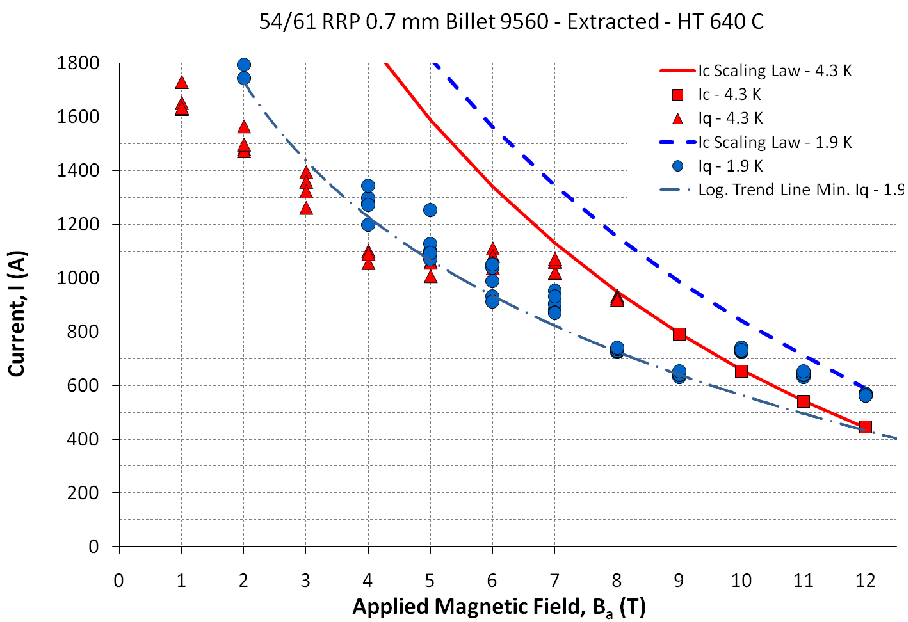
Single strand

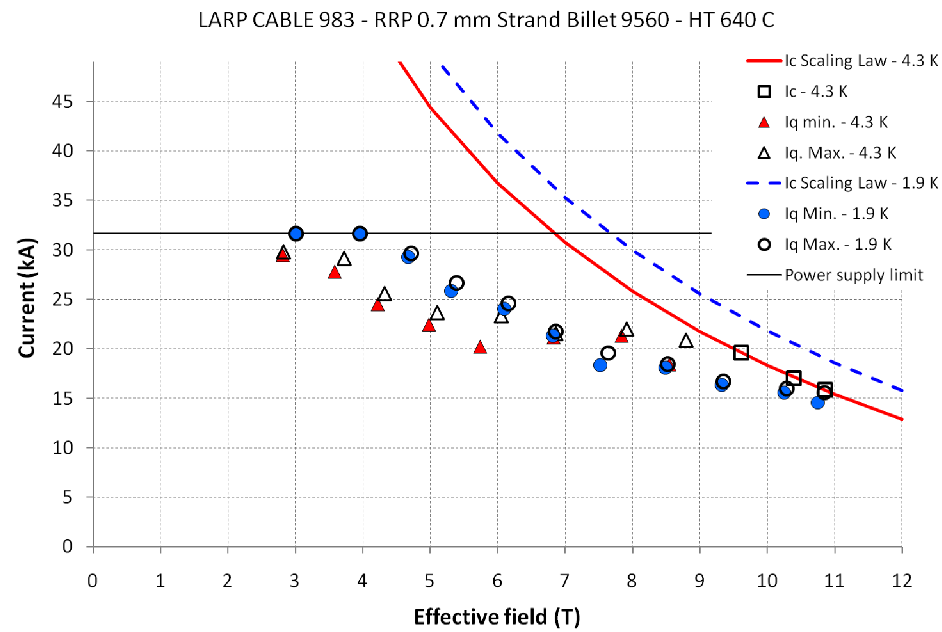
Ic station Bdg. 163

27 strands cable

FReSCa, Bdg. 163

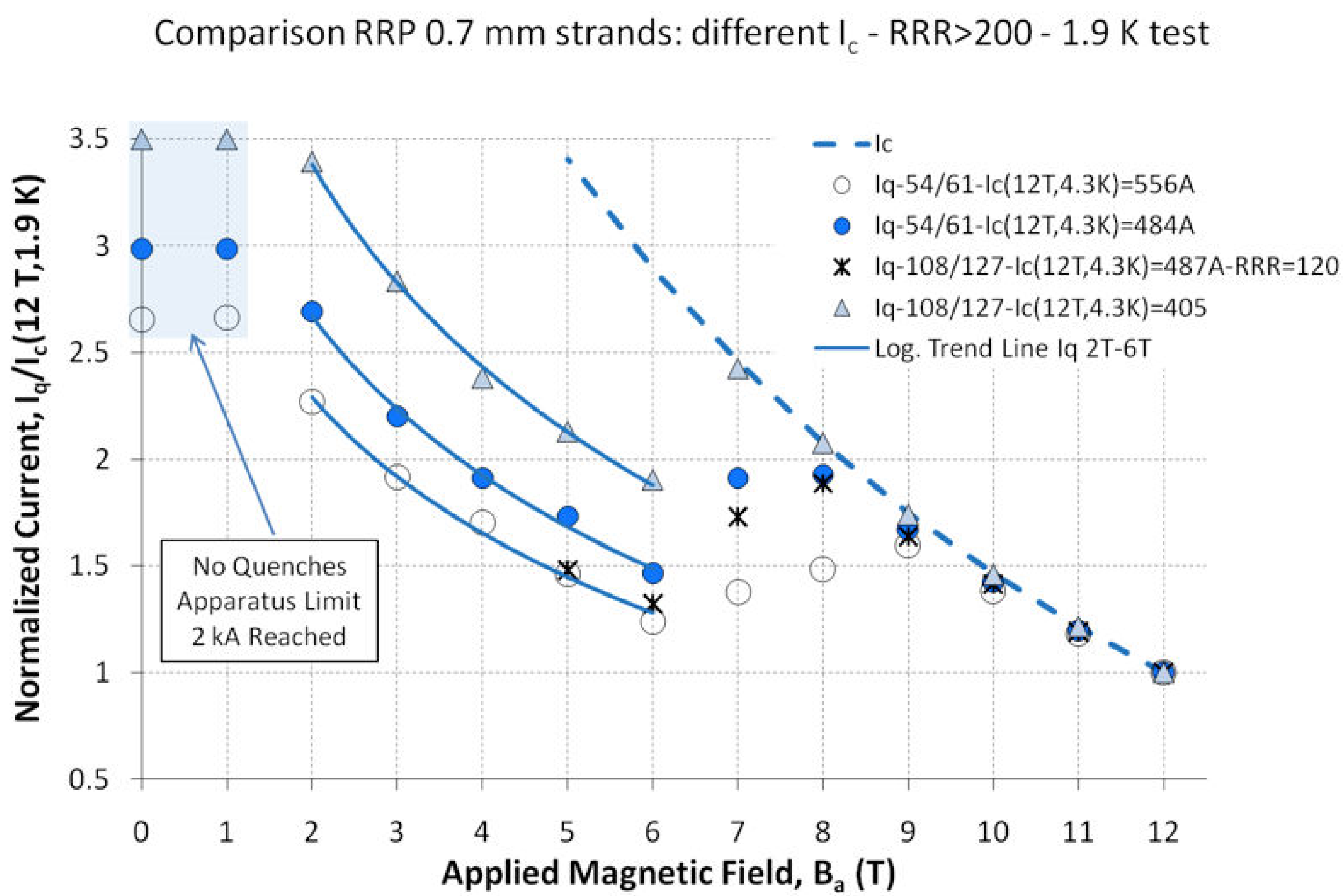






Courtesy of B. Bordini

Magneto-thermal stability - 2/2



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Motivation for an R&D - 2/2

- Most data was collected from experiments in research reactors, with typical energy spectrum in the range of thermal (0.025 eV) up to 14 MeV, peaked in the 1 MeV range
- The expected peaks in the spectra of the radiation in the IR quads of Phase II upgrades will be significantly higher (e.g. protons at 100 MeV), and the particle species will be much more varied
- Will the critical properties respond in a scalable manner to particle irradiation at much different energies ?

R&D program objectives

- Examine the sensitivity of new materials (High-J_C, optimized ternary Nb_3Sn, MgB_2 and HTS) and stabilizer (Cu) to LHC radiation (neutrons **and** protons) with distributions peaked at:
  - 1 MeV neutrons
  - 60 MeV protons
  - Significant tails at higher energy
- This is a *new domain* for which very little and very scattered data exists

Issues and hurdles

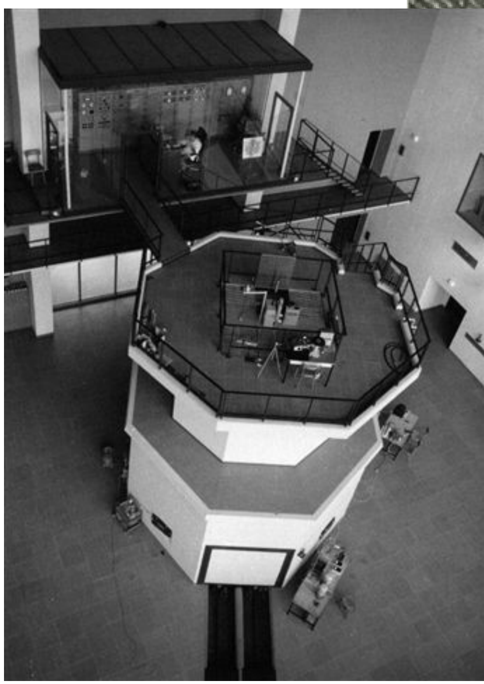
- Suitable facilities for irradiation are not easy to find:
  - Correct combination of particle/fluence/spectrum
  - Availability
  - Cryogenic environment (cold irradiation ?) and critical current test capability (12 T, 4.2 K, > 2 kA)
- Testing takes long times:
  - E.g. sample “cooling” after reactor irradiation takes typically a few months, making the sample turnover a long term project, and appropriate *experiment planning* an absolute priority

R&D backbone - 1/2

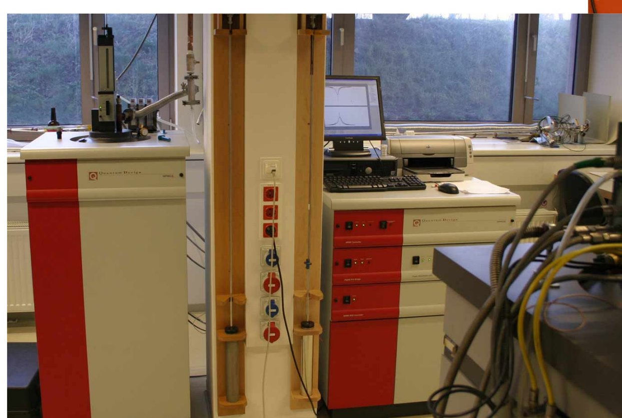
- Neutron irradiation tests in existing facility, with critical current and magnetization measurement capability, to collect data on new materials, for direct comparison to the existing database (same particle and spectrum):
  - Discussion with the Atominstitut in Vienna to perform neutron irradiation tests at relevant fluences in TRIGA
  - Critical current test capability in field up to 14 T, variable temperature insert and current up to 300 A (lower current at temperatures above 4.2 K)
  - Magnetization test capability in field up to 7 T, variable temperature insert (inductive J_C measurement, lower activated mass)

Atominstitut - TU Wien

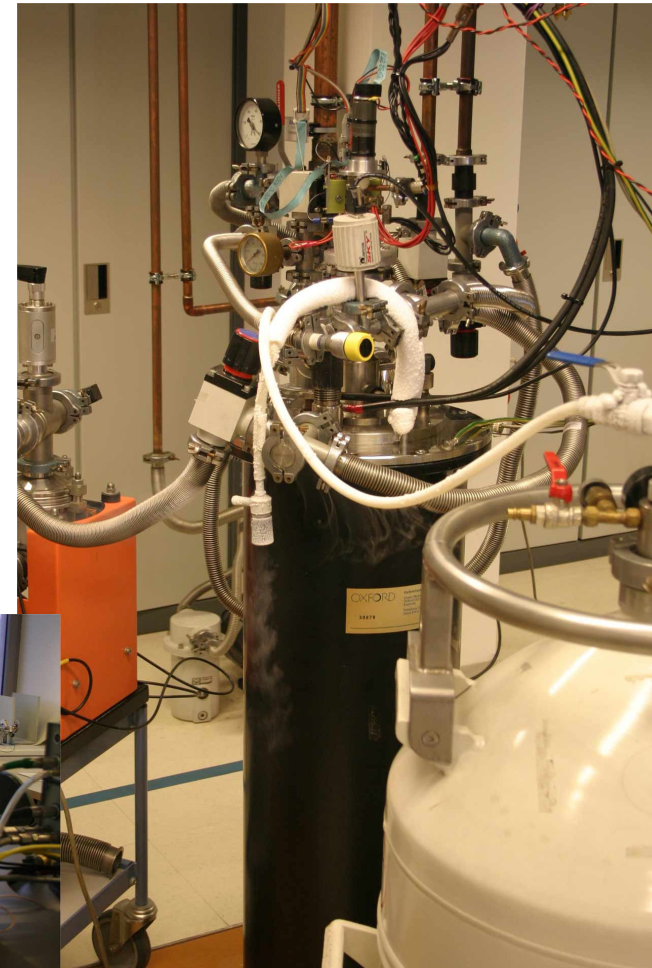
TRIGA Mark II



ATOMINSTITUT



8 T SQUID magnetometer



14 T (17 T) I_C test station

R&D backbone - 2/2

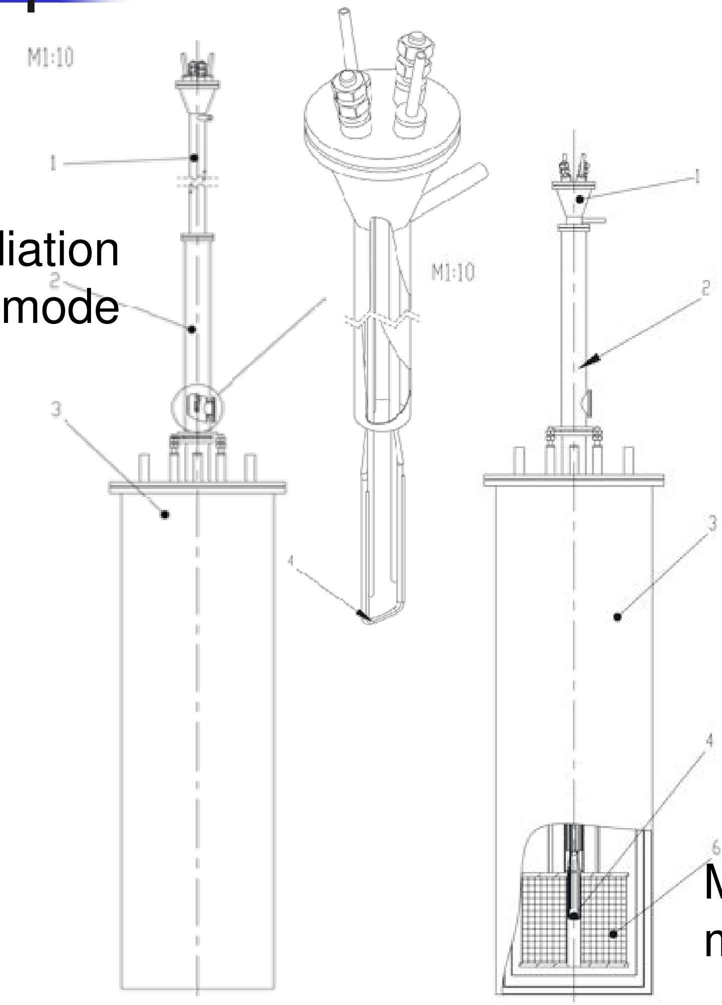
- Proton irradiation tests in a new facility, with on-site critical current measurement capability, to address the issue of scalability of the present database to the conditions of particle species and spectrum expected for LHC upgrades. In addition, foresee cold irradiation for verification measurements (possibly not required systematically)
  - Discussion with Kurchatov Institute in Moscow to set-up the critical current test station in the radiation environment of a 35 MeV proton beam line
  - Critical current test capability in field up to 12…13 T, temperature 4.2 K and current up to 2 kA

Proposal from A. Ryazanov & Co.

Kurchatov Institut - Moscow

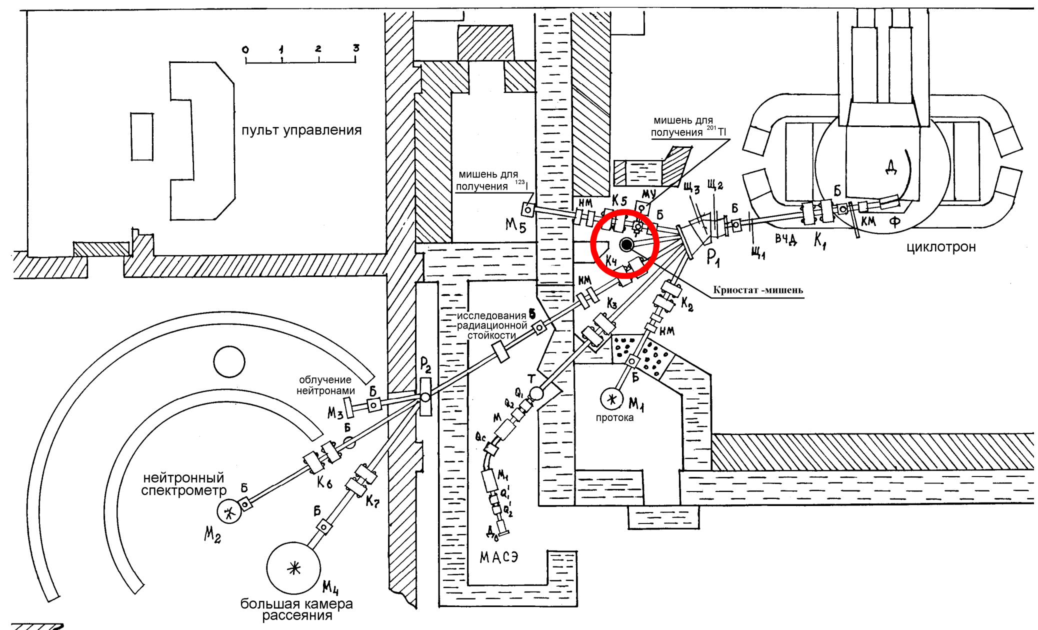
35 MeV cyclotron

Irradiation mode



Measurement mode

12T, 2 kA I_C test station



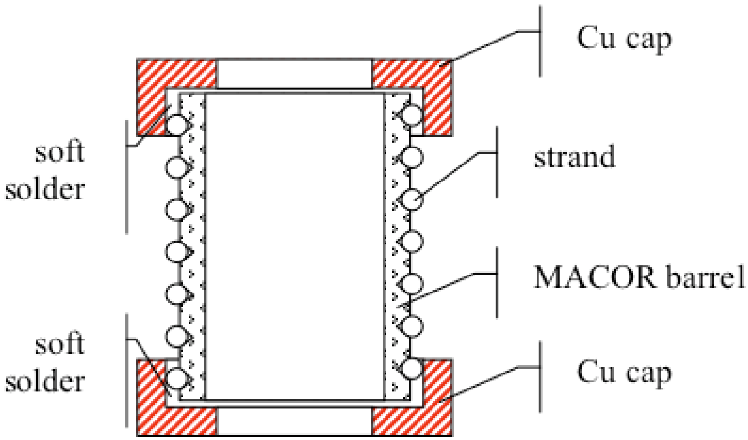
система транспортировки циклотрона

Samples

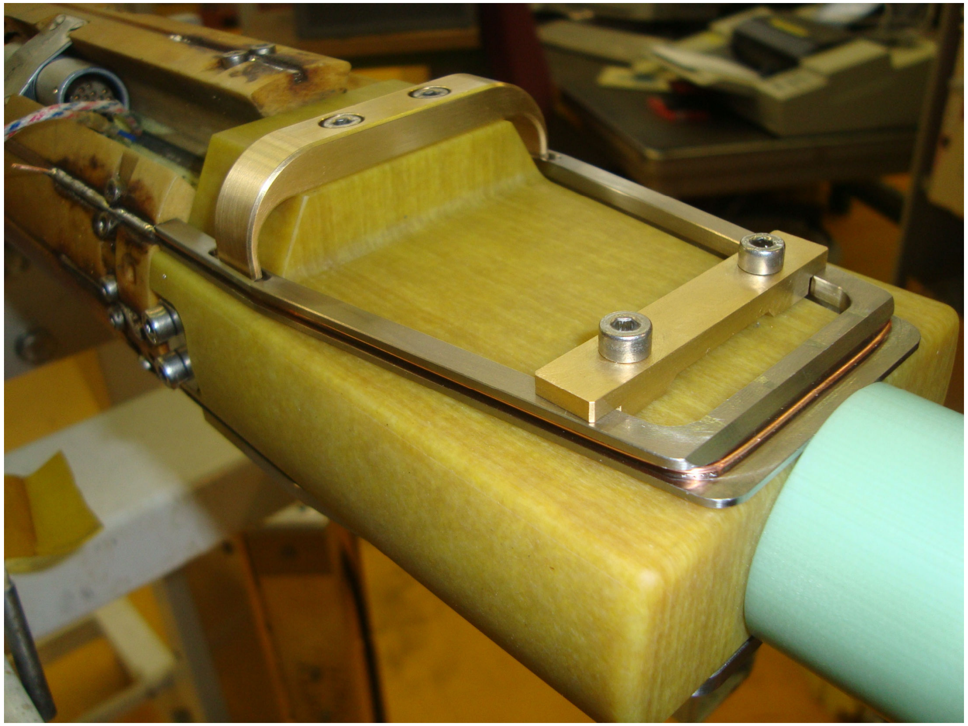
- Materials (already available)
  - Nb_3Sn (Ti and Ta additions)
  - MgB_2
  - HTS materials (BSCCO-2212)
  - Cu
- Tested quantities
  - I_C (B_C) vs. fluence, resistive or inductive method
  - Microstructure (?)
  - Normal state resistivity (?)
- Dedicated sample for irradiation tests in preparation for qualification at CERN

Design and realization by P. Jacquot, F. Liberati, L. Oberli, J.F. Poncet

Sample holders



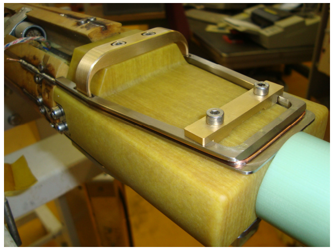
Neutron irradiation at Atominstitut Vienna

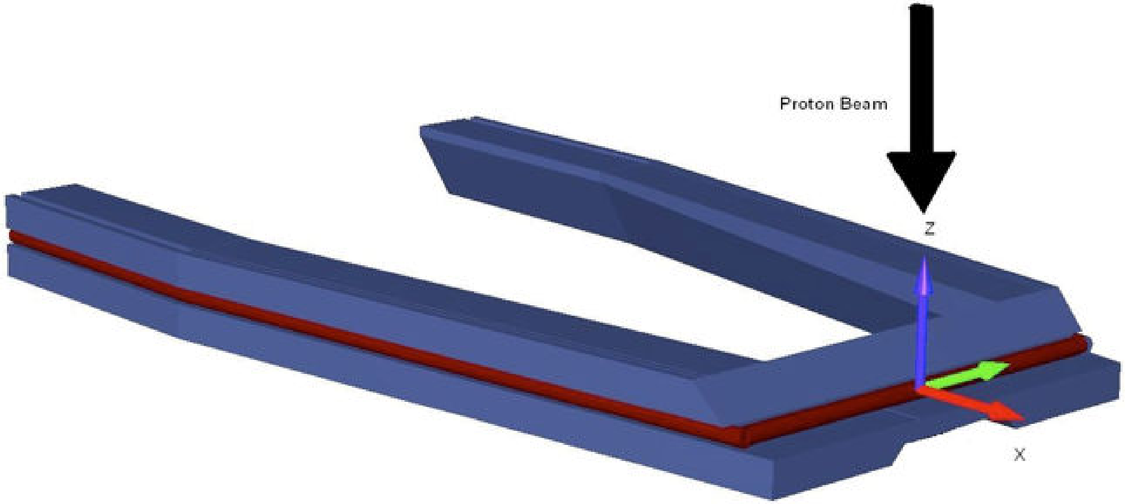


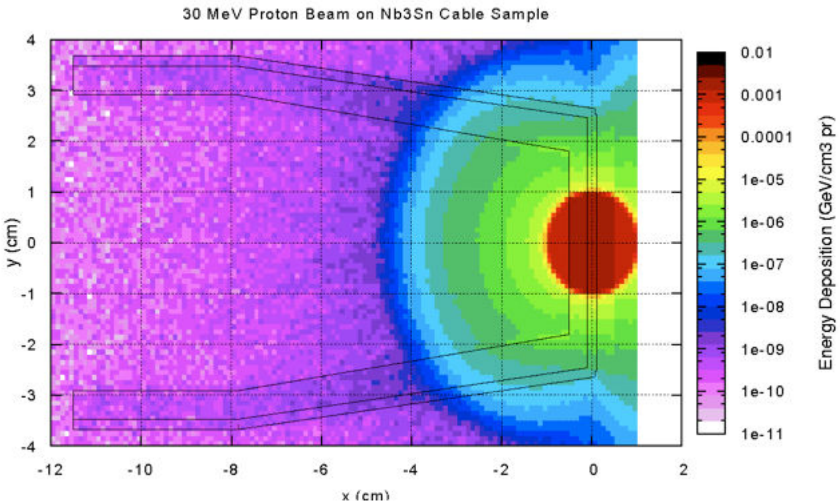
Proton irradiation at Kurchatov Institute Moscow

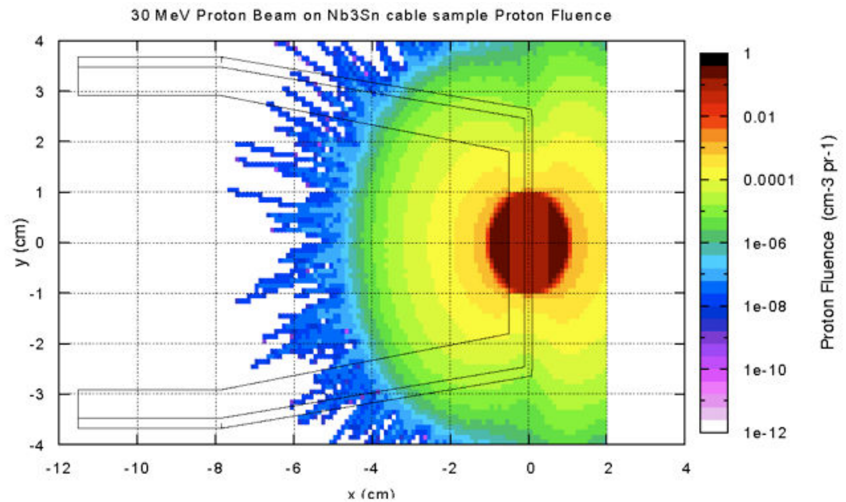
Simulations by F. Broggi

Sample holder design









Other 'minor issues' and plan

- Test currents (2 kA and above) exceed the capability of most standard installations
- Sample cooling during irradiation limits the flux and extends the duration of the irradiation, especially for cryogenic conditions
- Sample logistics after irradiation/test requires tracing/disposal (large overhead)
- **Cost !**
- Plan:
  - Finalize the discussions on installations and test methods by end 2009
  - First test samples for neutron irradiation ready by spring 2010
  - First tests (magnetization) in summer 2010 (**scaled dependencies !**)
  - Proton irradiation facility available by end 2010
  - Test of critical current dependency on neutron irradiation end 2010 to end 2012
  - Test of critical current dependency on proton irradiation beginning 2011 to end 2012 (**new results !**)