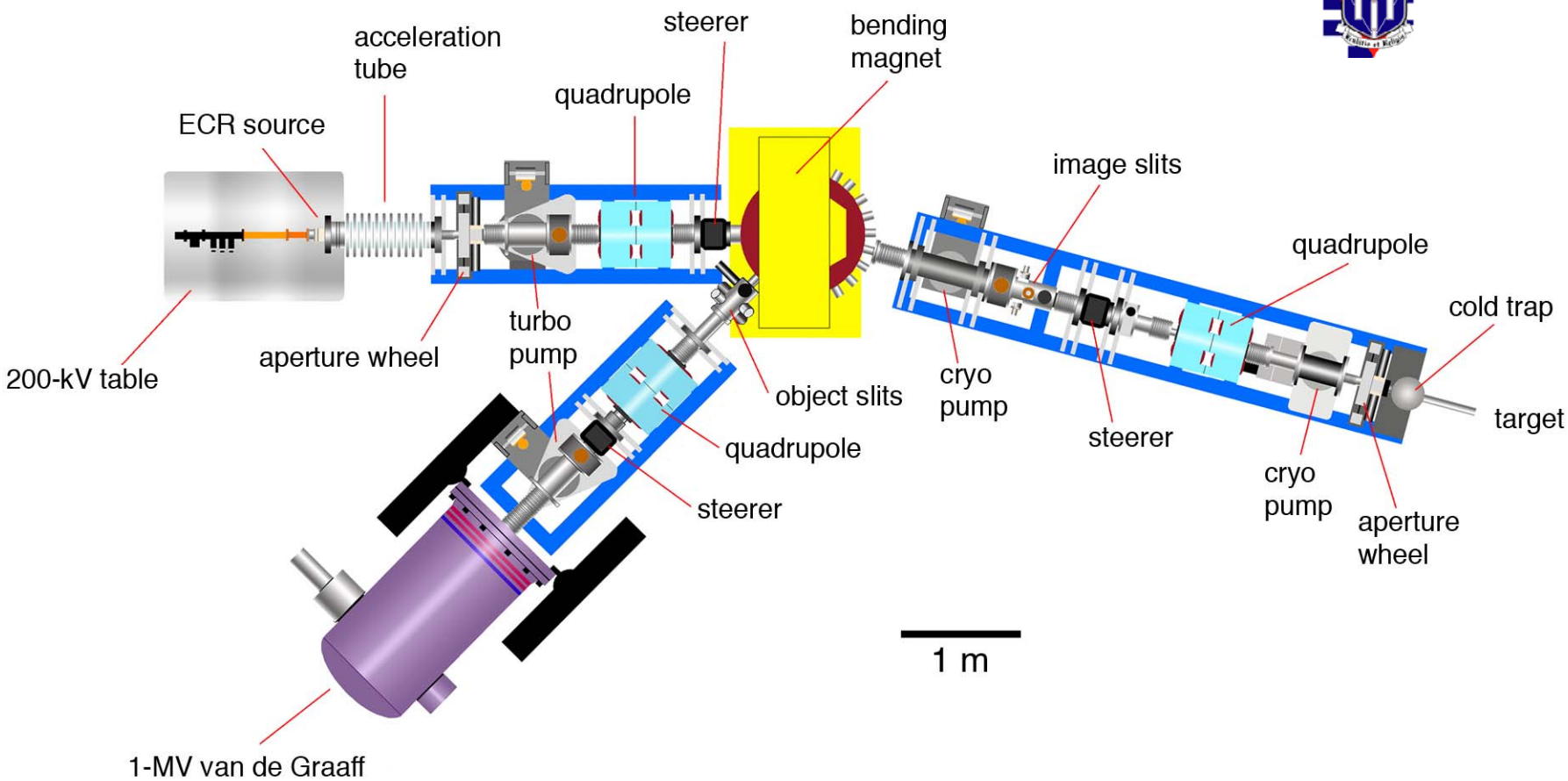
NUCLEAR ASTROPHYSICS ABOVE GROUND

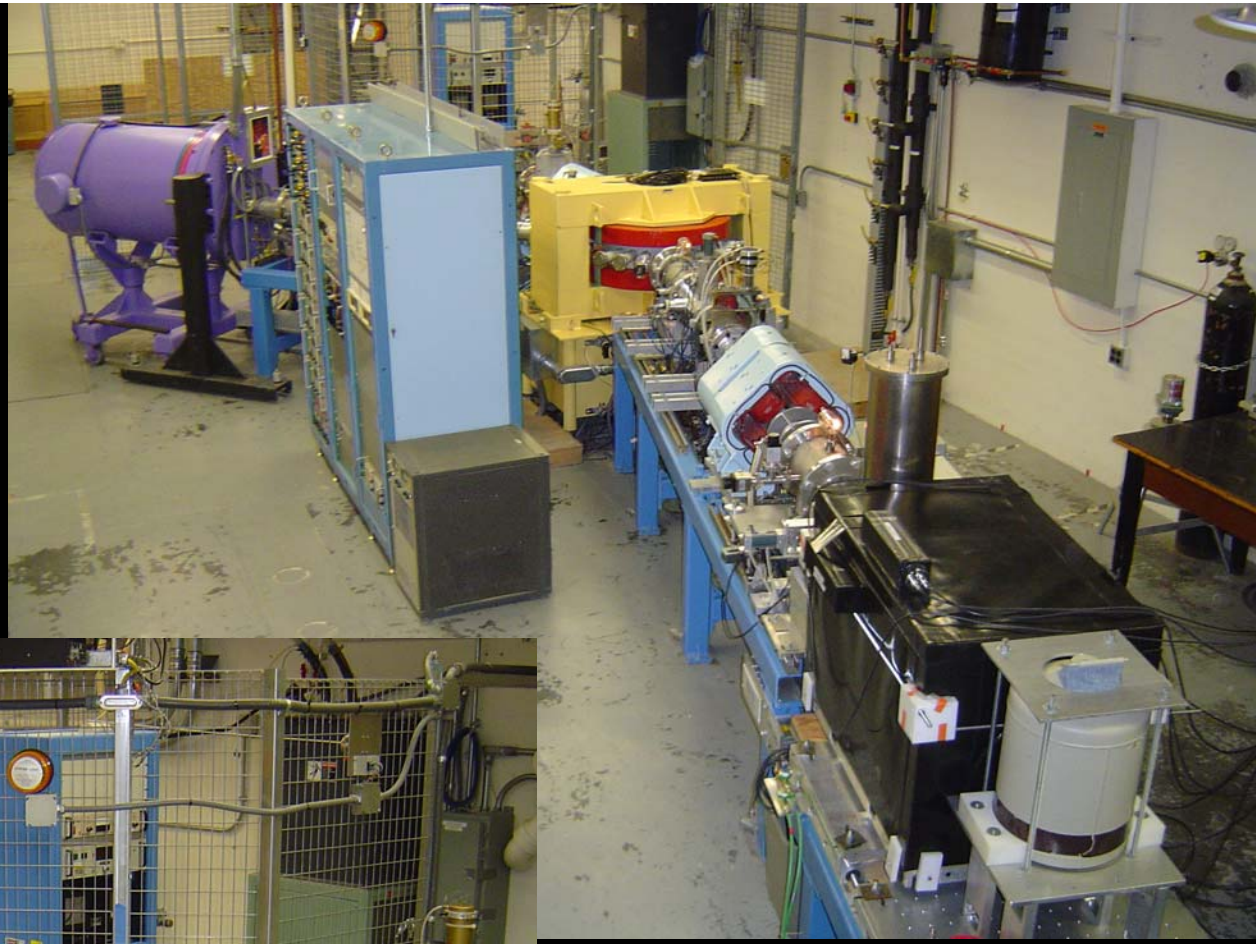
Design goals:

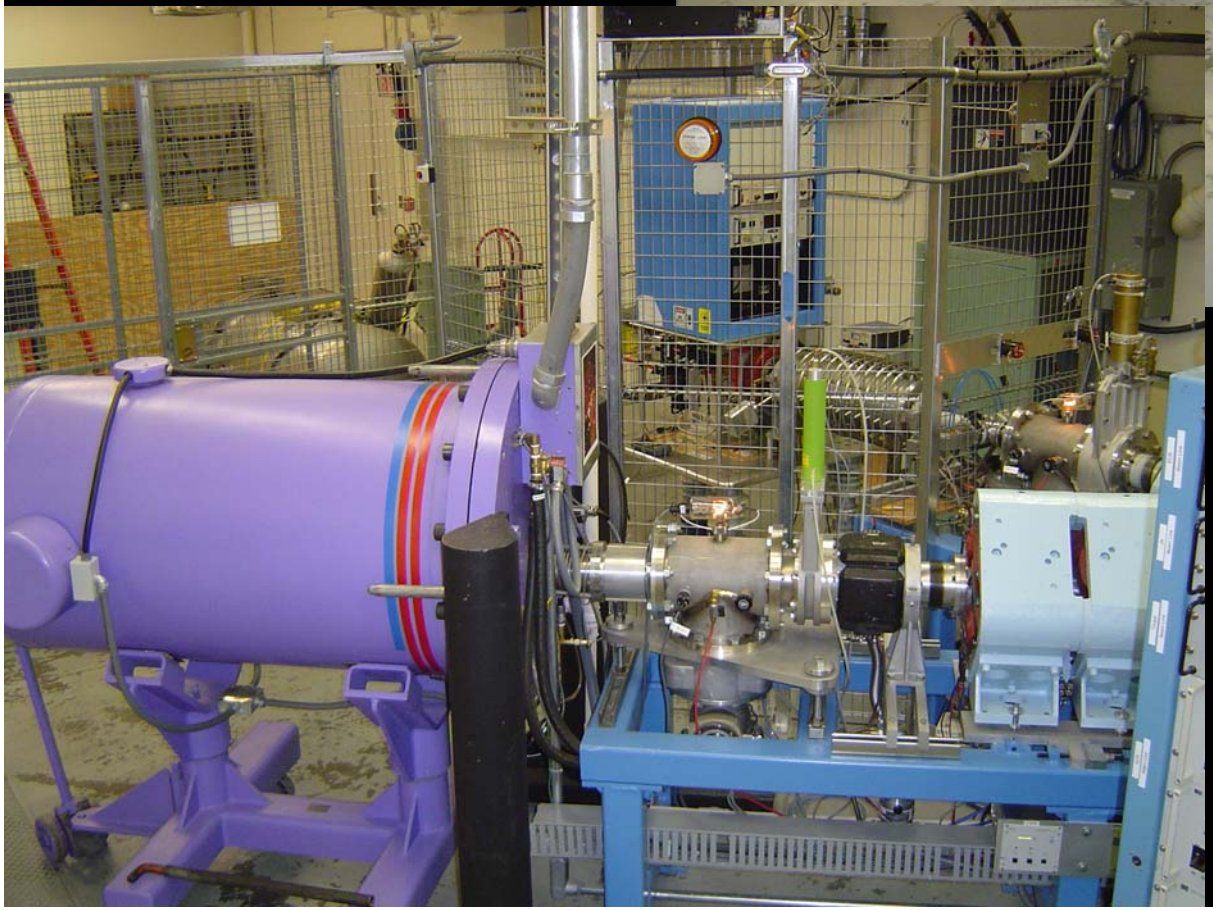
- Must be cheap
- Want E $\approx$ 0 - 1000 keV, $\Delta E \leq 1$ keV
  I_{avg} ~1 mA for E $\leq$ 200 keV
  I ~ 0.2 mA for E > 200 keV
- Beam quality should be “reasonable”
- Must run for extended periods with minimal effort

LENA

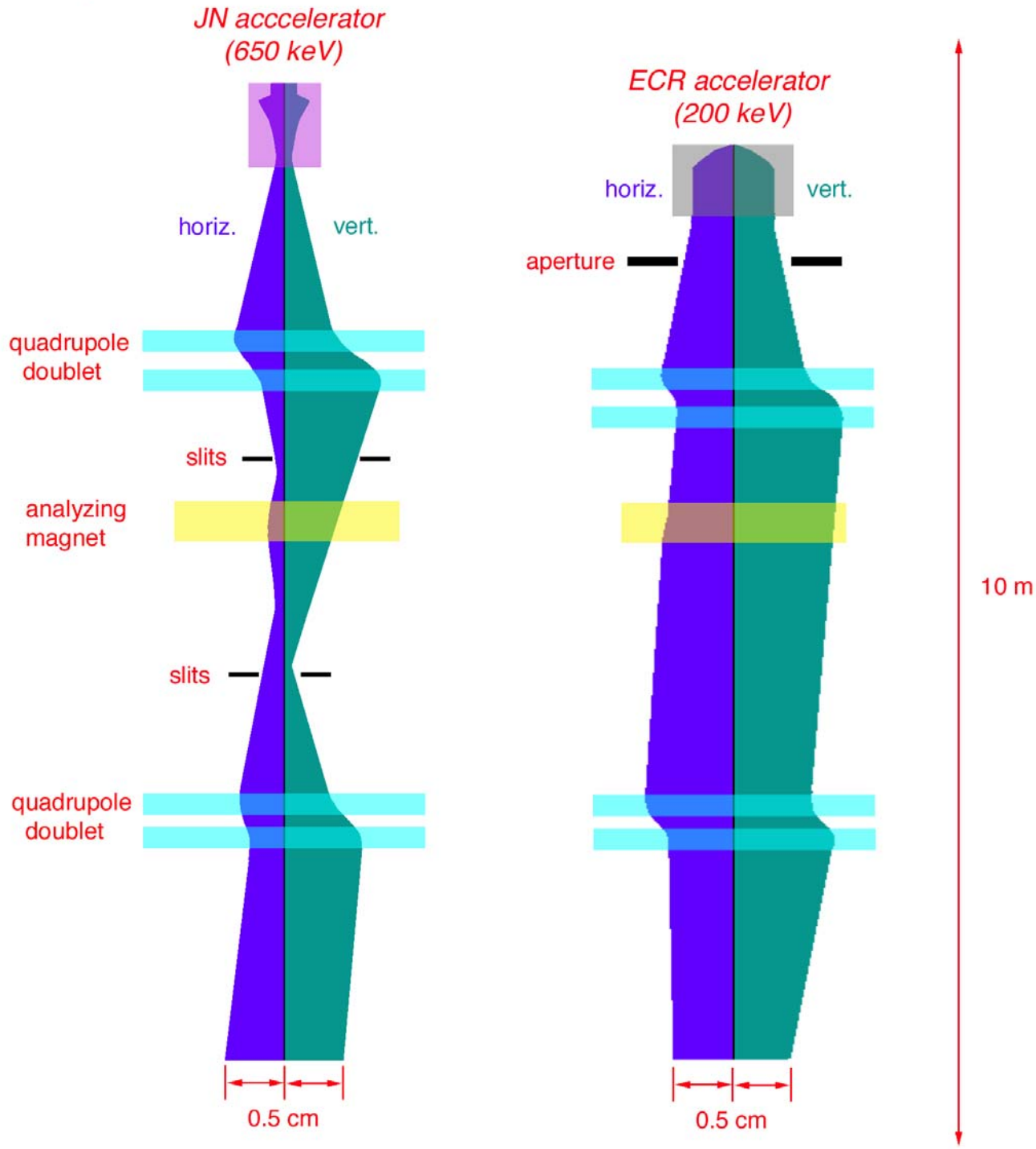


the Laboratory for Experimental Nuclear Astrophysics

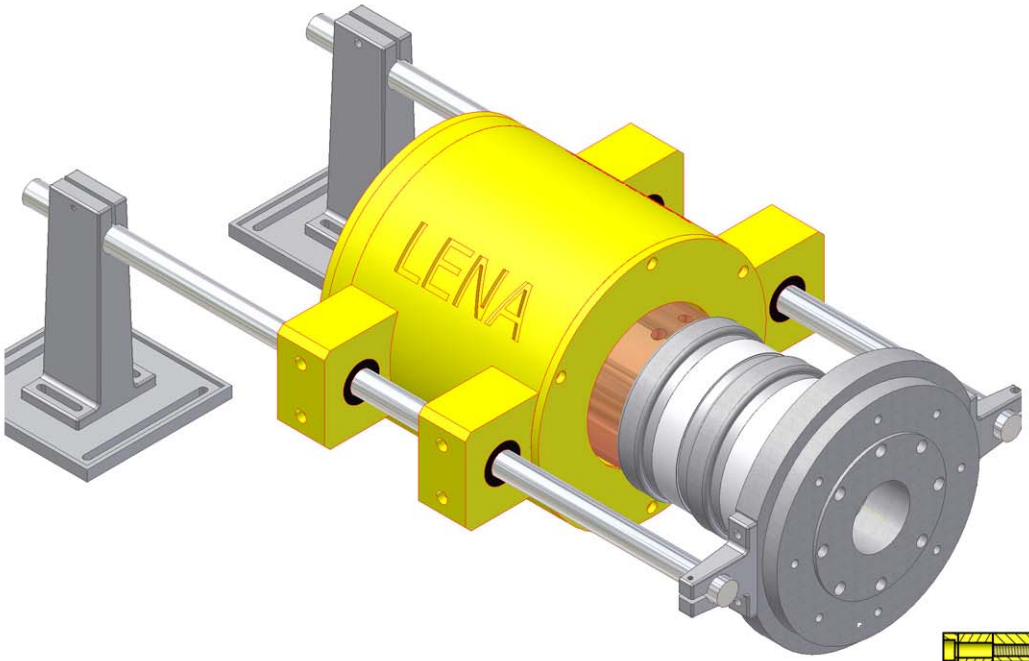


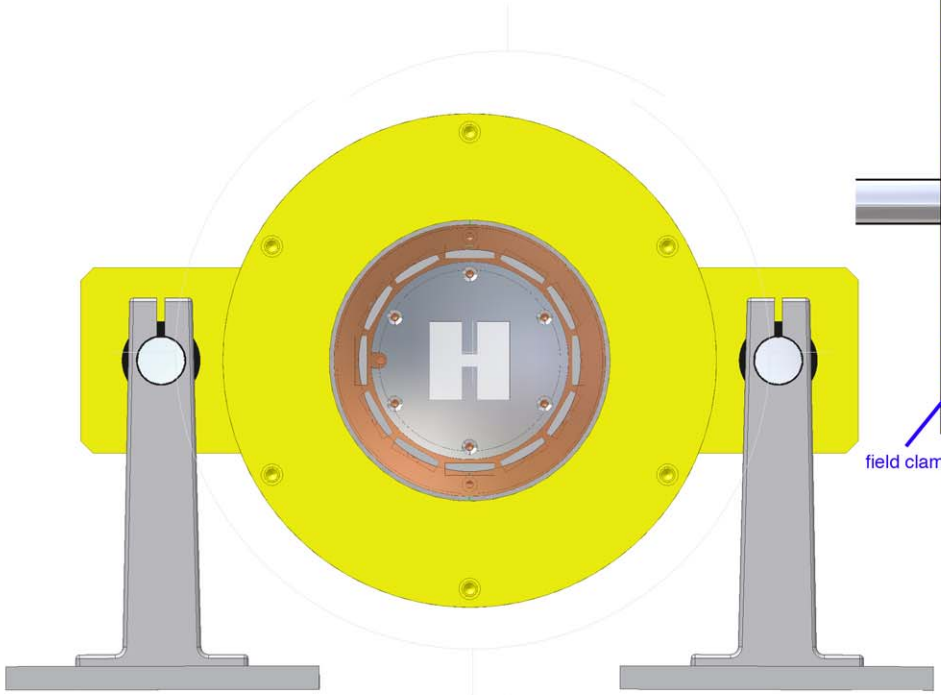


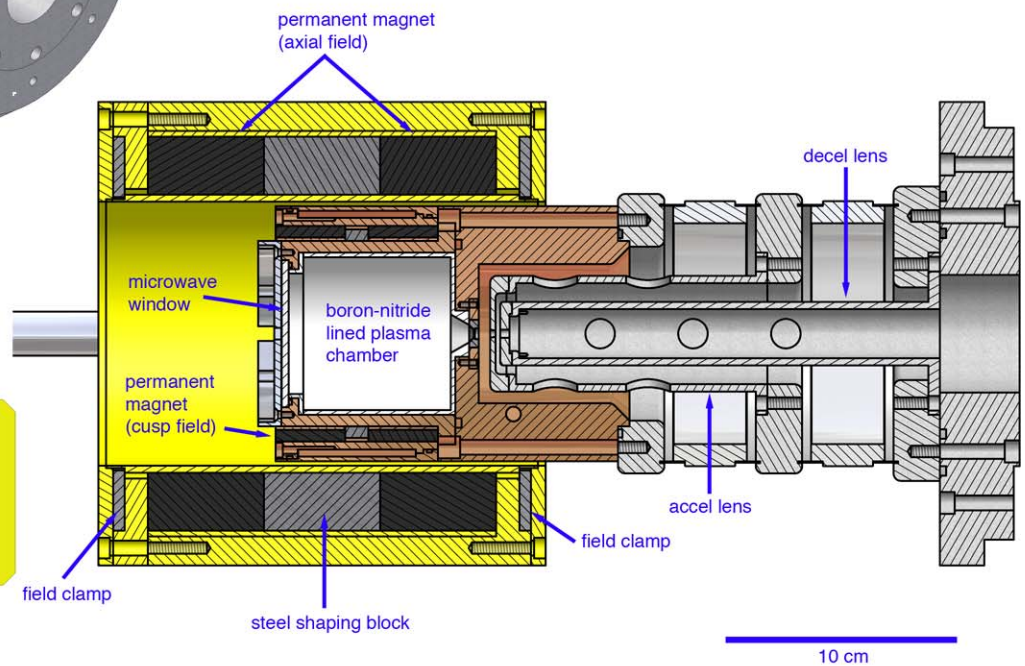
Beam Optics


JN acccelerator
(650 keV)
horiz.
vert.
quadrupole
doublet
slits
analyzing
magnet
slits
quadrupole
doublet
0.5 cm
ECR accelerator
(200 keV)
horiz.
vert.
aperture
0.5 cm
10 m

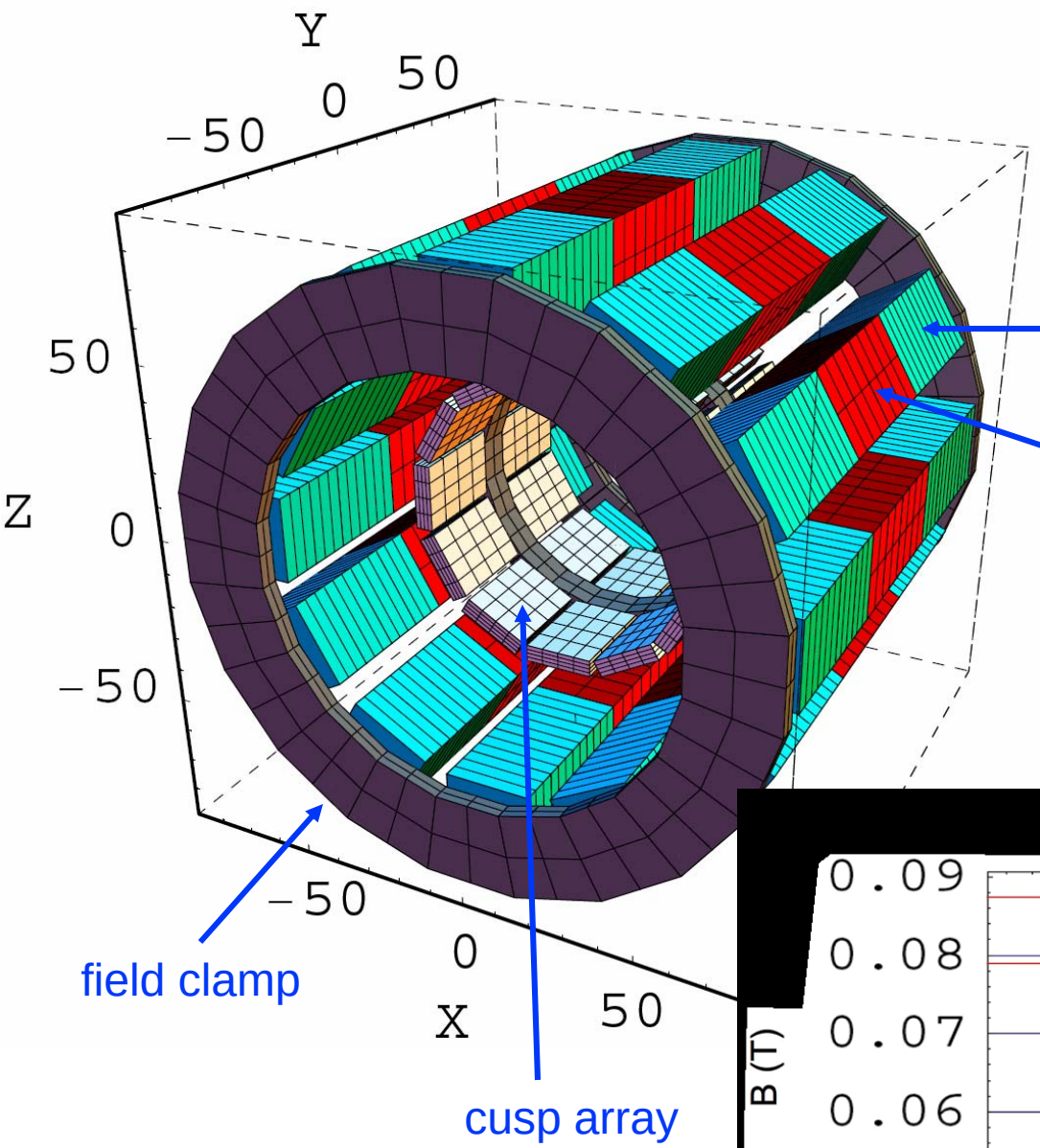
ECR source v.2.0



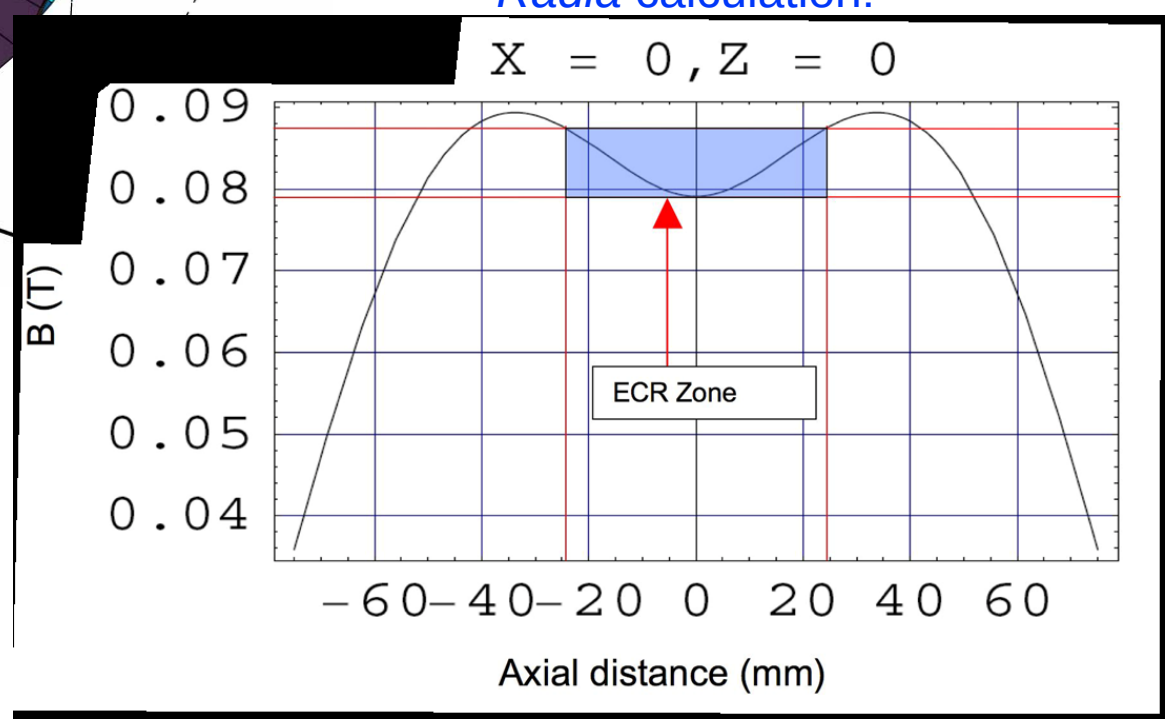


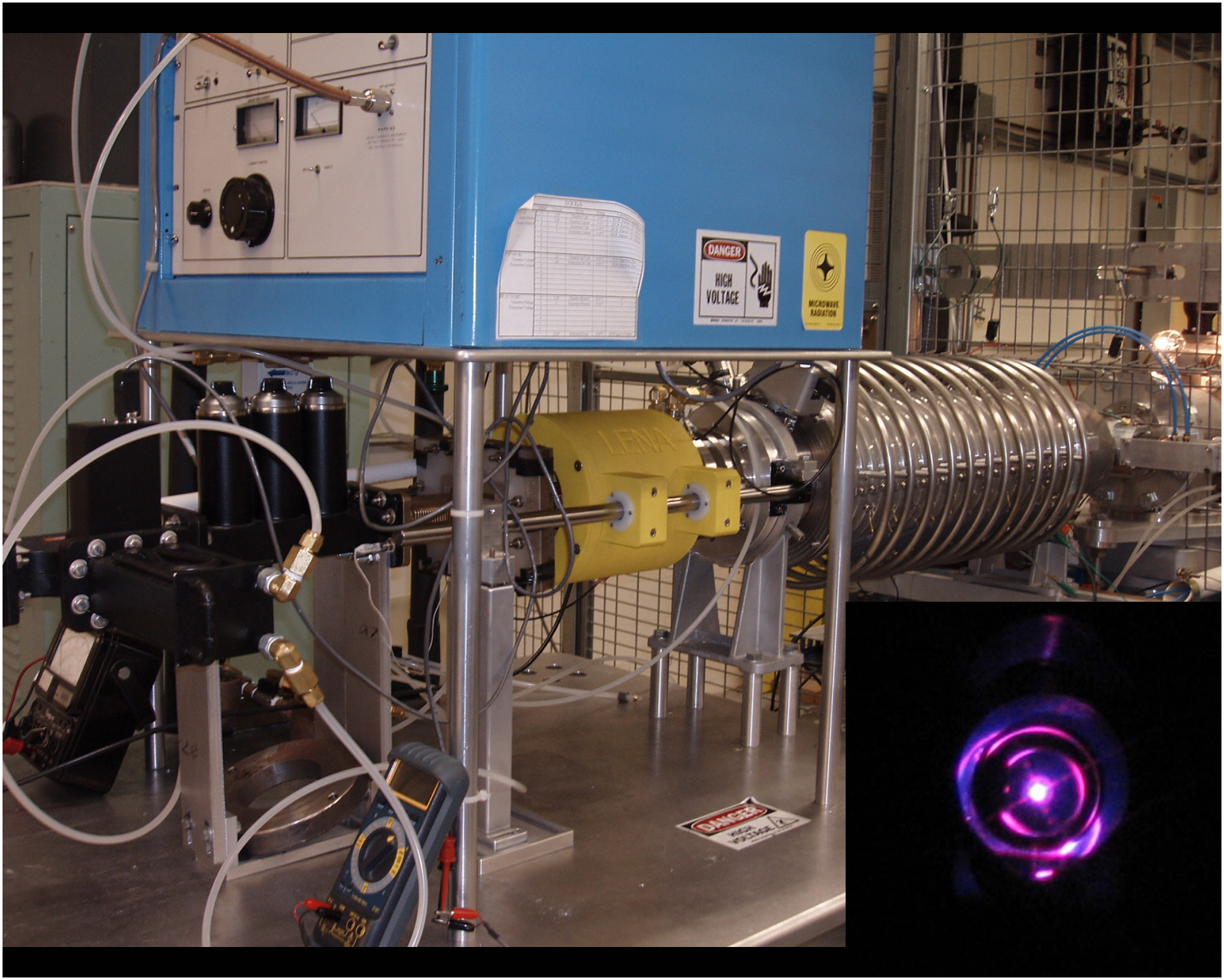


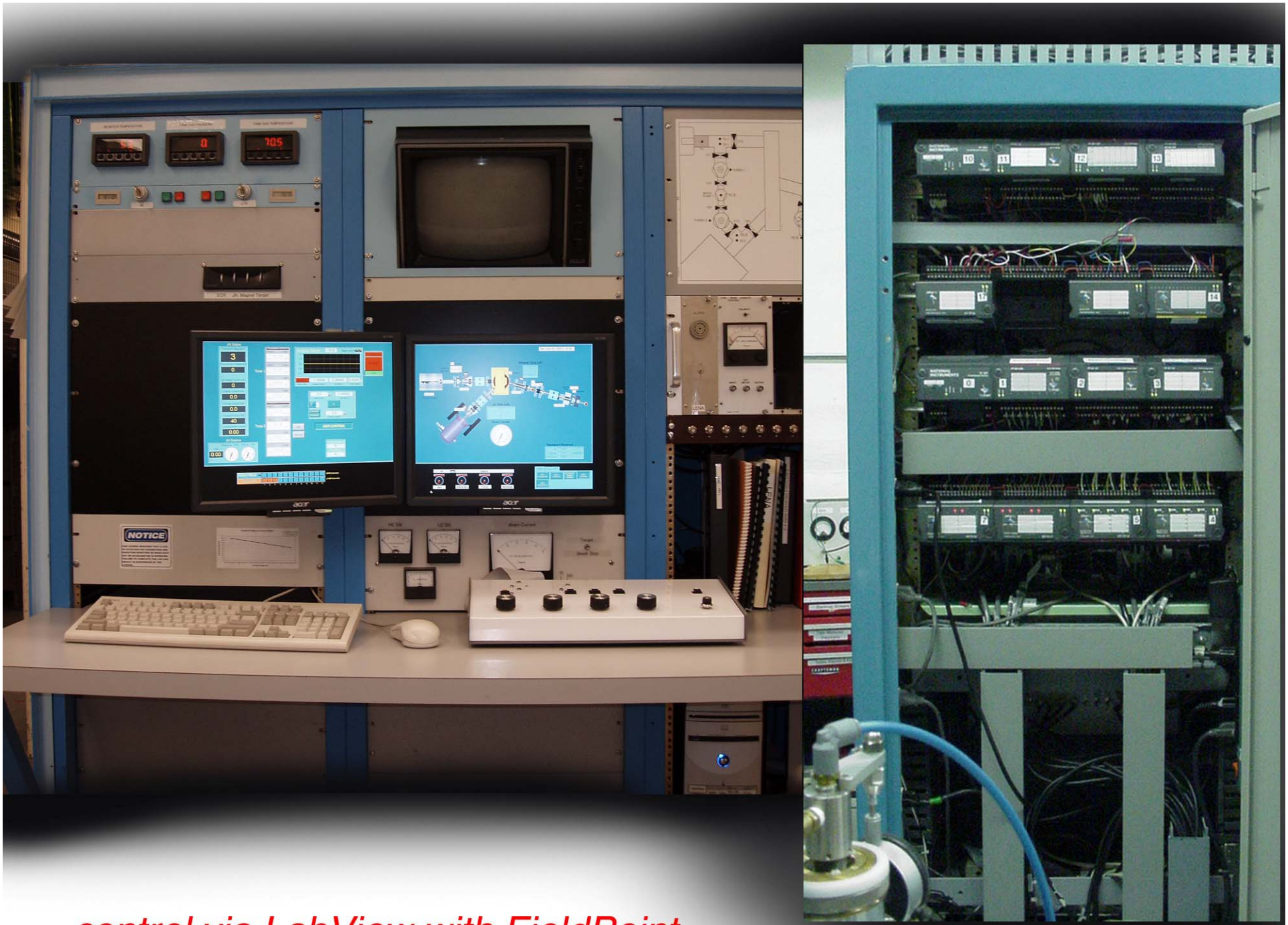
Magnet Design



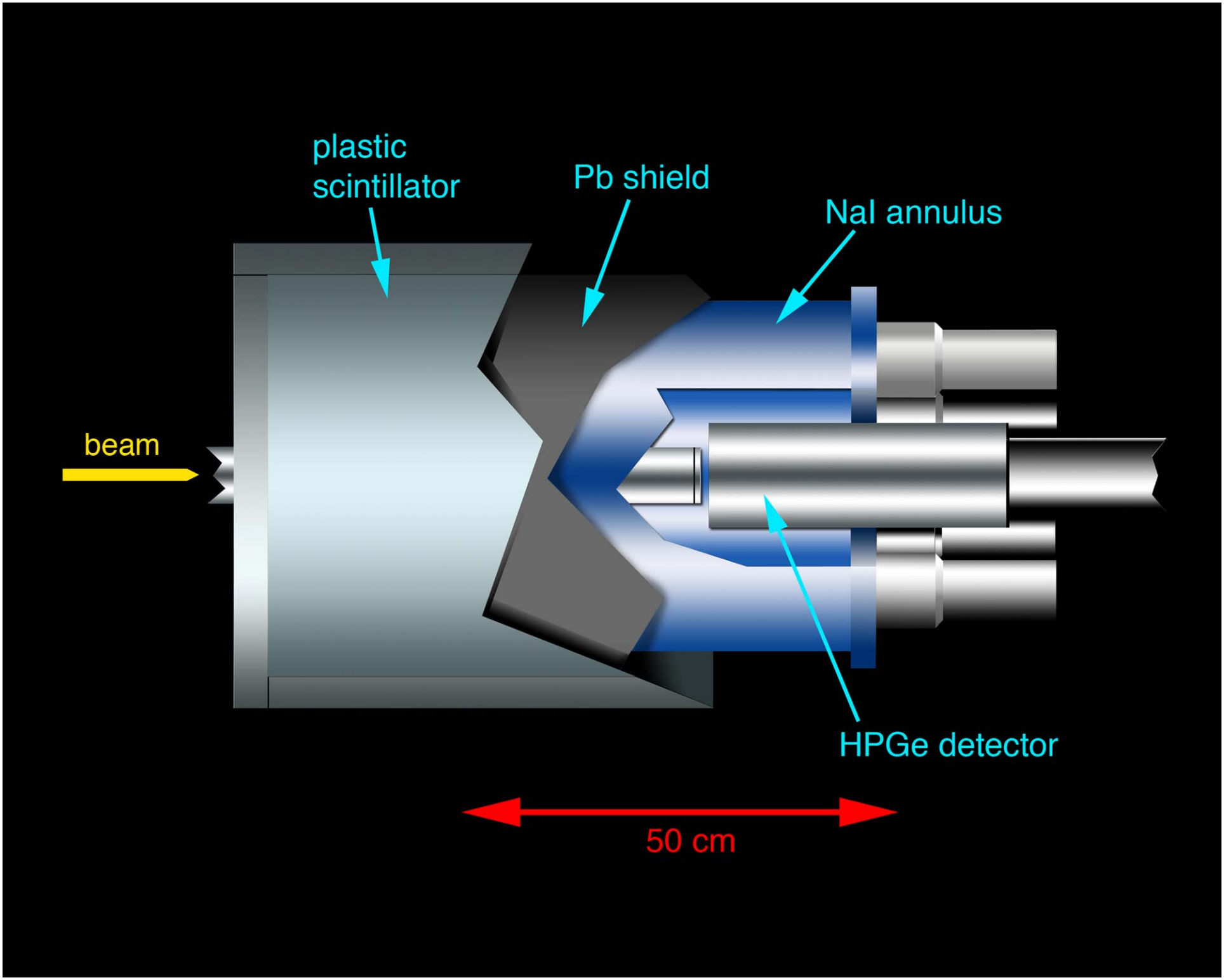
Radia calculation:



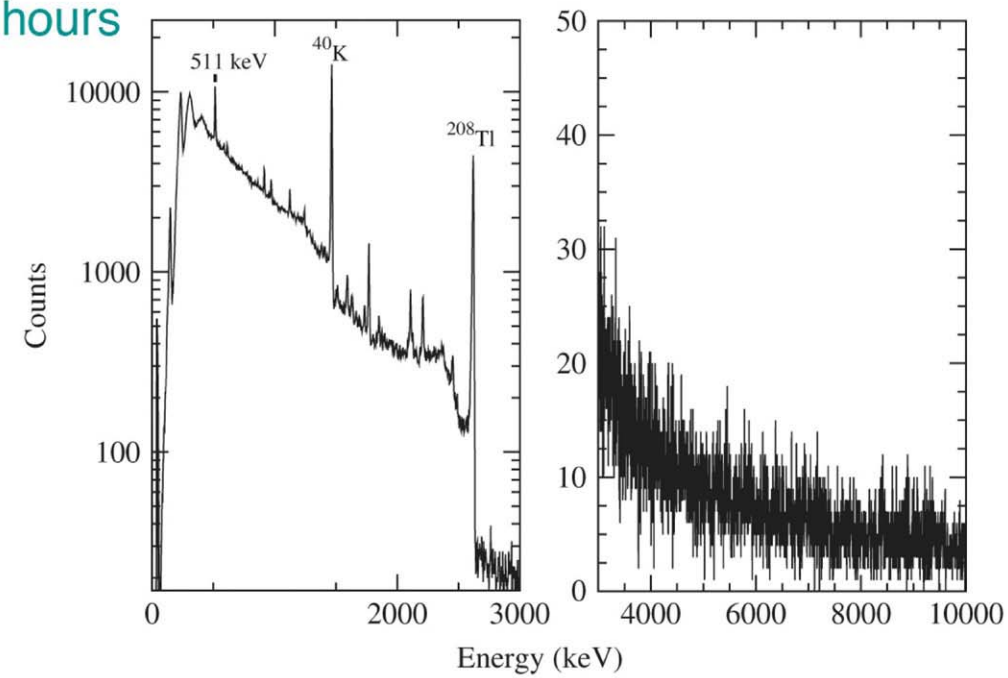

DANGER
HIGH VOLTAGE
MICROWAVE RADIATION
DANGER
HIGH VOLTAGE



control via LabView with FieldPoint


plastic
scintillator
Pb shield
NaI annulus
beam
HPGe detector
50 cm

HPGe detector+ lead shield
17 hours



backgrounds from room and apparatus: ^{40}K, ^{208}Tl, Rn gas, ^{238}U

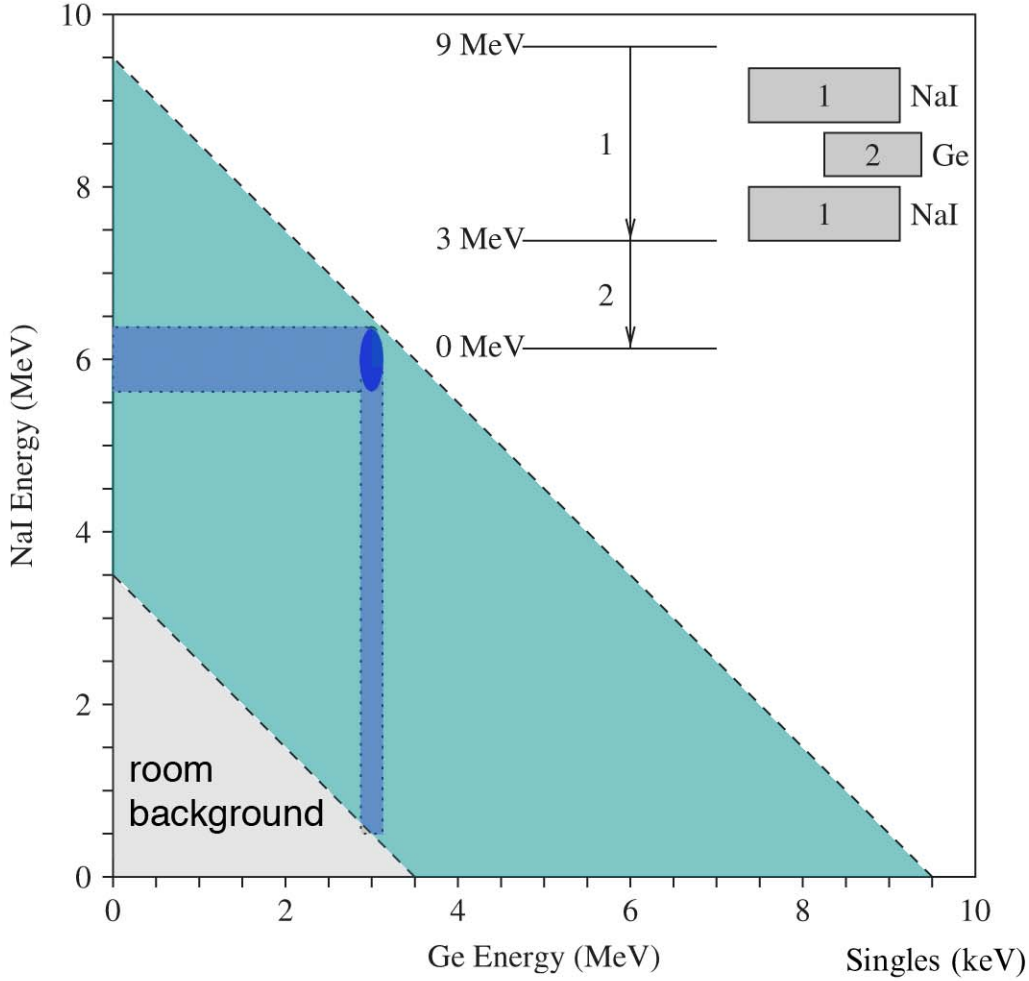
backgrounds from beam transport or target impurities (not shown here)

cosmic rays: secondary neutrons; muon-induced ionization, pair-production, bremsstrahlung, nuclear interactions, etc.

The singles background rate in the HPGe detector for a range of shielding techniques

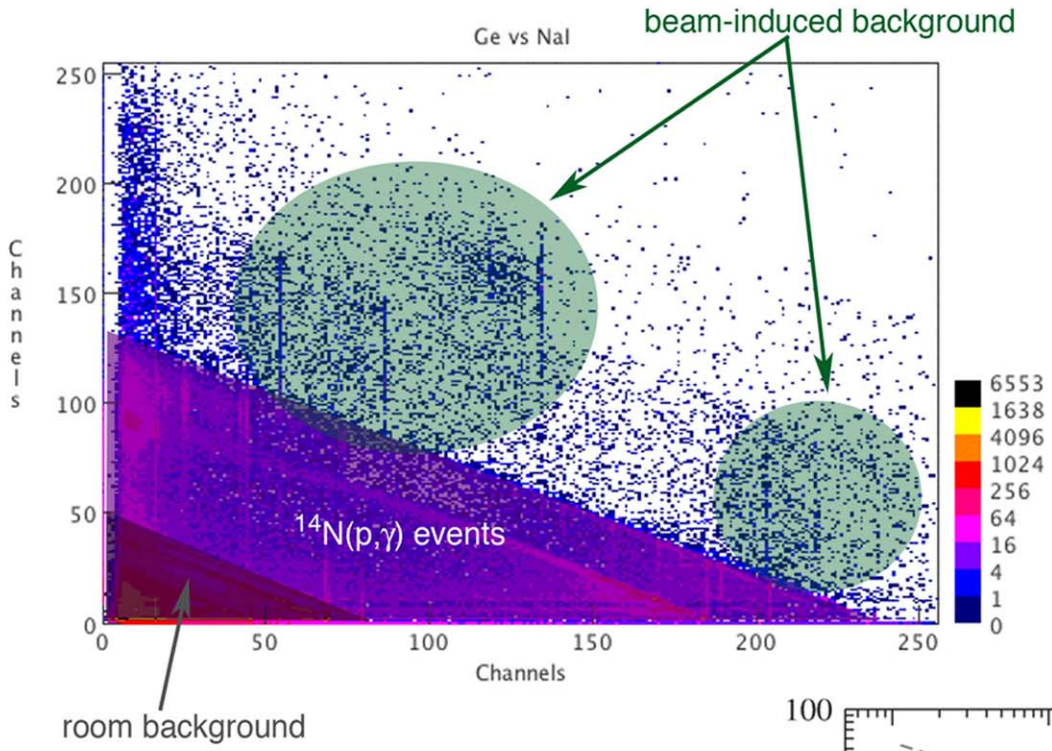
Singles (keV)	$N^{Ge}_{\gamma,BG}$ (cpm)		
	No shield	Passive shield	Passive and active shield
600–3000	7620	770	742
3000–9000	20	13	3.1

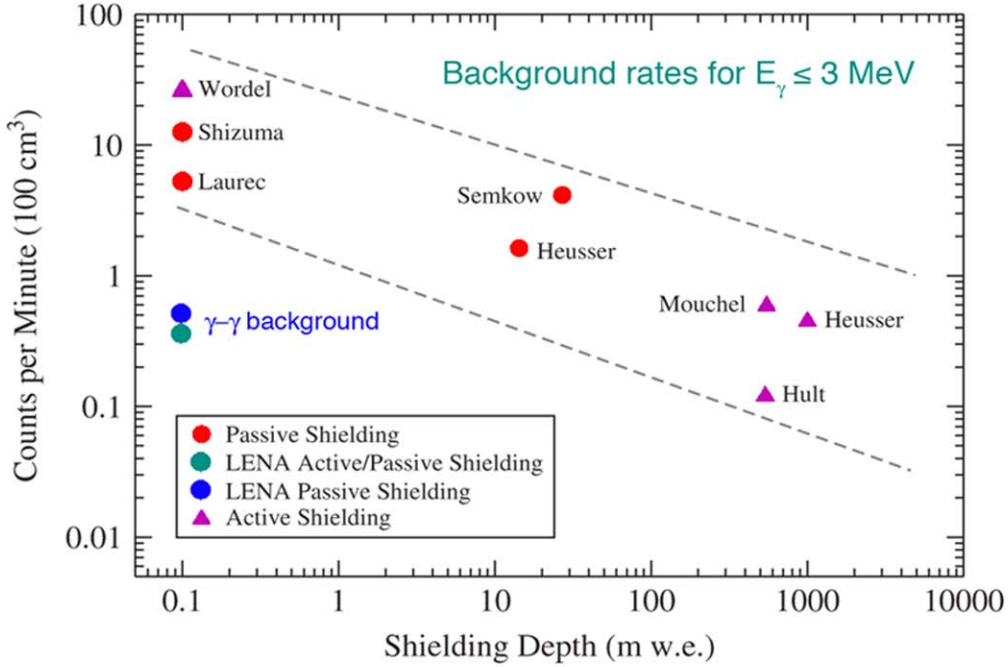
R. Longland et al. / Nuclear Instruments and Methods in Physics Research A 566 (2006) 452–464



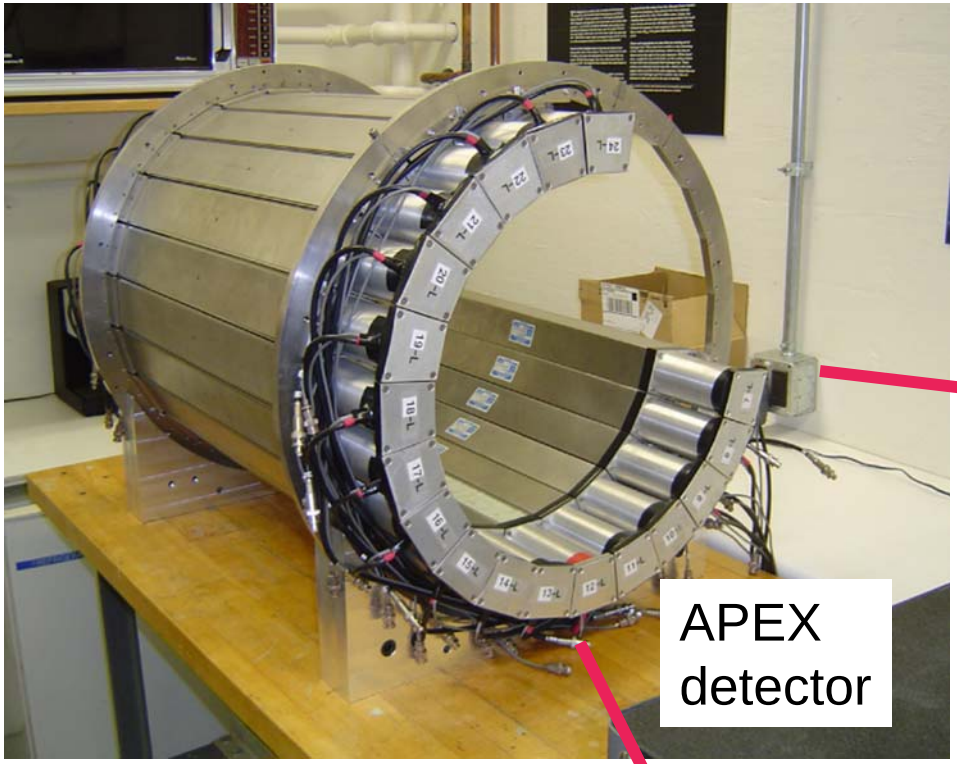
Singles (keV)	$N^{Ge}_{\gamma,BG}$ (cpm) No shield	Passive shield	Passive and active shield
600–3000	7620	770	742
3000–9000	20	13	3.1

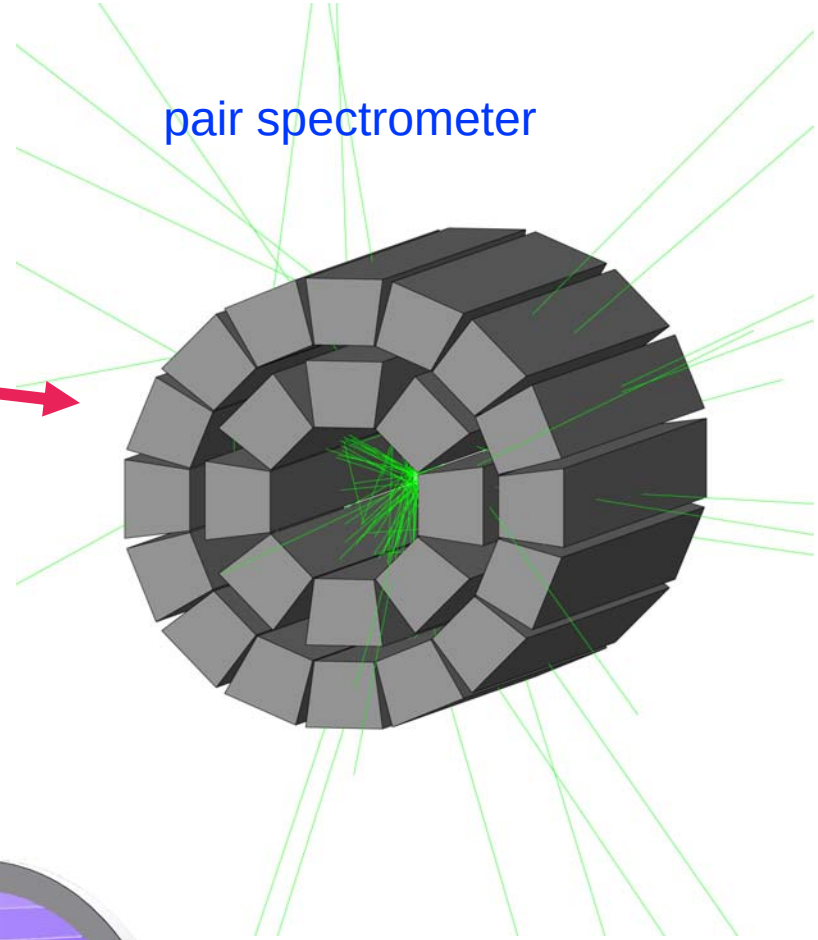
Coincidence (keV)	Passive shield	Passive and active shield
600–3000	3.0	2.1
3000–9000	1.3	0.95

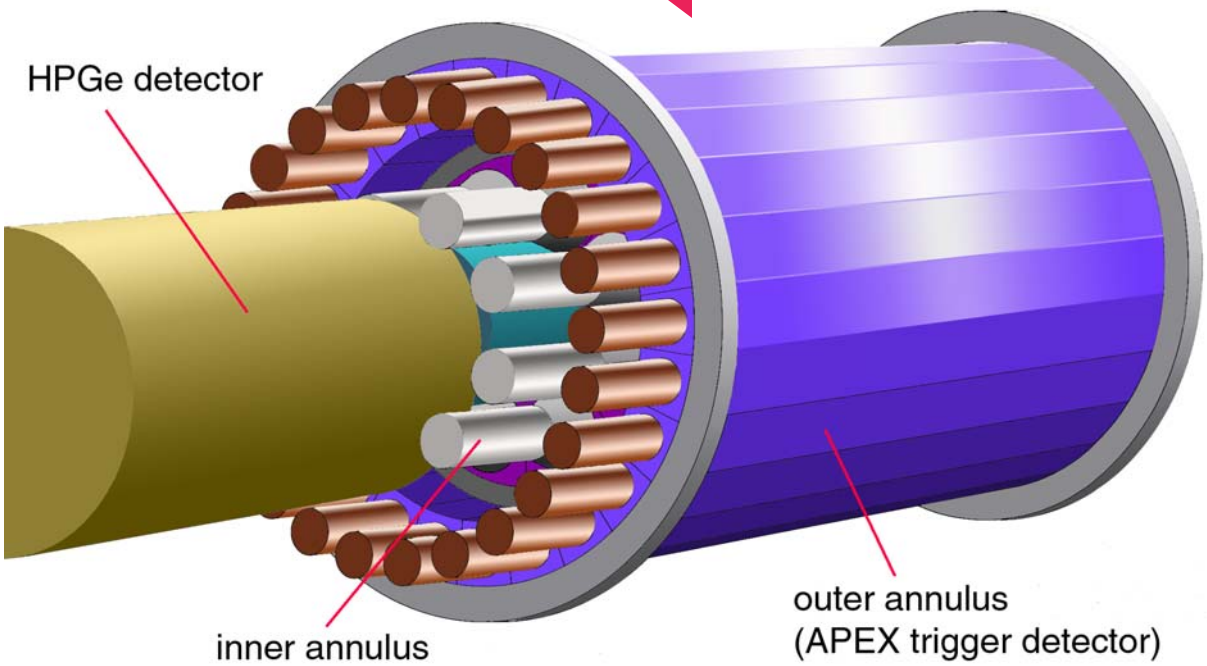




R. Longland et al. / Nuclear Instruments and Methods in Physics Research A 566 (2006) 452–464


APEX
detector


pair spectrometer


HPGe detector
inner annulus
outer annulus
(APEX trigger detector)

outer veto

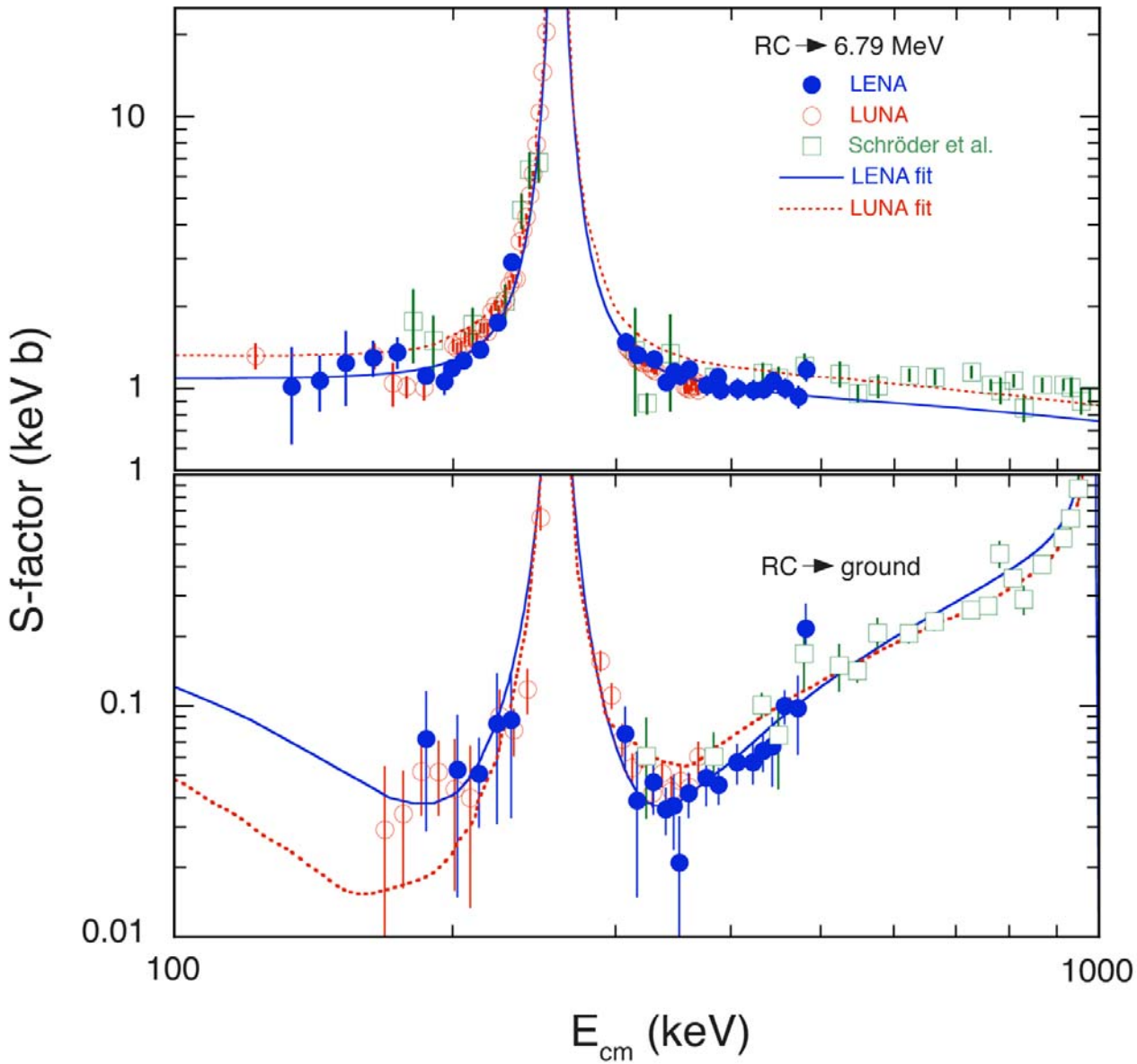
Event trigger:

1. Ge-veto anticoincidence
2. beam pulse (under development)

Cuts:

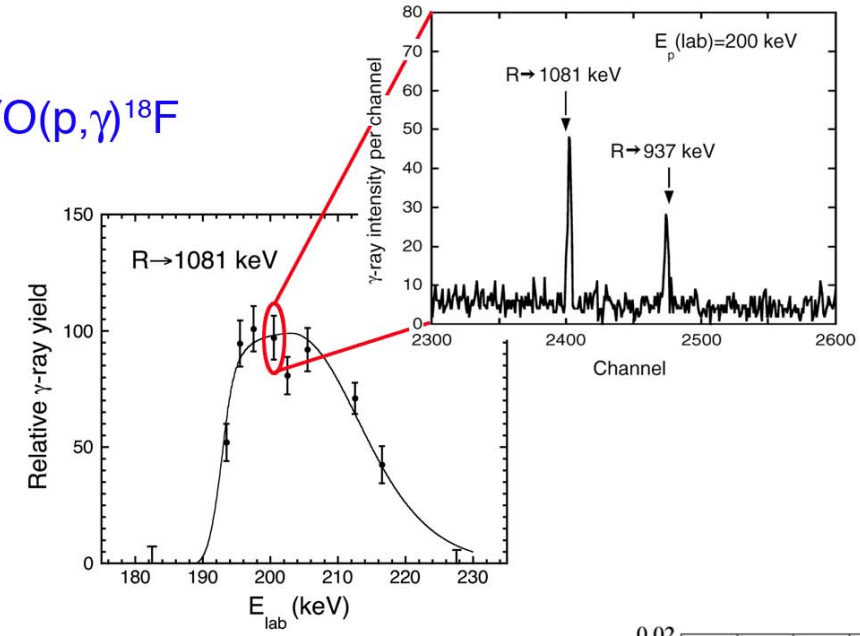
1. time
2. E(Ge) vs. E(NaI)
3. multiplicity
4. inner NaI vs. outer NaI
   (under development)
5. Ge pulse shape
   (under development)

Research at LENA



*R.C. Runkle et al. Phys. Rev. Lett **94**, 082503 (2005)*

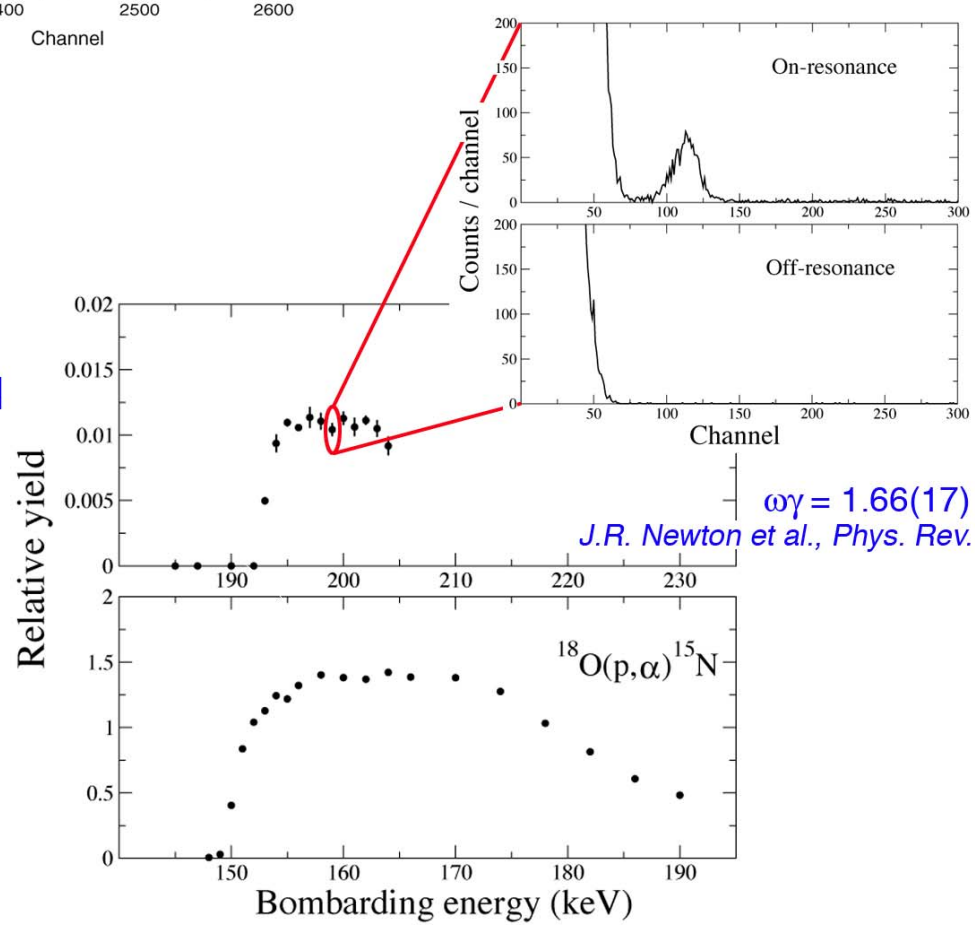
$^{17}O(p,\gamma)^{18}F$



$\omega\gamma = 1.2(2)\ \mu eV$

C. Fox et al., Phys. Rev. Lett. ***93*** *081102 92004); Phys. Rev. C.* ***71*** *055801 (2005)*

$^{17}O(p,\alpha)^{14}N$

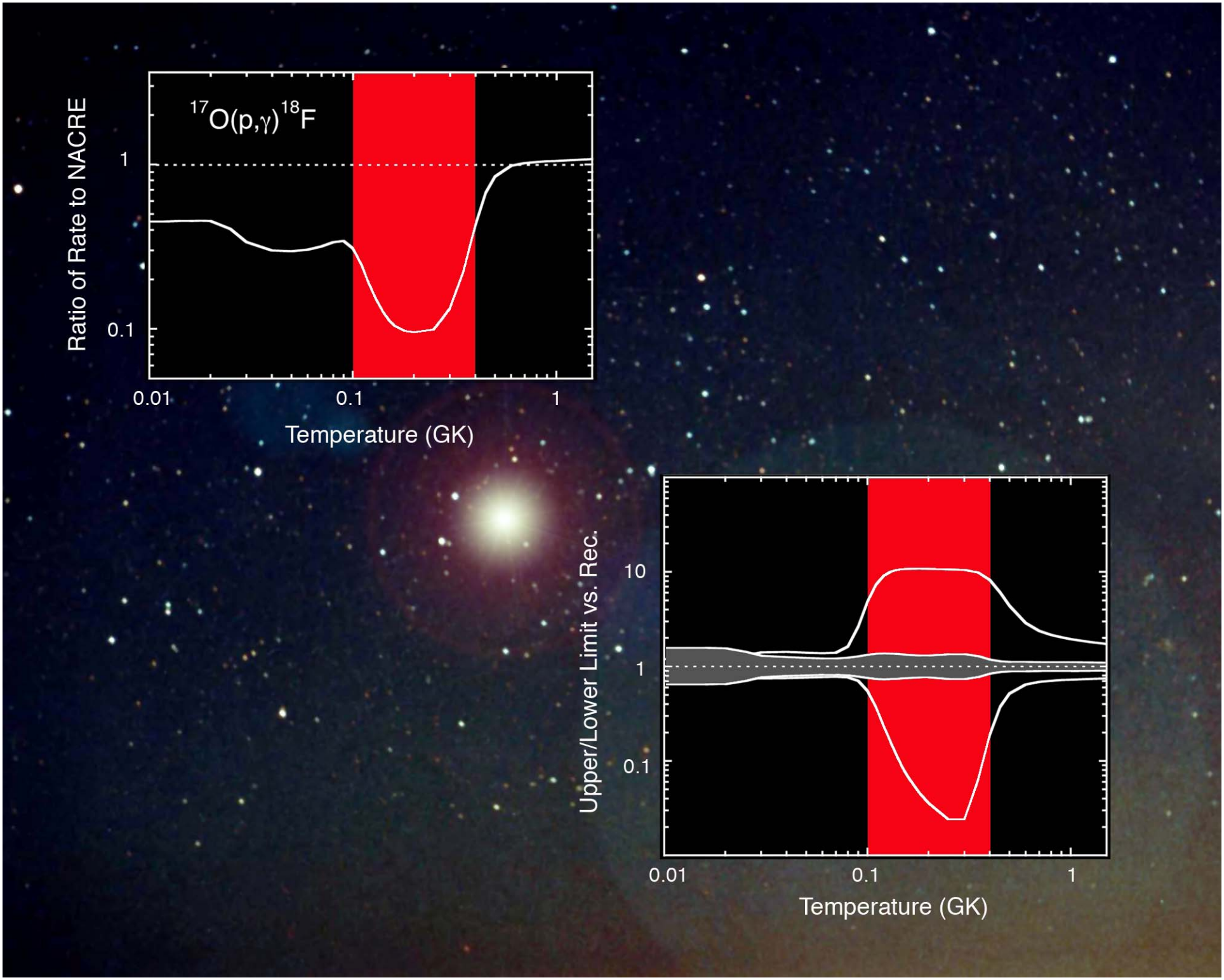


$\omega\gamma = 1.66(17)$ meV

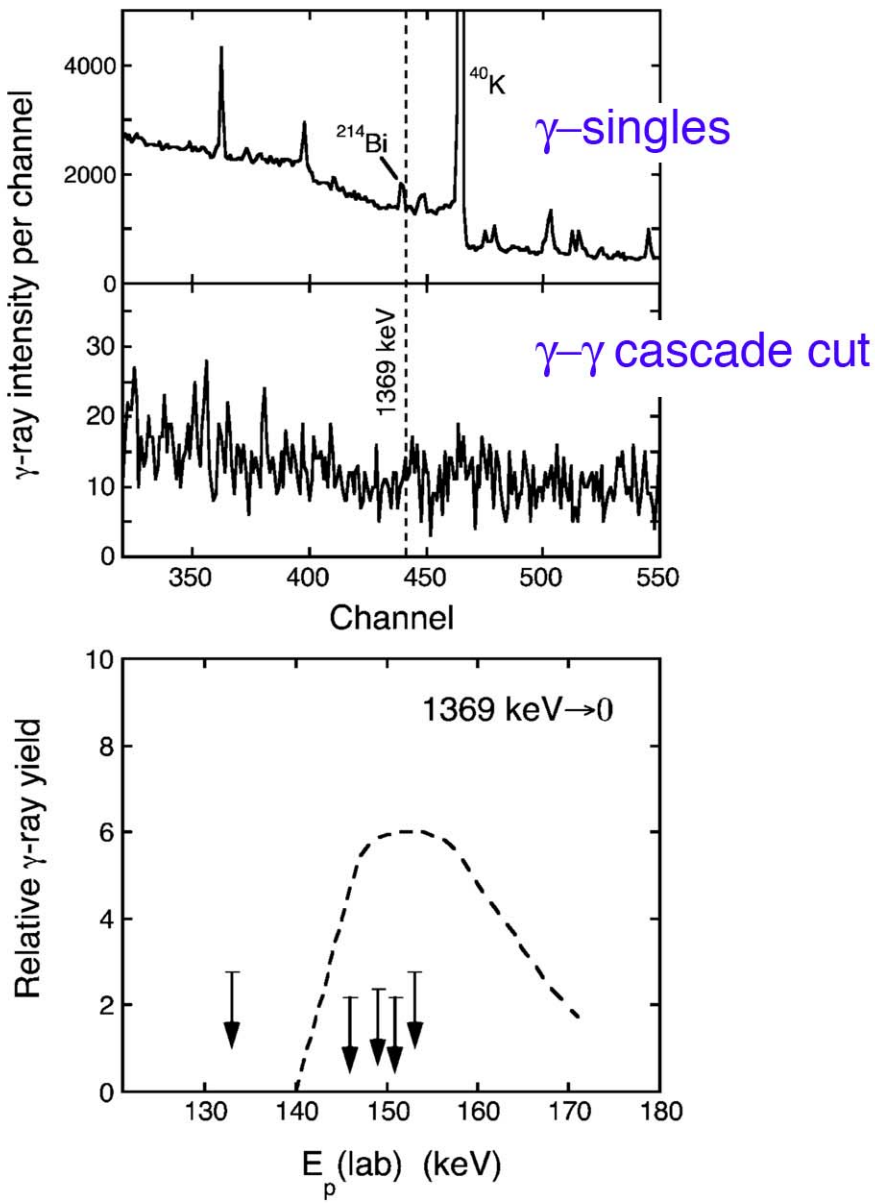
J.R. Newton et al., Phys. Rev. C (2007)

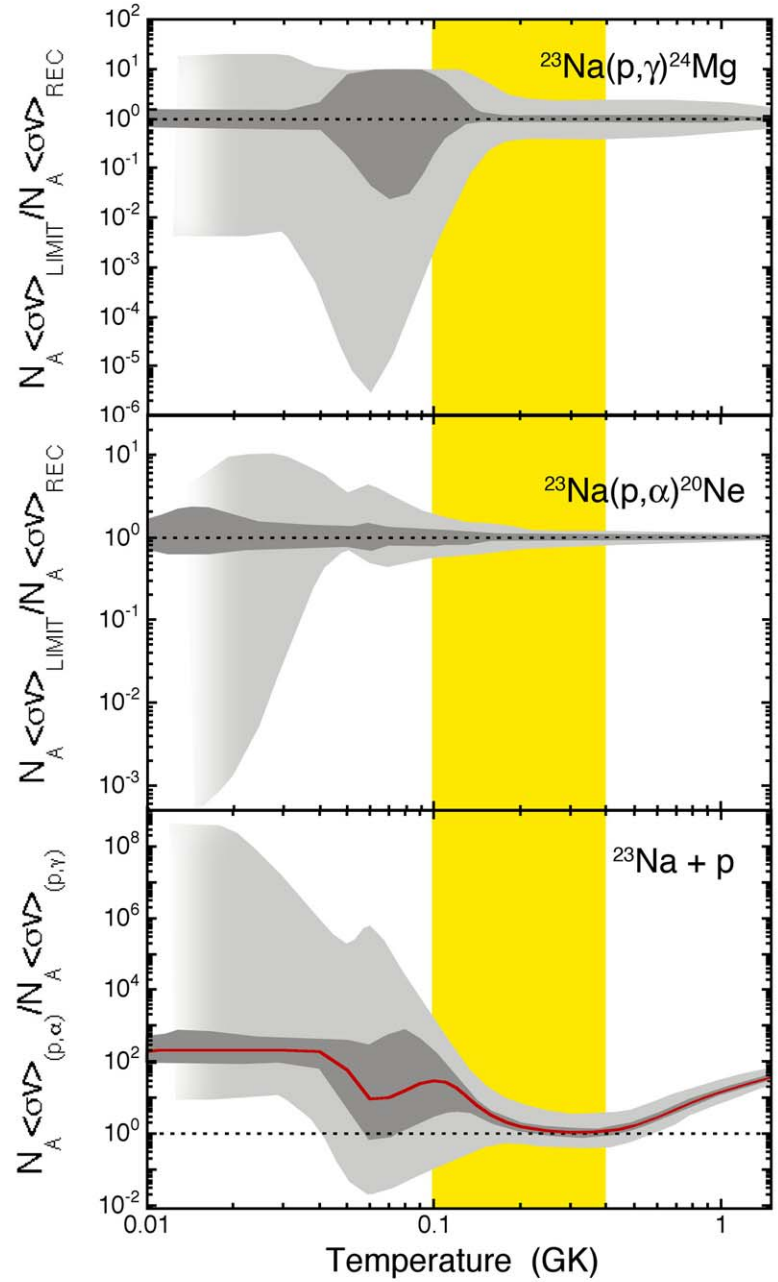
see also A. Chafa et al., PRL ***95*** *031101 (2005); PRL* ***96*** *019902 (2006) (erratum):* $\omega\gamma = 1.6(2)$ *meV*

B.H. Moazen at al. PRC ***75*** *065801 (2007)*


$^{17}O(p,\gamma)^{18}F$
Ratio of Rate to NACRE
1
0.1
0.01
0.1
1
Temperature (GK)
Upper/Lower Limit vs. Rec.
10
1
0.1
0.01
0.1
1
Temperature (GK)

$^{23}Na(p,\gamma)^{24}Mg$

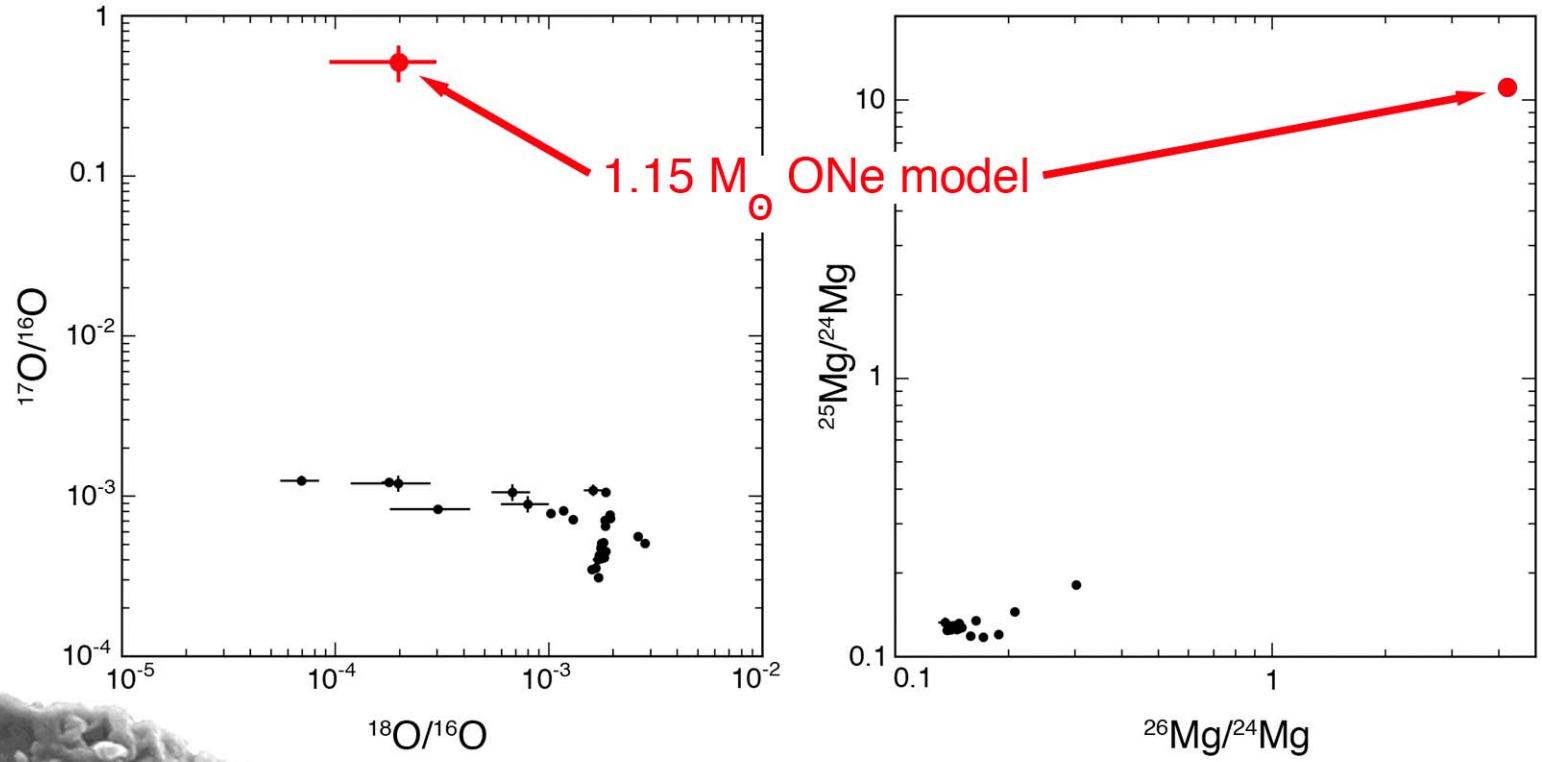


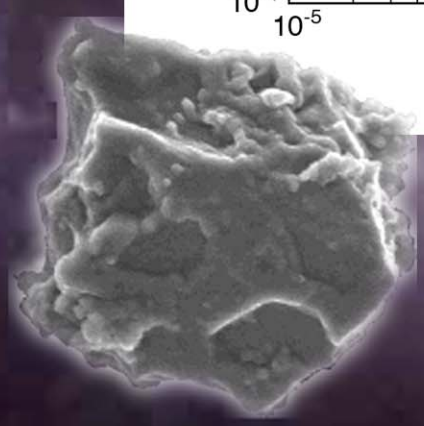


ROWLAND ET AL.

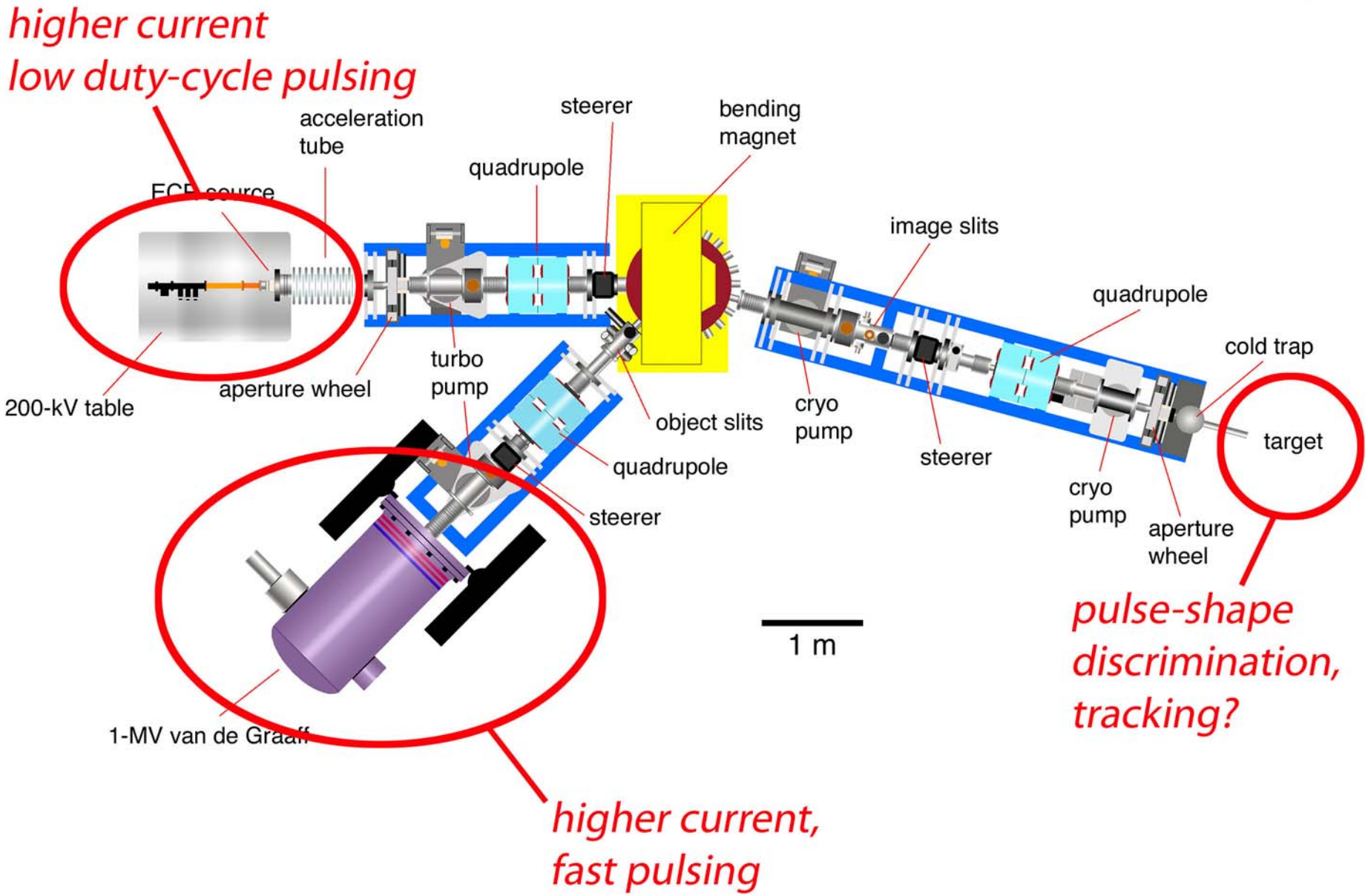
THE ASTROPHYSICAL JOURNAL, 615:L37–L40, 2004

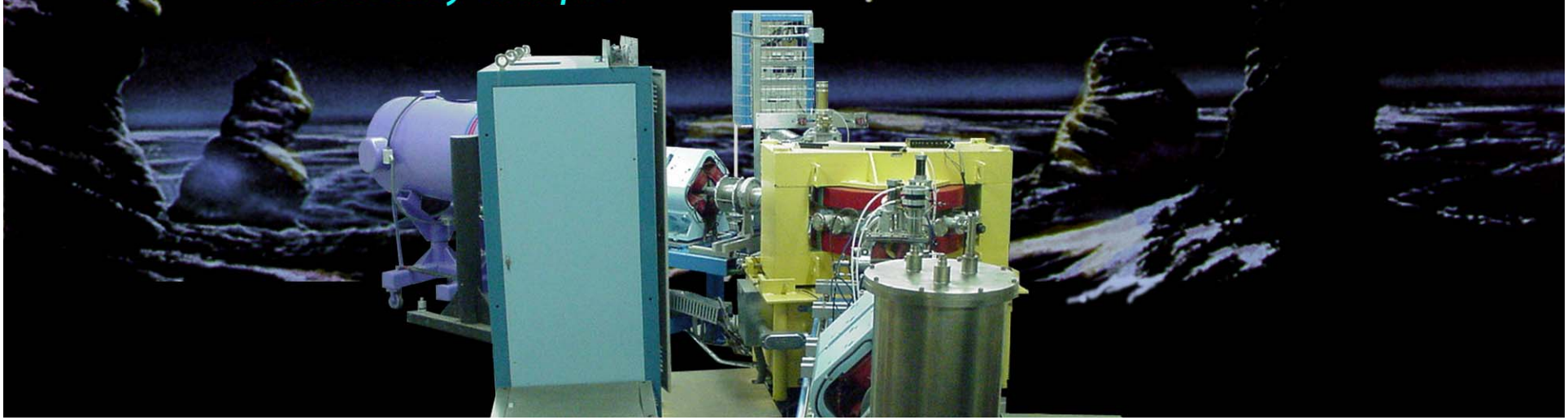
Oxide grains from novae?





Po$$ible upgrade$



The role of a ground-level laboratory:

1. *development of target/detection schemes for future underground measurements*
2. *measurements at higher energies*
3. *measurements where cosmic rays are not a limiting factor*
4. *measurements where the reaction signature is sufficiently unique*