Proposal to activate a BEGe detector with at IRRAD-6 facility @ CERN

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Purpose

- Produce ^{68}Ge and ^{60}Co in a working BEGe detector to experimentally determine ^{68}Ge and ^{60}Co decay rejection power and cross check simulations.
- Study pulse shapes of several β^{+} decaying isotopes produced in the irradiation
  - ^{57}Co(β^{-} + γs), t1/2=272 d, Q_{β}= 699 keV,E_{γ}=122 keV, 136 keV
  - ^{54}Mn(β^{+}),Q_{β}=1377, $t_{1/2}$=312 d,
  - ^{68}Ge(EC followed by ^{68}Ga(β^{+}), Q_{β}= 1.8 MeV),
  - ^{65}Zn (b^{+}), $t_{1/2}$= 244 d,Q_{b}=1352 keV, E_{γ}=1115 keV
  - ^{60}Co (β^{-}), $t_{1/2}$= 5.27 y, Q_{b}=2824 keV, E_{γ}=1173 keV, 1332 keV

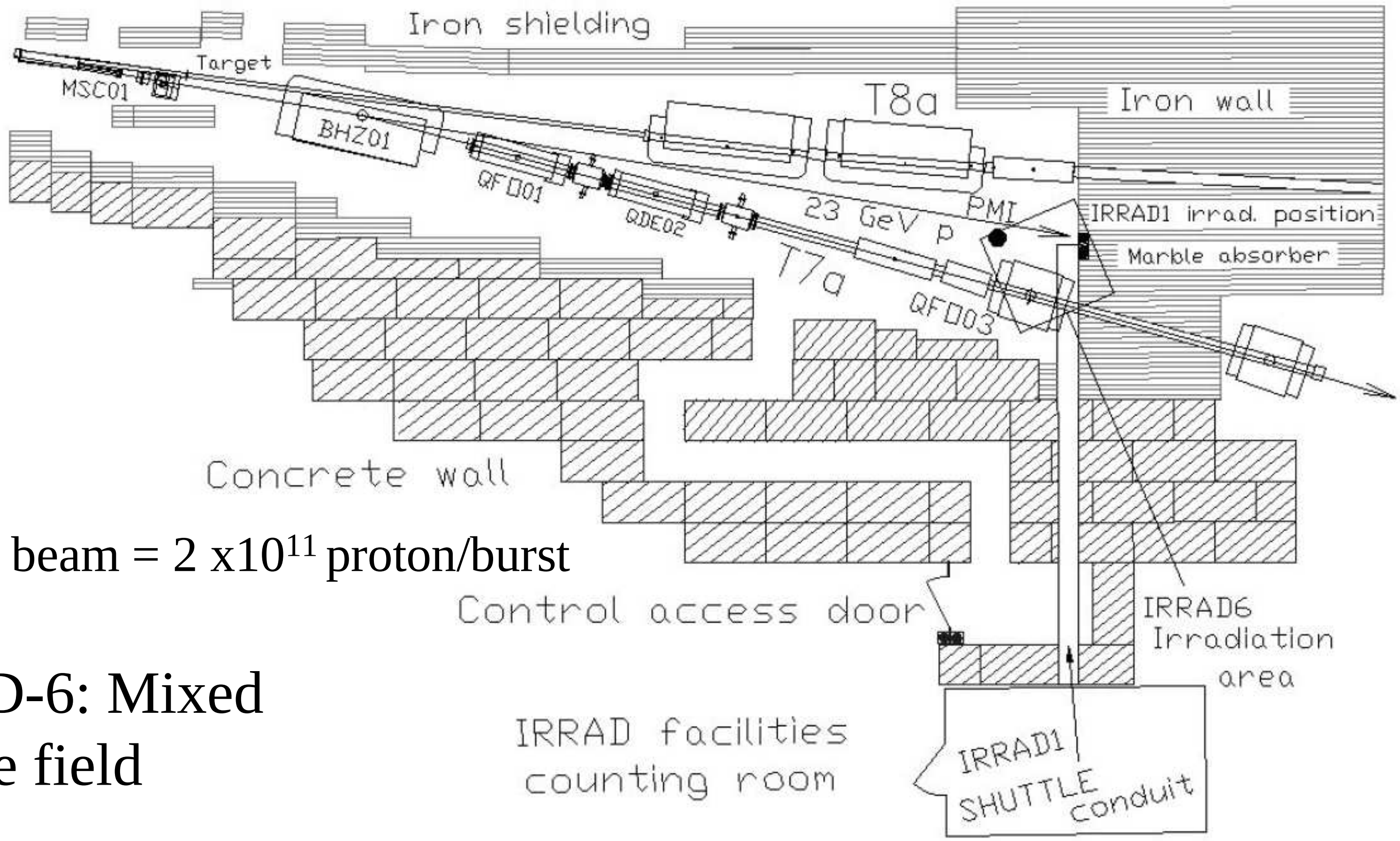
  by tagging the 511 kev gamma line in coincidence with a gamma spectrometer (Legnaro, LNGS depending on the activity to be measured), uniformely distributed in the detector.
- Study pulse shapes of low energy events (X follwing EC).
- Study pulse shapes of events localized in the external part of the detector……..

Requirements

- The detector should work after irradiation, possibly without annealing cycle, therefore
  - an irradiation site with low flux particle field (Integral irradiation < $10^8 - 10^9$ n),
  - n,p energy > 200 MeV (to produce not only ^{68}Ge but also ^{60}Co from ^{nat}Ge)

  is required.

Where: IRRAD-6 facility @ CERN 23 GeV proton beam T7 beam line



Primary beam = 2 x10^{11} proton/burst

IRRAD-6: Mixed particle field

Label	r = 60	r = 90	r = 100	PMI Loc.	Mag. QF003
Z (cm)	15	15	15	130	60
r (cm)	60	90	100	80	140

5 irradiation sites have been fully characterized by measurements with RadFET and p-i-n diodes and radiation fileds have been simulated

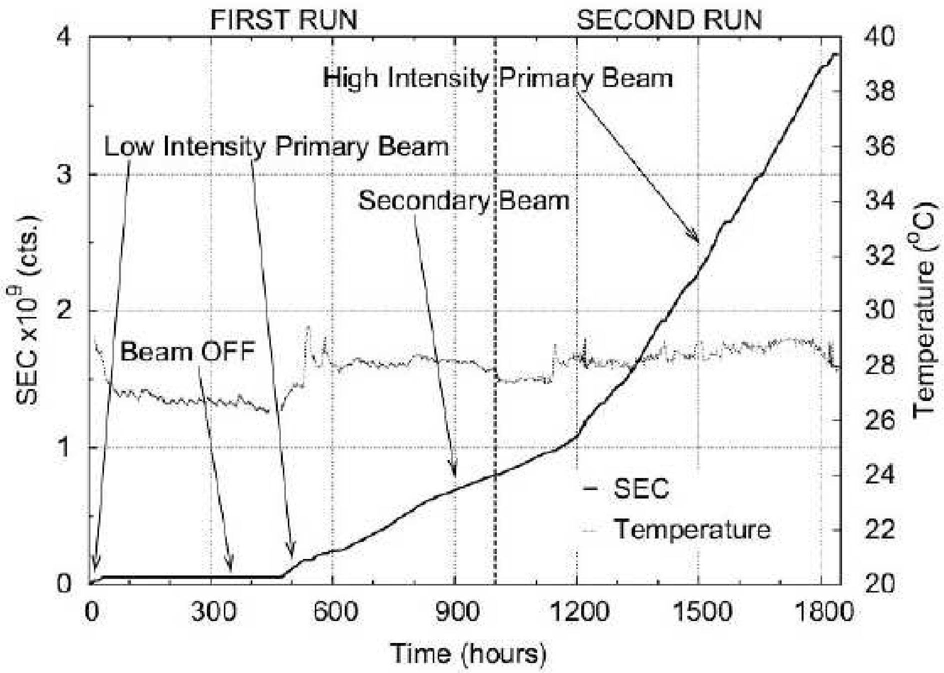
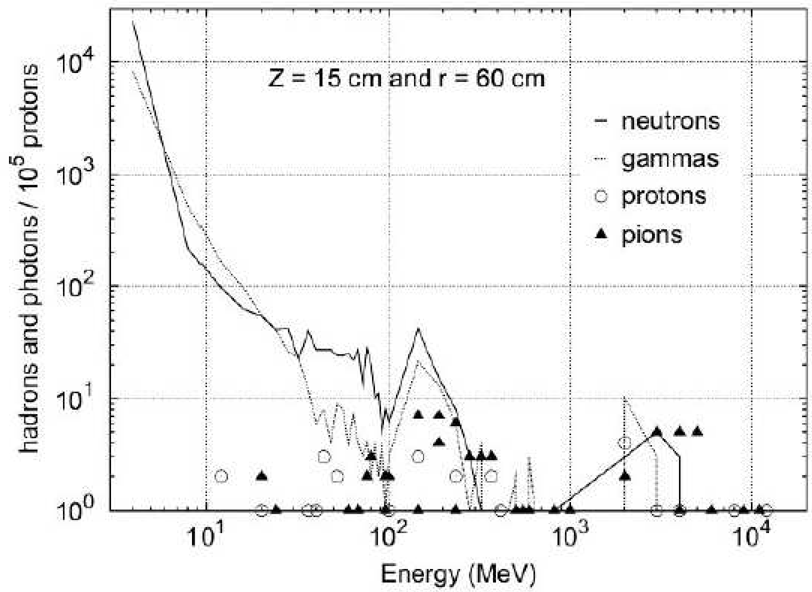
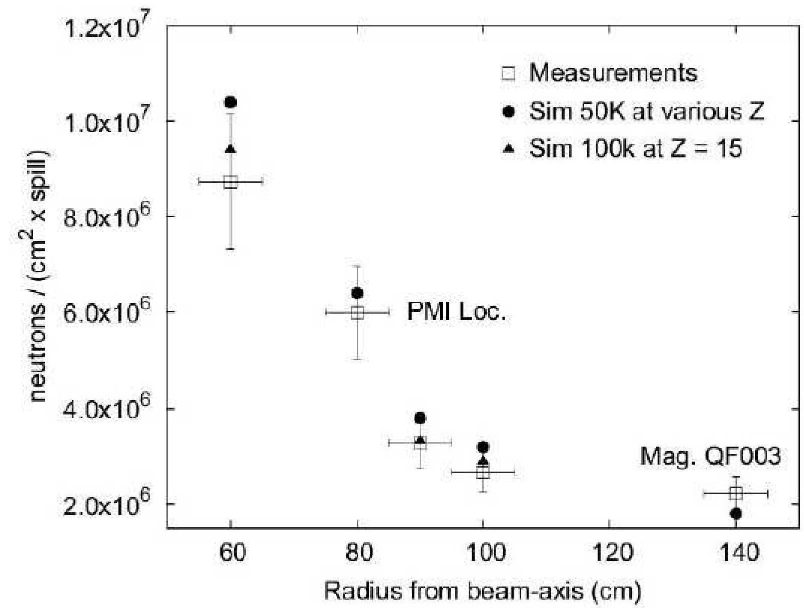


Fig. 2. Intensity of the 23 GeV proton beam delivered to T7



(a) Particle Spectra from *Sim 100k* at Z = 15 cm and r = 60 cm



(b) Comparison between simulations and the CMRP measurements

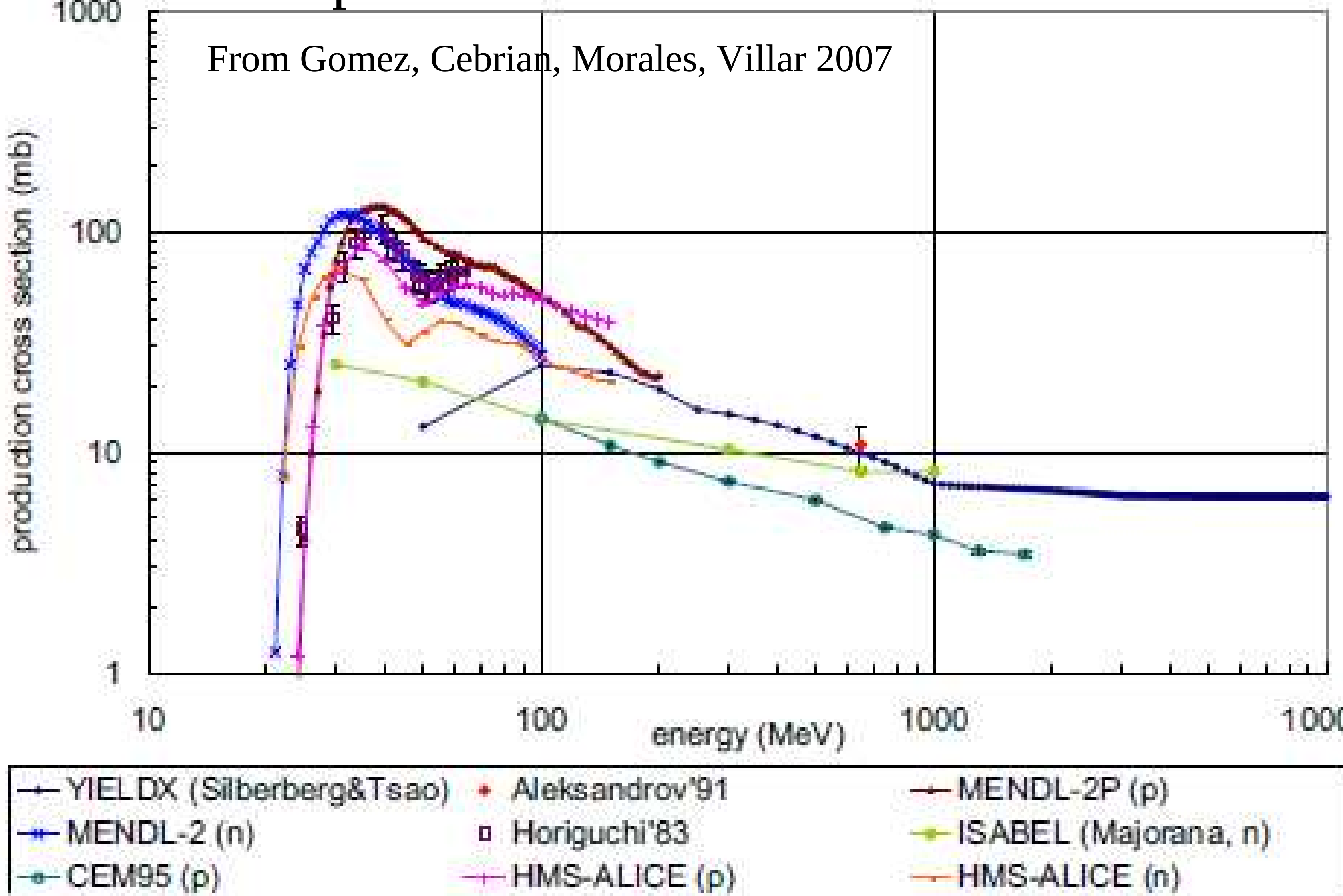
Radiation fields

Primary beam conditions: $(p,n,\pi^{\pm},\gamma)$

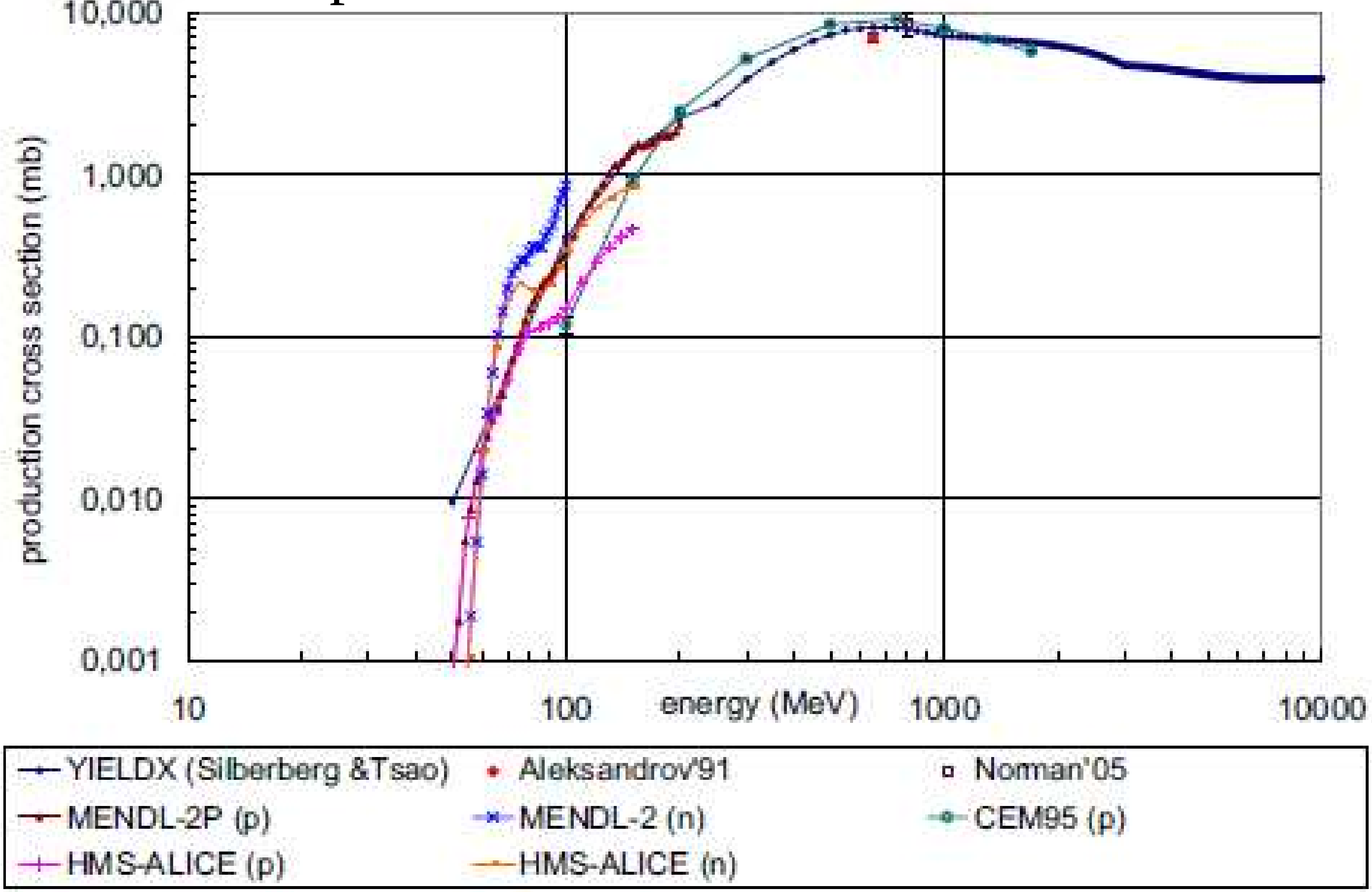
Secondary beam conditions: $(p,\pi^{\pm},e^{\pm})$

Possible to irradiate with low flux of hadrons ~ 4×10^{9} cm^{-2} h^{-1}

^{68}Ge production cross section in ^{nat}Ge



^{60}Co production cross section in ^{nat}Ge



Isotopes production rate (activation)

$$dN/dt = N_{target} * \int \sigma(E) * \varphi(E) dE$$

$\sigma(E)$ – cross section

$\varphi(E)$ – hadrons (neutrons + protons) flux

3,85E+07

4,81E+06

Estimated activity produced in a 8 moles (640 g) BEGe detector for an integral flux of 10^8 interacting particles

^{68}Ge: ~4 10^7 nucleai produced ~ 2 Bq

^{60}Co: ~6 10^6 ~10^{-2} Bq

Experimental procedure

Important: To keep the irradiation rate low, being able to see the ^{68}Ge and ^{60}Co decays in the irradiated detector, it is necessary to irradiate the detector in an Al chamber, in order not to activate the cryostat.

→ Define the proper irradiation exposure (time x position) @ IRRAD-6 performing activation tests with optical grade Ge.

→ Build an Al irradiation chamber (done)
→ Remove the detector from its cryostat
→ Put the detector in the irradiation chamber
→ Irradiate it @ the proper exposure (position x time)
→ Put back the detector in its cryostat
→ Start measurements in coincidence/anticoincidence with a (multiple to increase the efficiency of γ-tagging) Ge spectrometer. From the ratio of

$$\frac{\text{Tagged Event}}{\text{SSE observed in detector}} = \text{Rejection efficiency}$$

Problems

- Risky for the detector (dismounting, remounting, irradiation)
- Complex experimental procedure
- Authorizations? To transfer irradiated material (no problem towards Legnaro auth. already existing)

What has been already done:

Advanced Contact with IRRAD facilities responsible (M. Glaser)

To be defined

- Is it worthwhile?
- Location:
  - IRRAD-6 or
  - INAF Lab @ Plateau Rosa (Breuil Cervinia)
- Which detector? 70x30 mm ^{nat}Ge BEGe or a depleted one prior diode implantation?

When irradiation is possible?

- IRRAD facility doesn’t have beam before end of april.
- PlateauRosa: Better before they close the cableway for mantainance (May)

Scheme of Ge-68 decay

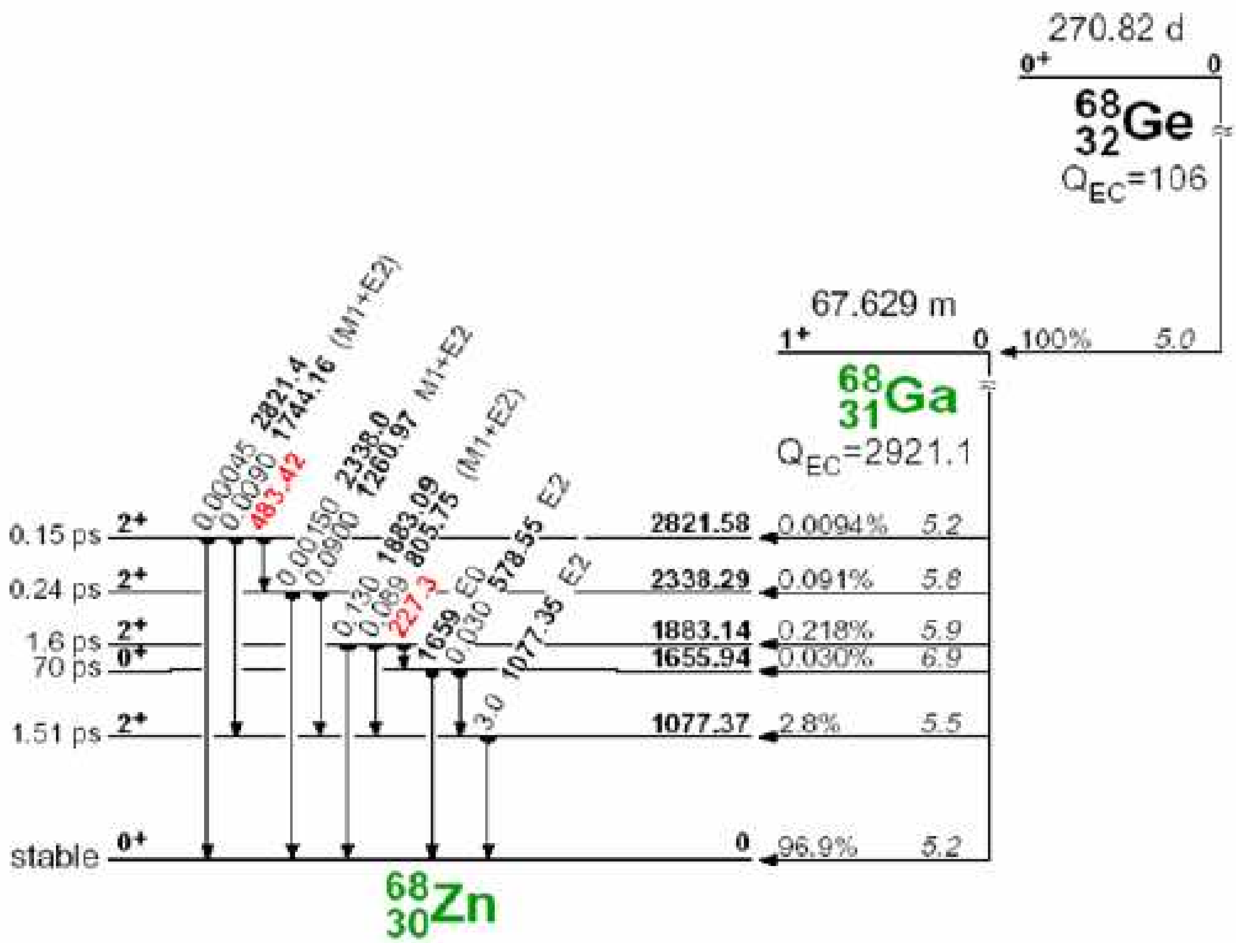


Figure 3-5 Decay schemes of ^{68}Ge and ^{68}Ga adapted from 8th Edition Table of Isotopes.

^{68}Zn:^{68}Ga e decay

Ee	E_{level}	Jp	$T_{1/2}$	Ib^+†	Ie†	$I(e+b^+)$†	Log *ft*
2921.1 *12*	0	0+		88.0 *4*	8.94 *9*	96.9 *4*	5.192 *2*
(1843.7 *12*)	1077.37 *4*	2+	1.51 ps *6*	1.1 *1*	1.7 *2*	2.8 *3*	5.52 *5*
(1265.2 *12*)	1655.94 *6*	0+	70 ps *35*		0.031 *4*	0.031 *4*	6.93 *6*
(1038.0 *12*)	1883.14 *5*	2+	1.6 ps *3*		0.222 *24*	0.222 *24*	5.89 *5*
(582.8 *12*)	2338.29 *6*	2+	0.24 ps $^{+11}_{-6}$		0.083 *10*	0.083 *10*	5.81 *6*
(99.5 *12*)	2821.58 *12*	2+	0.15 ps *3*		0.0097 *11*	0.0097 *11*	5.14 *5*

†: For intensity per e 100 decays, multiply by 1 .

Scheme of Co-60 decay

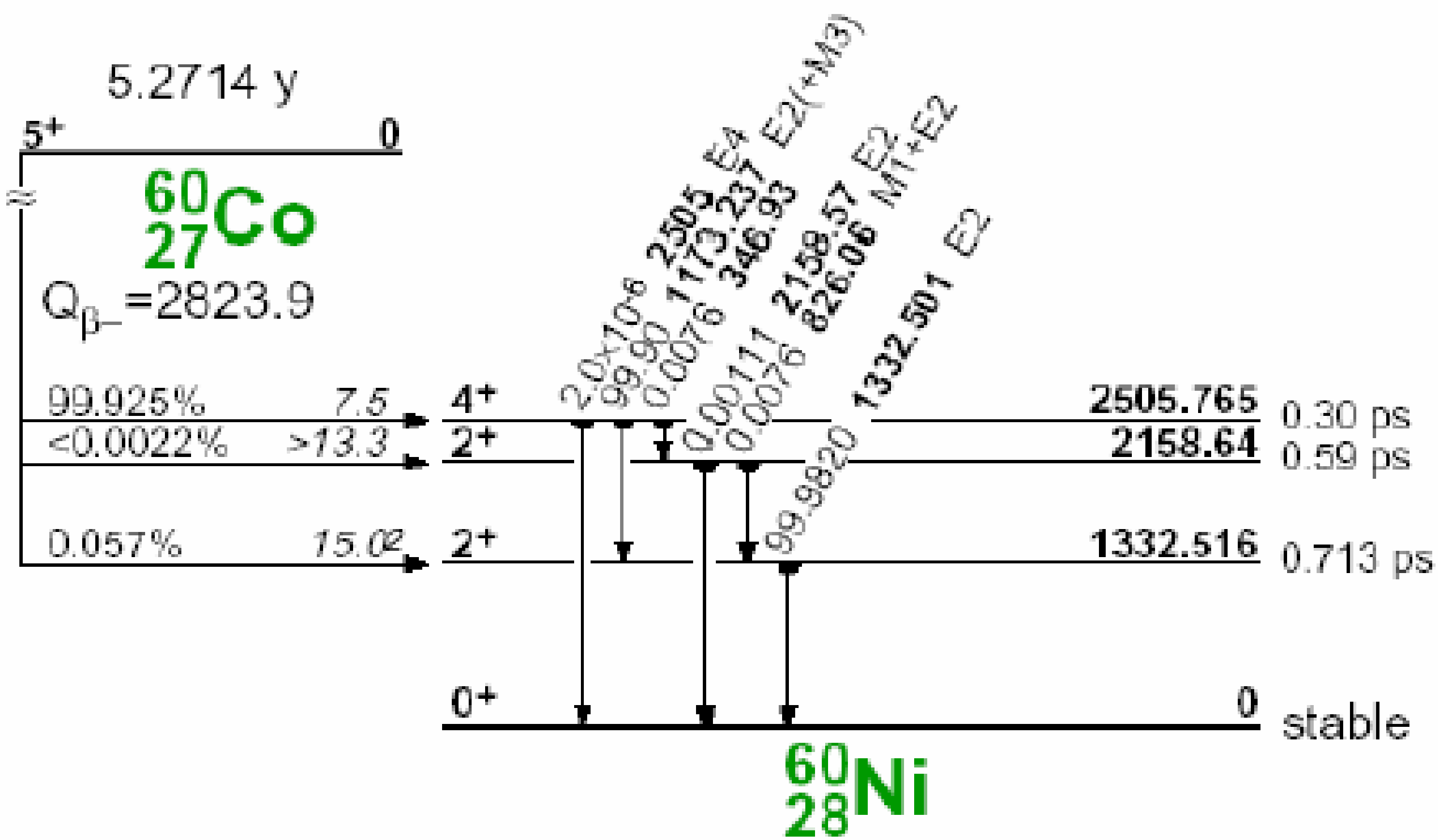
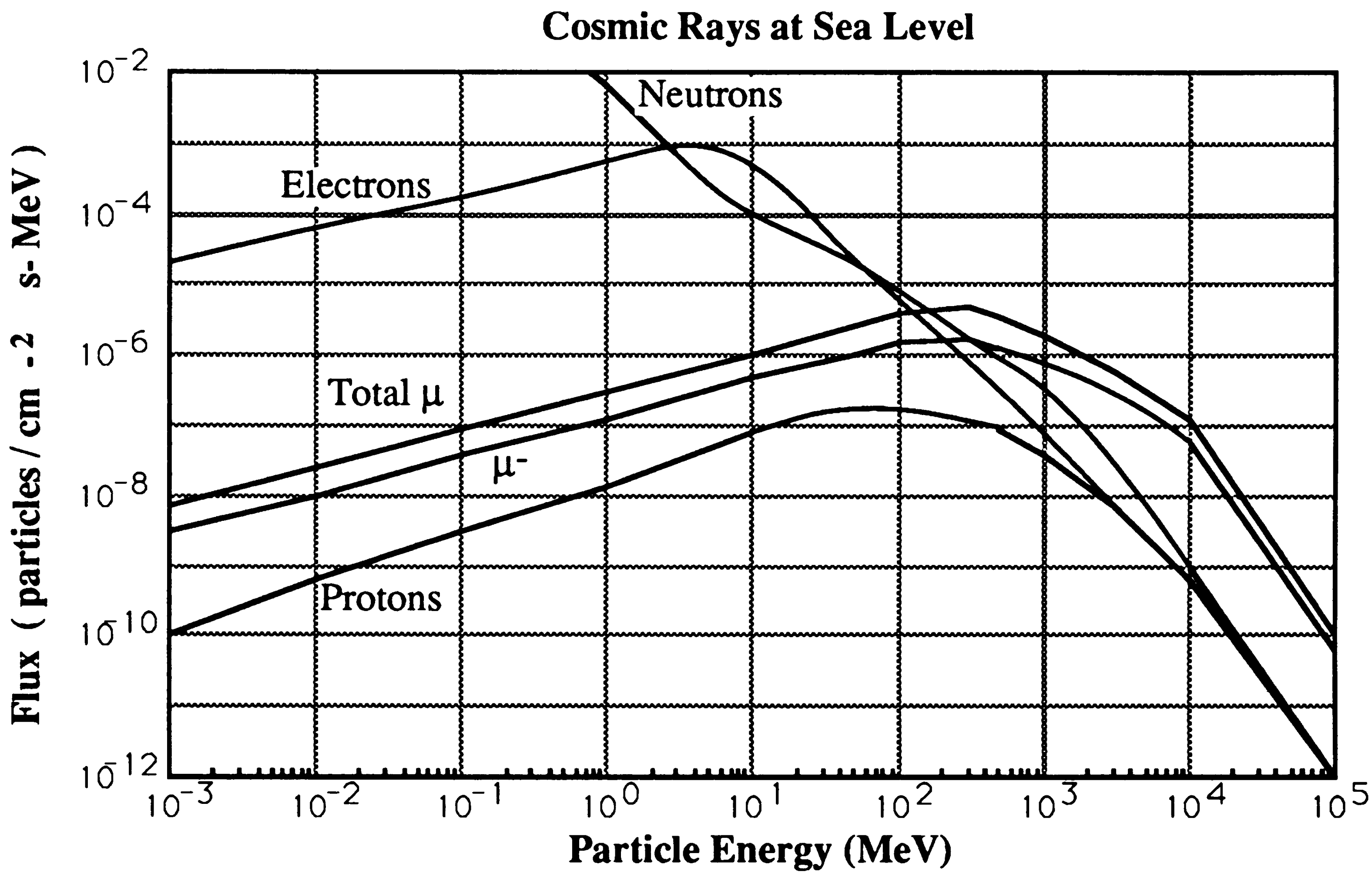


Figure 3-8 Decay scheme of ^{60}Co from 8th Edition Table of Isotopes.



Flux of cosmic ray particles at sea level at 40° N geomagnetic latitude. Data from J. Ziegler, Nucl. Instr. Methods, **191** (1981) 419. Below 3 MeV for electrons and about 10 MeV for protons the fluxes depend on local atmospheric conditions.