Beam Line and Scattering Chamber Issues

1. Arrangements for GRETINA
    1. Energy resolution and efficiency for various reactions and Beam energies.
    2. Quality Factors.

2. Scattering chamber
    1. New optimal design
    2. What internal auxiliary devices will fit inside GRETA

Energy resolution for in-beam measurement of γ rays

The observed $\gamma-$ray energy is given by

$$E_\gamma = \frac{E^0_\gamma\sqrt{1-\beta^2}}{1-\beta\cos(\theta)} \tag{1}$$

There are four contributions to the overall energy resolution in a measurement. They are:

1. Intrinsic detector resolution given as

   $$\frac{\Delta E^{source}_\gamma \text{ or } FWHM(E_\gamma)}{E_\gamma} \text{ is the intrinsic resolution}$$

   This term is independent of reaction and is obtained from $FWHM(E_\gamma)$ measured with sources (^{152}Eu, ^{56}Co, etc.) and the E_γ from eq. 1.

2. The contribution from the opening angle of the detector (from eq. 1):

   $$\frac{\Delta E(\theta)}{E_\gamma} = \frac{1}{E_\gamma}\frac{dE_\gamma}{d\theta}\Delta\theta = \frac{\beta\sin\theta}{1-\beta\cos\theta}\Delta\theta.$$

   This term depends only on β and the opening angle $\Delta\theta$ of the detectors.

3. The contribution due to slowing down of the emitter in the target (from eq. 1):

   $$\frac{\Delta E(\beta)}{E_\gamma} = \frac{1}{E_\gamma}\frac{dE_\gamma}{d\beta}\Delta\beta = \frac{\beta-\cos\theta}{(1-\beta^2)(1-\beta\cos\theta)}\Delta\beta.$$

   This term strongly depends on the type of nuclear reaction of interest.

4. The contribution from the opening angle of the recoil cone due to emission of particles or straggling in the target give approximately by

   $$\frac{\Delta\theta_{cone}}{E_\gamma} = \frac{\Delta E_\gamma(\theta_{rec})}{E_\gamma} = \left\{\frac{\beta\left[\cos(\theta+\theta_R)-\cos(\theta-\theta_R)\right]}{\sqrt{1-\beta^2}}\right\}.$$

   This term depends on the reaction of interest. It is absent in Coulex, and its importance decreases with increasing projectile energy.

The above contributions must be added in quadrature to give the

$$\frac{\Delta E_\gamma}{E_\gamma} = \sqrt{\left(\frac{\Delta E^{source}_\gamma}{E_\gamma}\right)^2 + \left(\frac{\Delta E(\theta)}{E_\gamma}\right)^2 + \left(\frac{\Delta E(\beta)}{E_\gamma}\right)^2 + \left(\frac{\Delta\theta_{cone}}{E_\gamma}\right)^2} \tag{2}$$

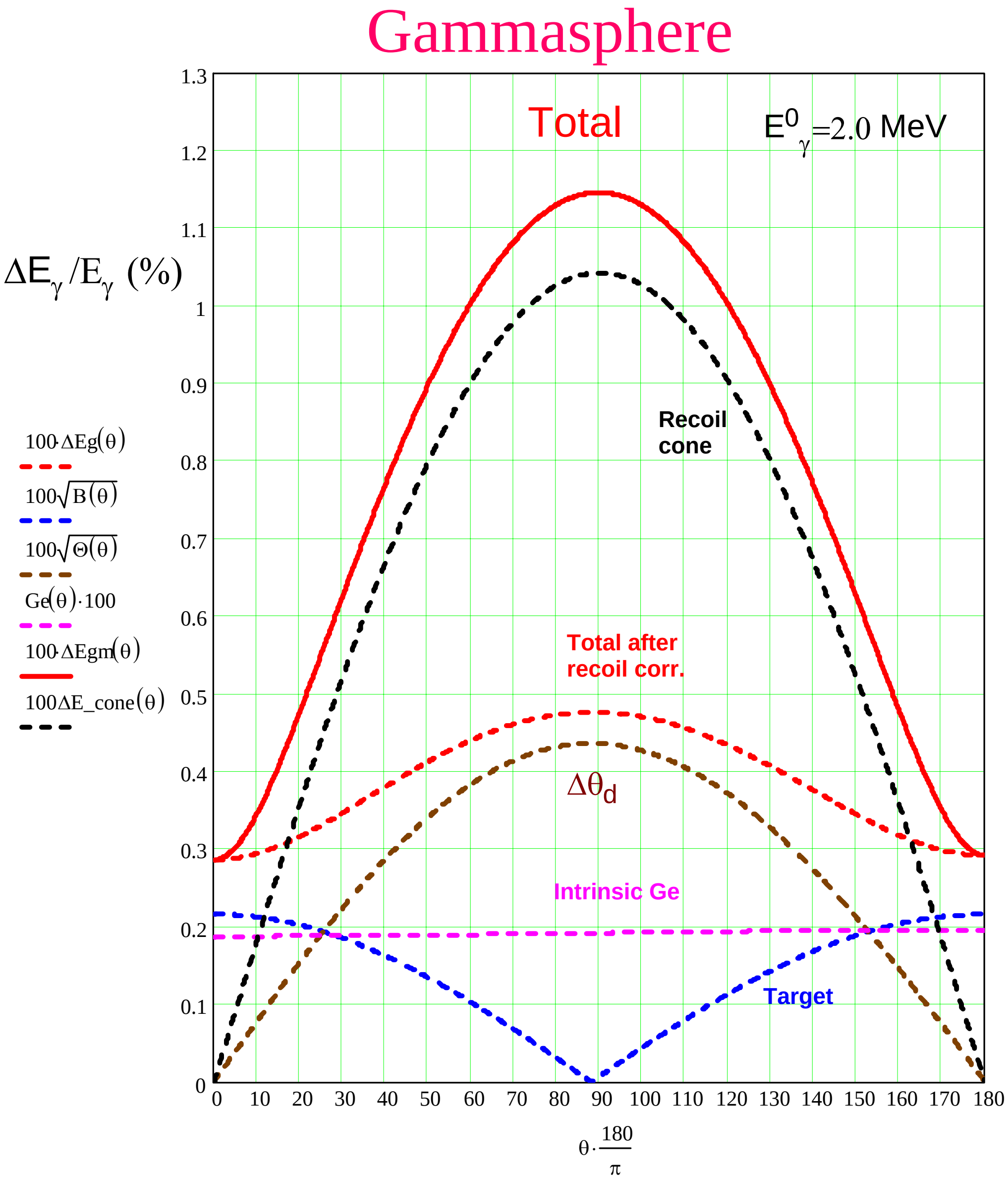
The following classes of reactions will be considered:

1. Fusion near the barrier, typically E$_{prog}$ $\leq$ 10 MeV/A. Here the assumptions are straight forward and a good check is resolutions based on Gammasphere. For the emitter cone it can be taken as the momentum kick of a Coulomb barrier α emitted at 90° lab. Calculations are made with and without the recoil correction (Microball for light particles, or other tracking schemes).

2. Coulex at E$_{proj}$ $\geq$ 10 MeV/A (10, 100 MeV/A) and for target thicknesses of 10, 100, and 300 mg/cm^2. From the relativistically calculated $\beta = v/c$ one can calculate easily the time needed to traverse a target of given thickness, i.e. at 100 MeV/A for 100 and 300 mg/cm^2 these times are ~1.0 and ~3 ps. For Coulex there is no particle emission and only straggling contributes to the recoil cone, which is ignored here. For decays downstream from the target, the effect of the target is to contribute only an energy loss which is the same for all decays.

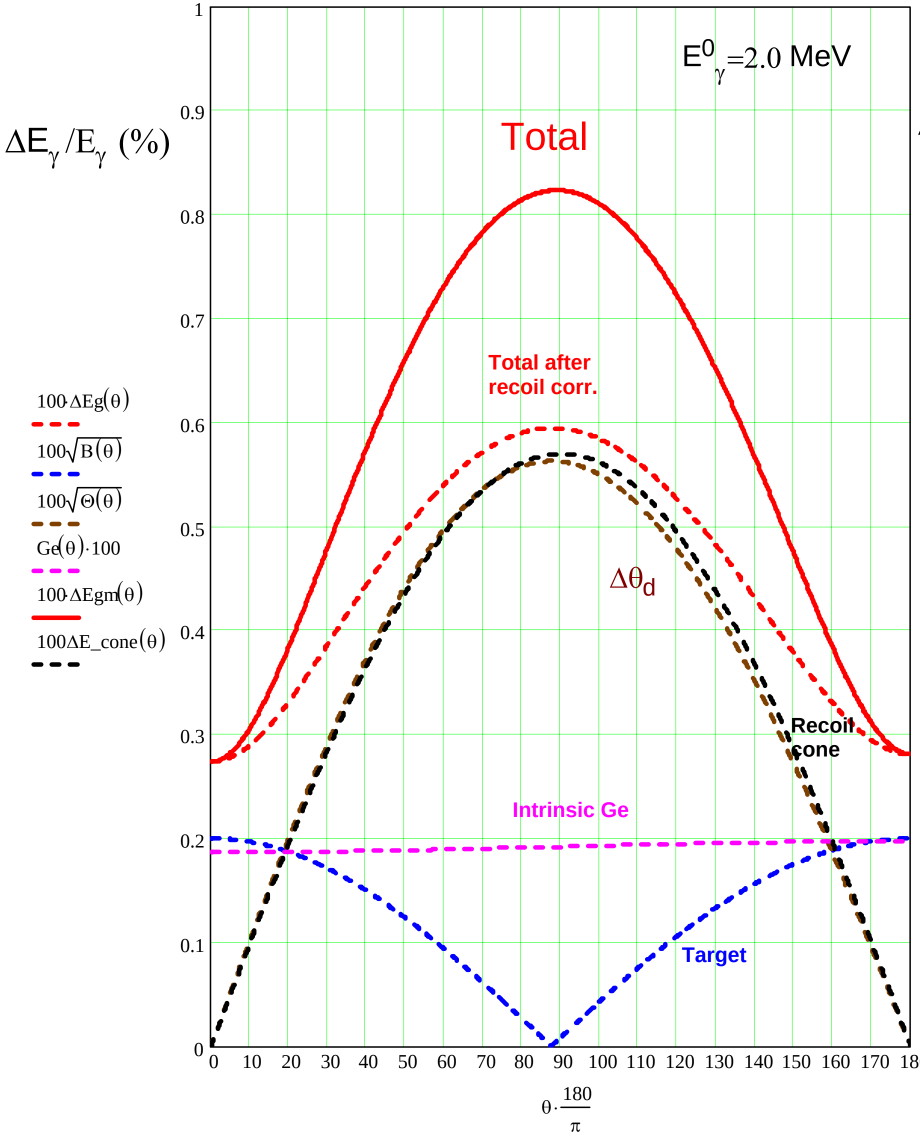
3. For hard collisions (deep inelastic, transfer etc.). There is an energy loss of a heavy projectile of interest by interacting with a target. Then with this reduced energy we can calculated from reaction kinematics and for decays in the target its effect on resolution can be taken as the range of β values for reactions in the front and the back of the target.

Check of procedure with mass A~80, values as measured.
^{58}Ni(^{28}Si,α2p)^{80}Sr, 130 MeV, 0.5 mg/cm^2 thick target in Gammasphere

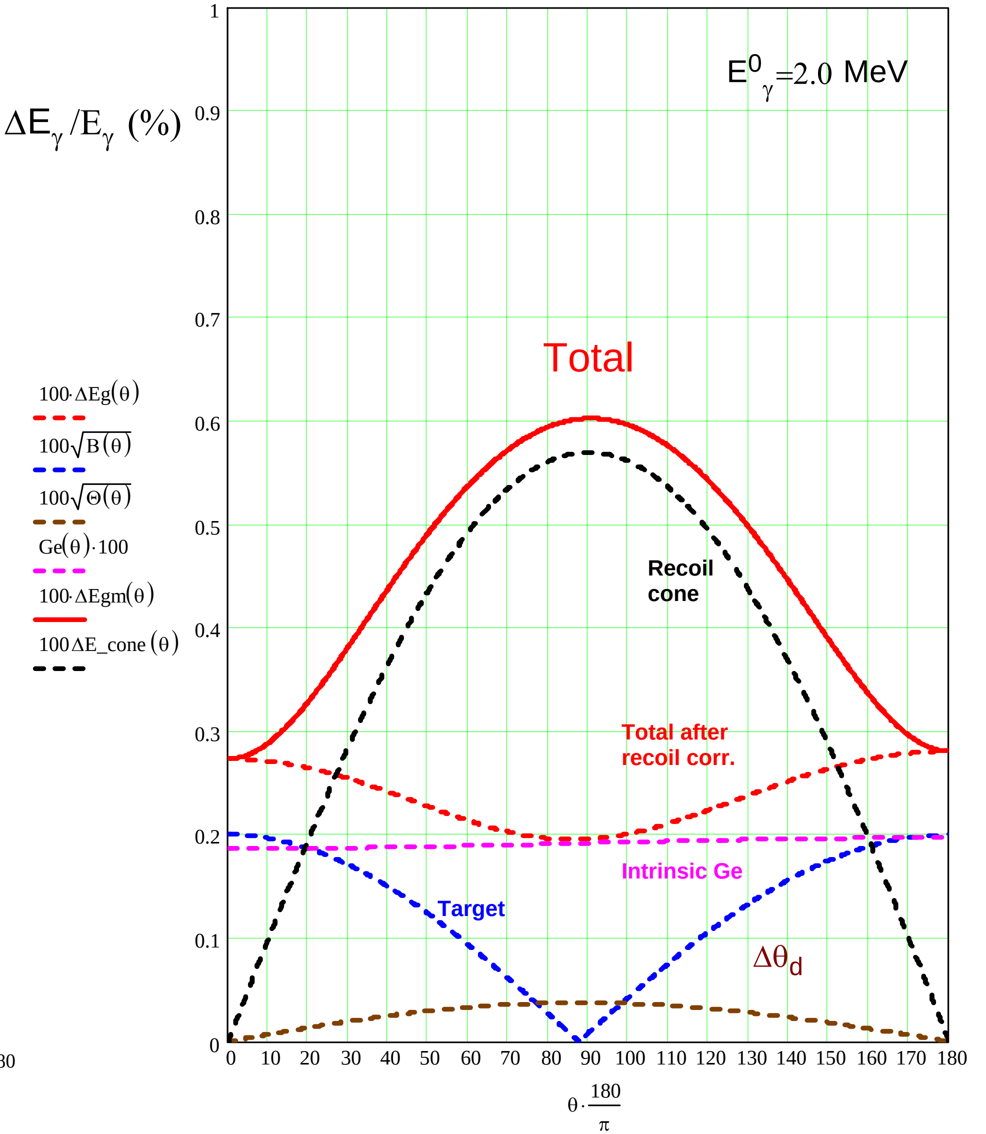


The ^{58}Ni(^{48}Cr,α2n)^{100}Sn case at 200 MeV and 0.5 mg/cm^2 thick target

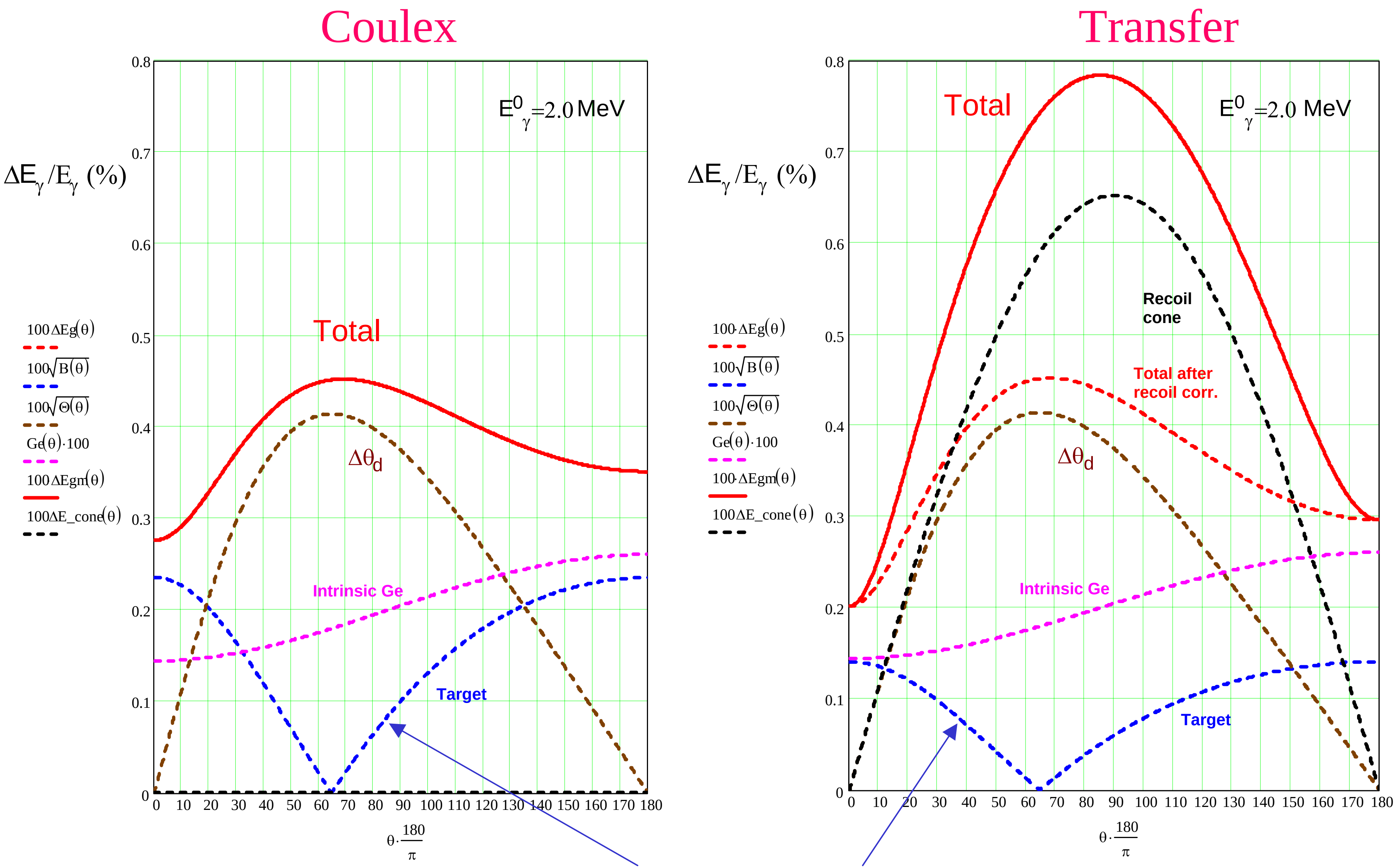
Gammasphere



GRETA/Gretina



^{130}Te+^{58}Ni at100 MeV/A, 10 mg/cm^2 target, $t_{1/2}$ < 0.1 ps



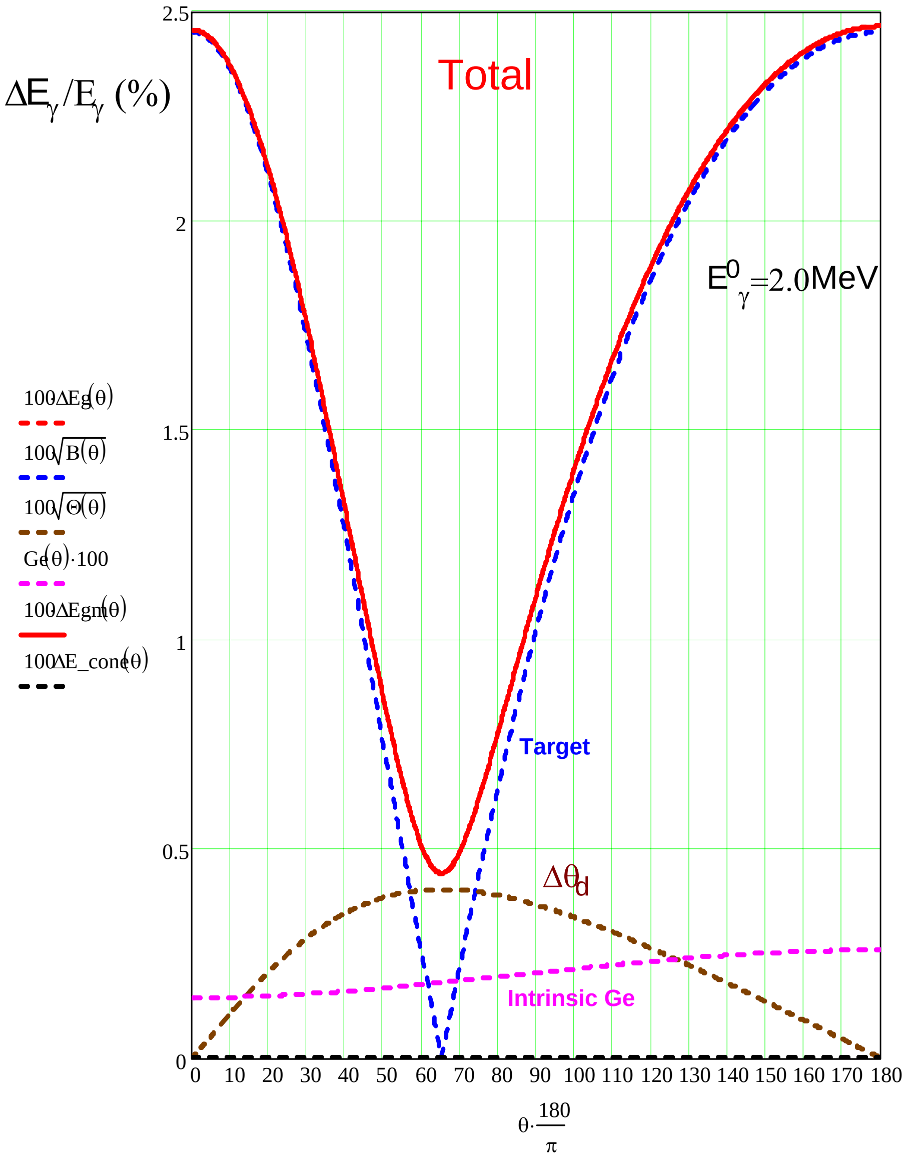
Coulex

Transfer

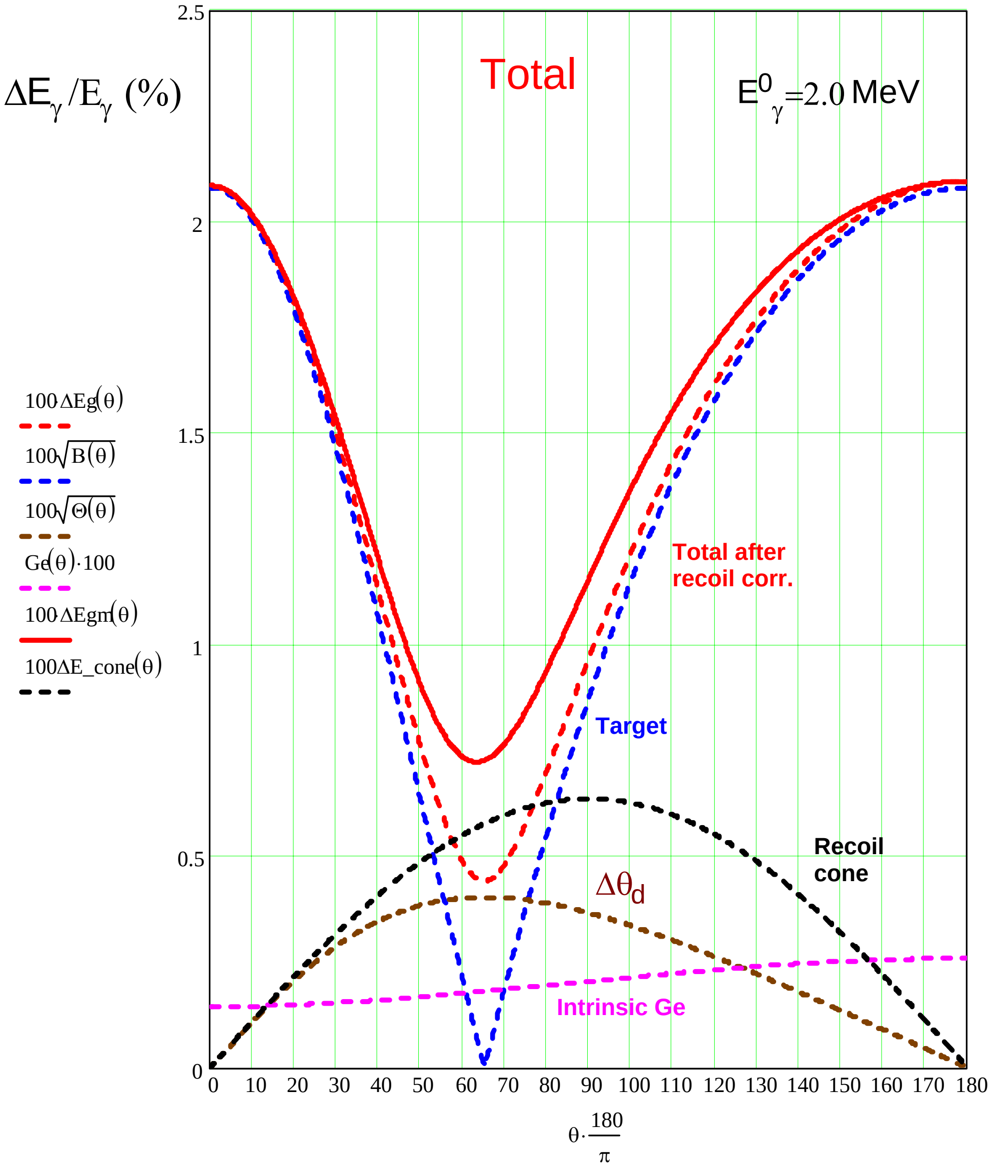
If $t_{1/2}$ longer then the target effect is not there

^{130}Te+^{58}Ni at100 MeV/A, 100 mg/cm^2 target

Coulex: $t_{1/2}$< 1 ps

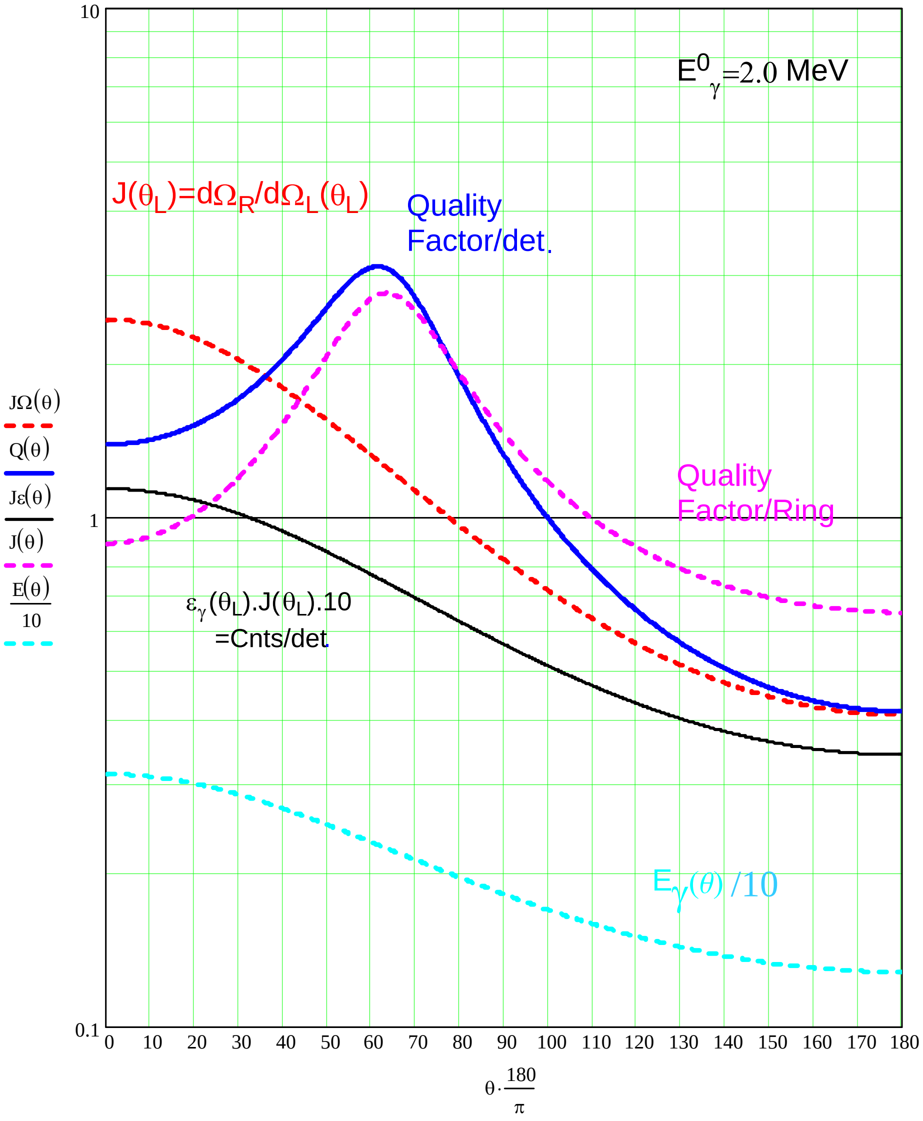


Transfer $t_{1/2}$< 1 ps



Quality Factors for ^{130}Te+^{58}Ni at100 MeV/A, 100 mg/cm^2 target

Coulex: $t_{1/2} < 1$ ps



Quality factor/det =

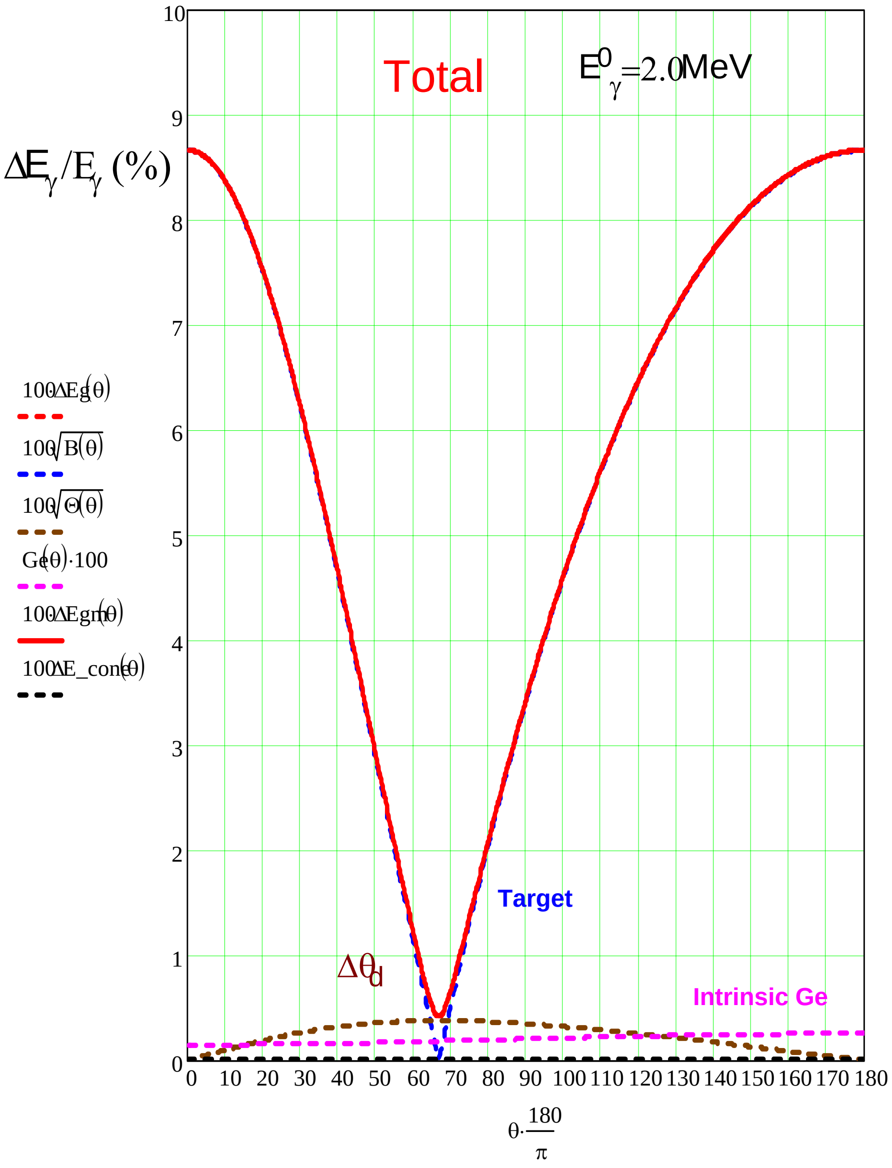
$$\frac{(d\Omega_R/d\Omega_{Lab})}{(\Delta E_{tot.\ Res})}$$

Quality factor/ring =

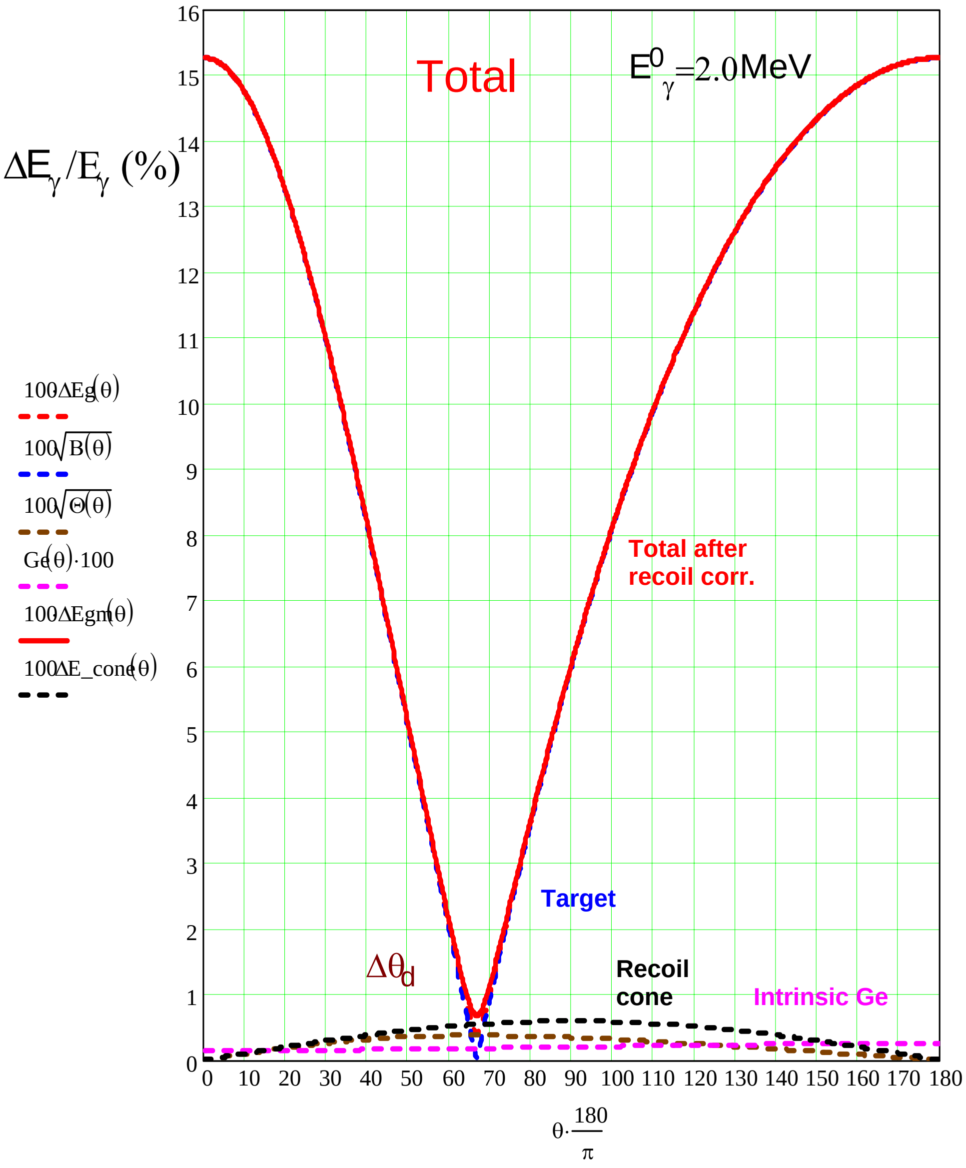
$$\frac{(d\theta_R/d\theta_{Lab})}{(\Delta E_{tot.\ Res})}$$

Resolutions for ^{130}Te+^{58}Ni at for 100 MeV/A, 300 mg/cm^2 target

Coulex: $t_{1/2}$< 3 ps

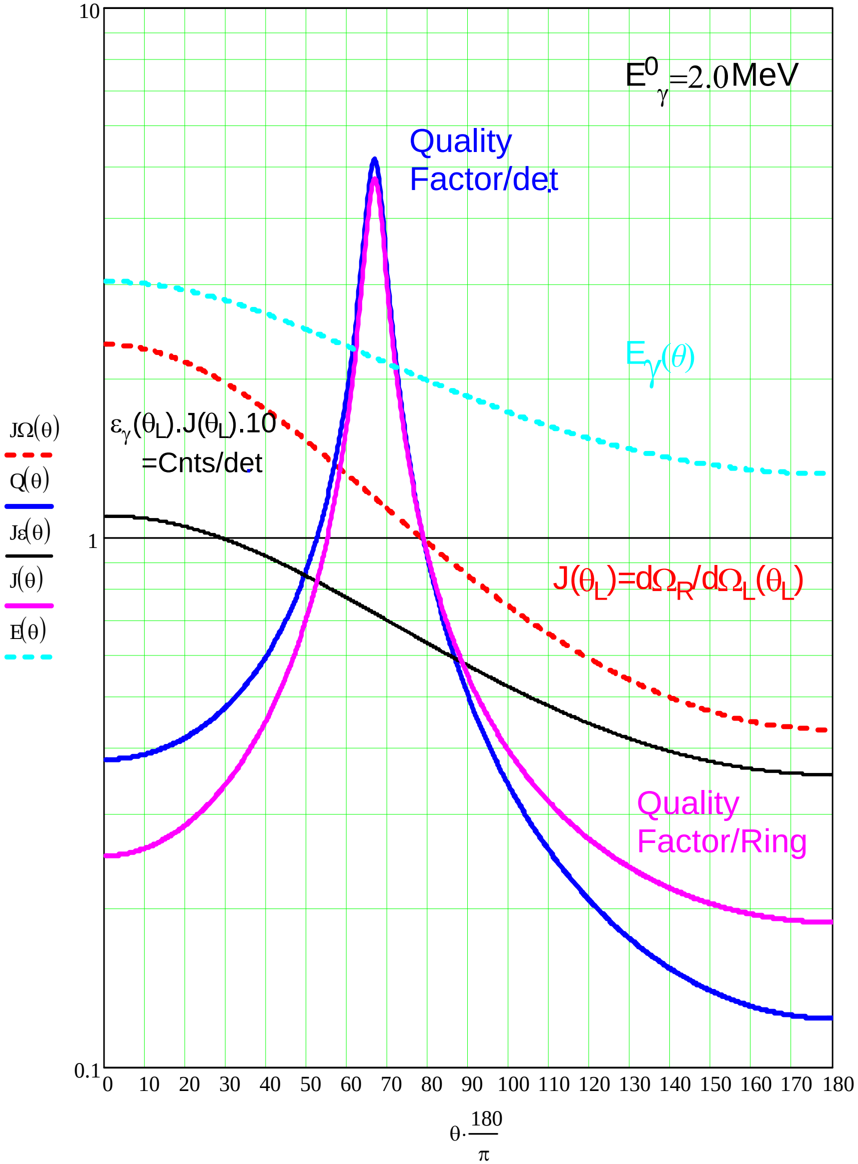


Transfer: $t_{1/2}$< 3 ps

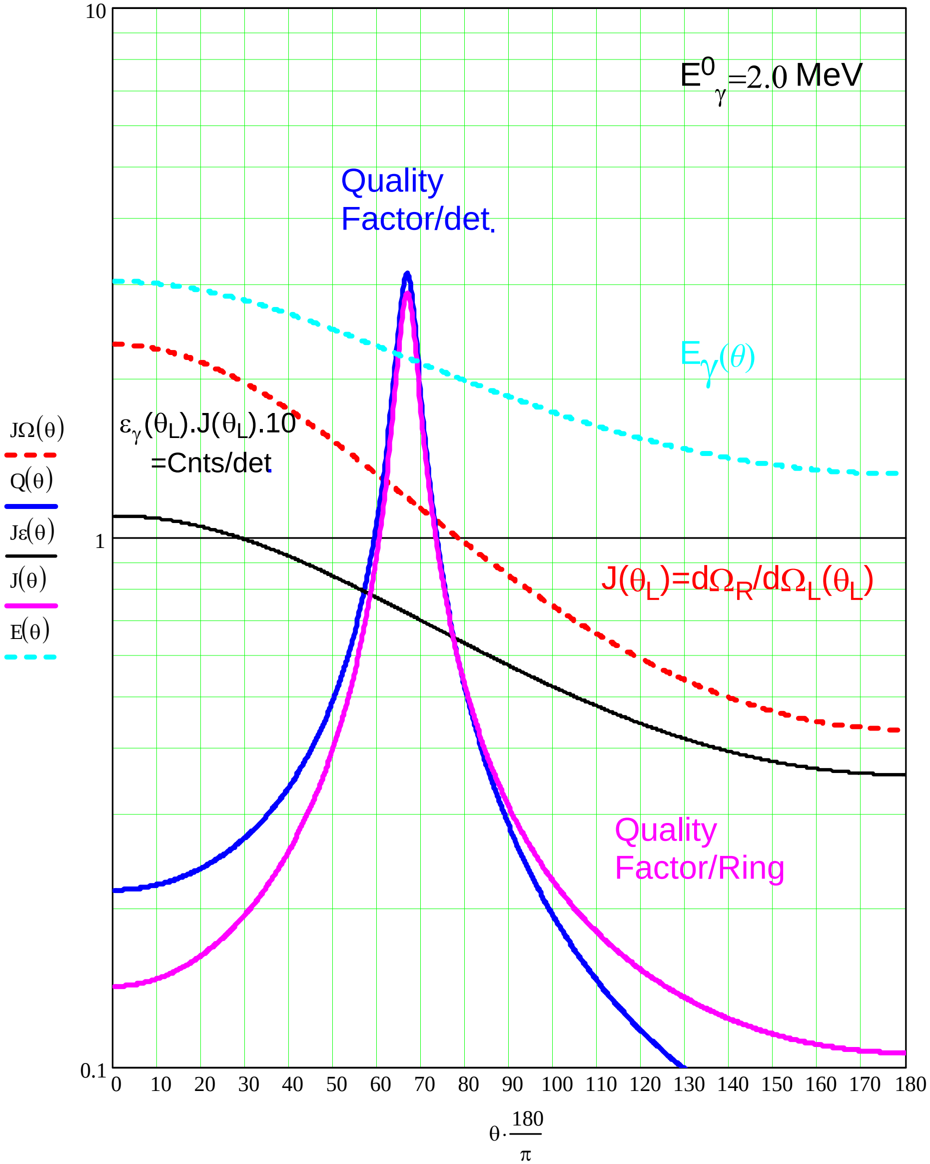


Quality Factors for $^{130}Te+^{58}Ni$ at100 MeV/A, 300 mg/cm^2 target

Coulex: $t_{1/2}< 3$ ps



Transfer: $t_{1/2}< 3$ ps

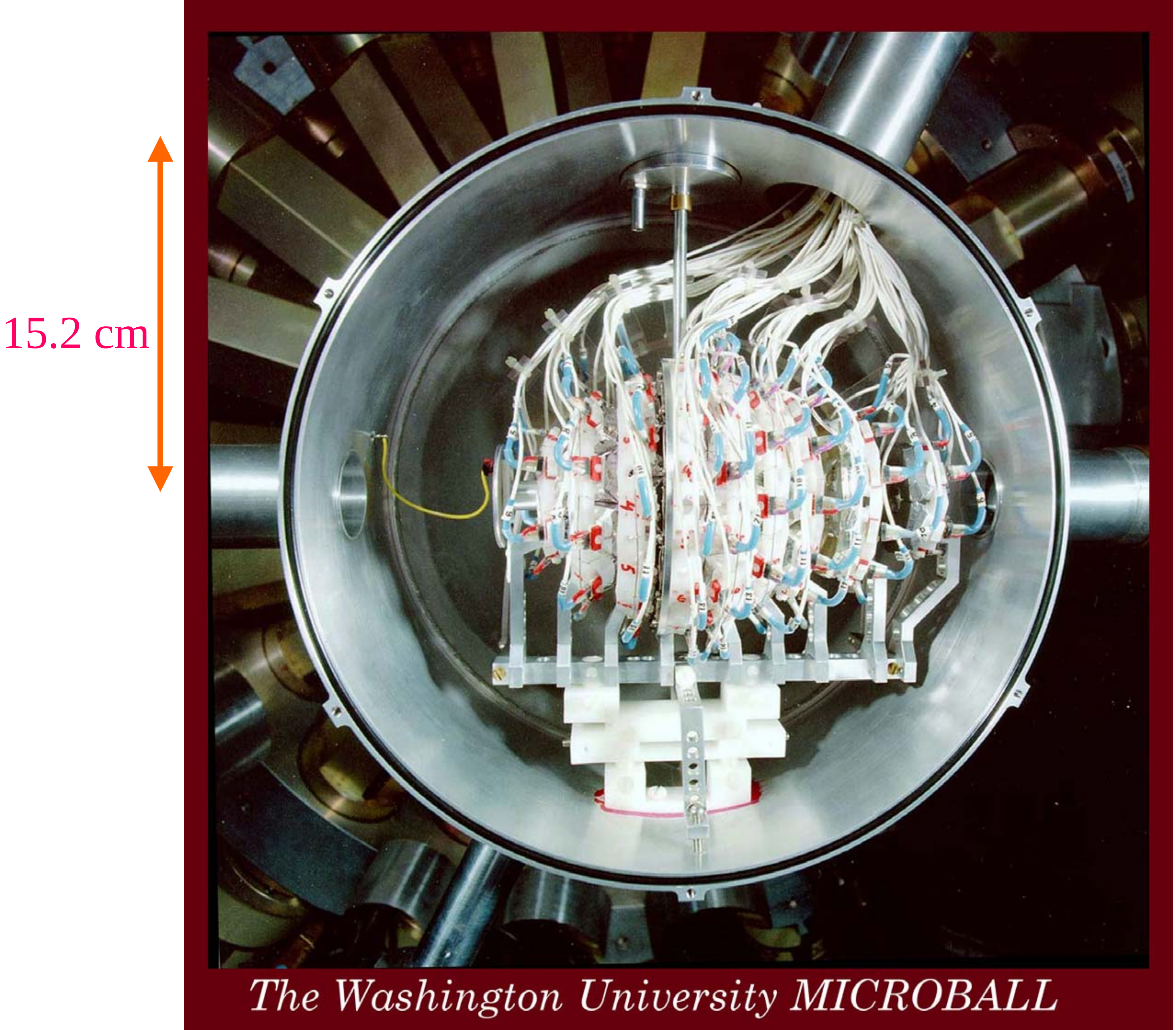


A Versatile Scattering Chamber for GRETINA

Requirements

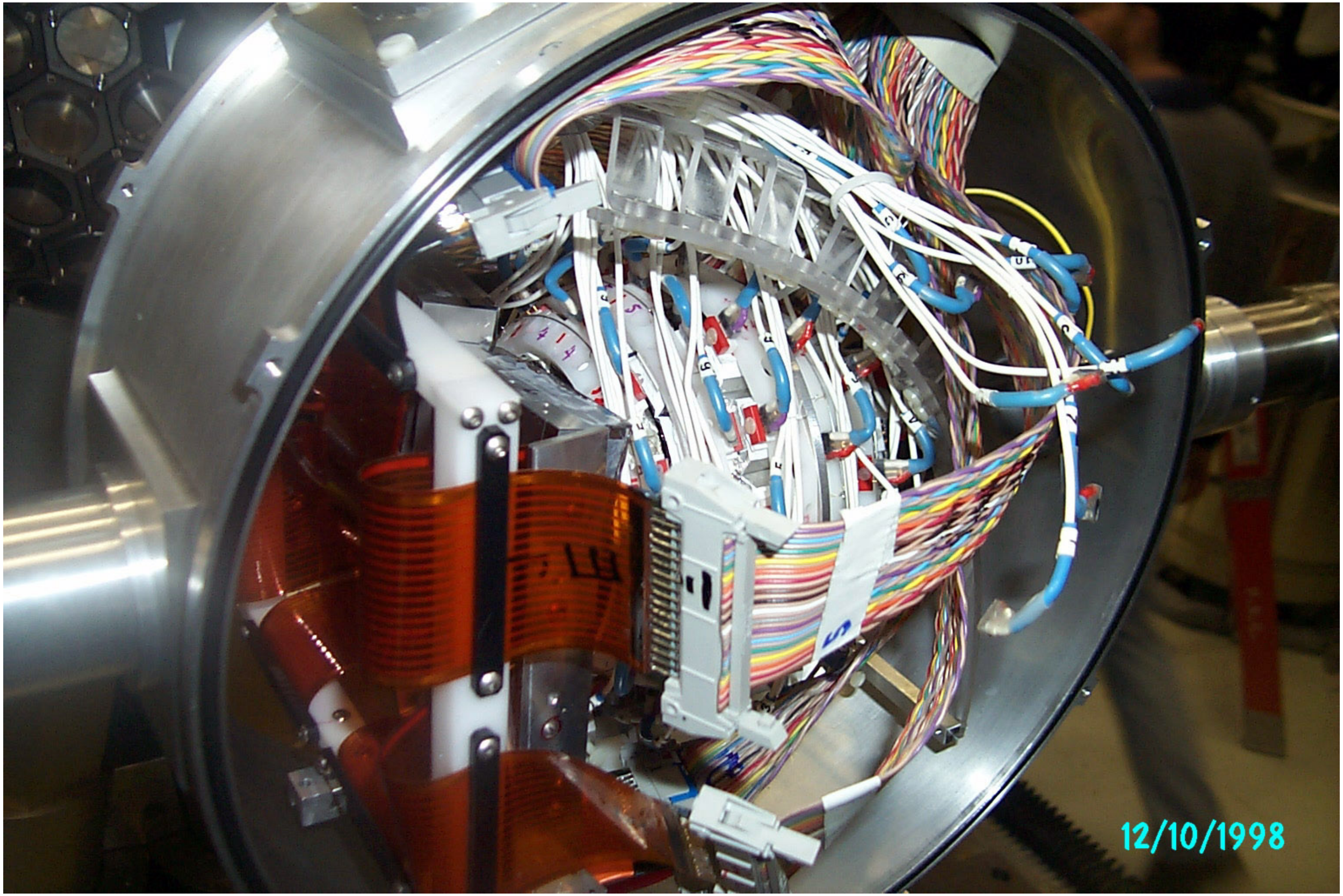
Given: target to Ge-detector distance of ~17.0 cm

- Minimum mass and Largest internal volume, consistent with the limited internal space
- Include a remote control of target positioning ladder
- Allow for a variety of internal Auxiliary multi-detector arrays
  - Adequate ports for feed-through of the detector signals
  - Permit easy access to internal detectors for repairs etc.
  - A suitable entry port for the target in Aux. Detector systems

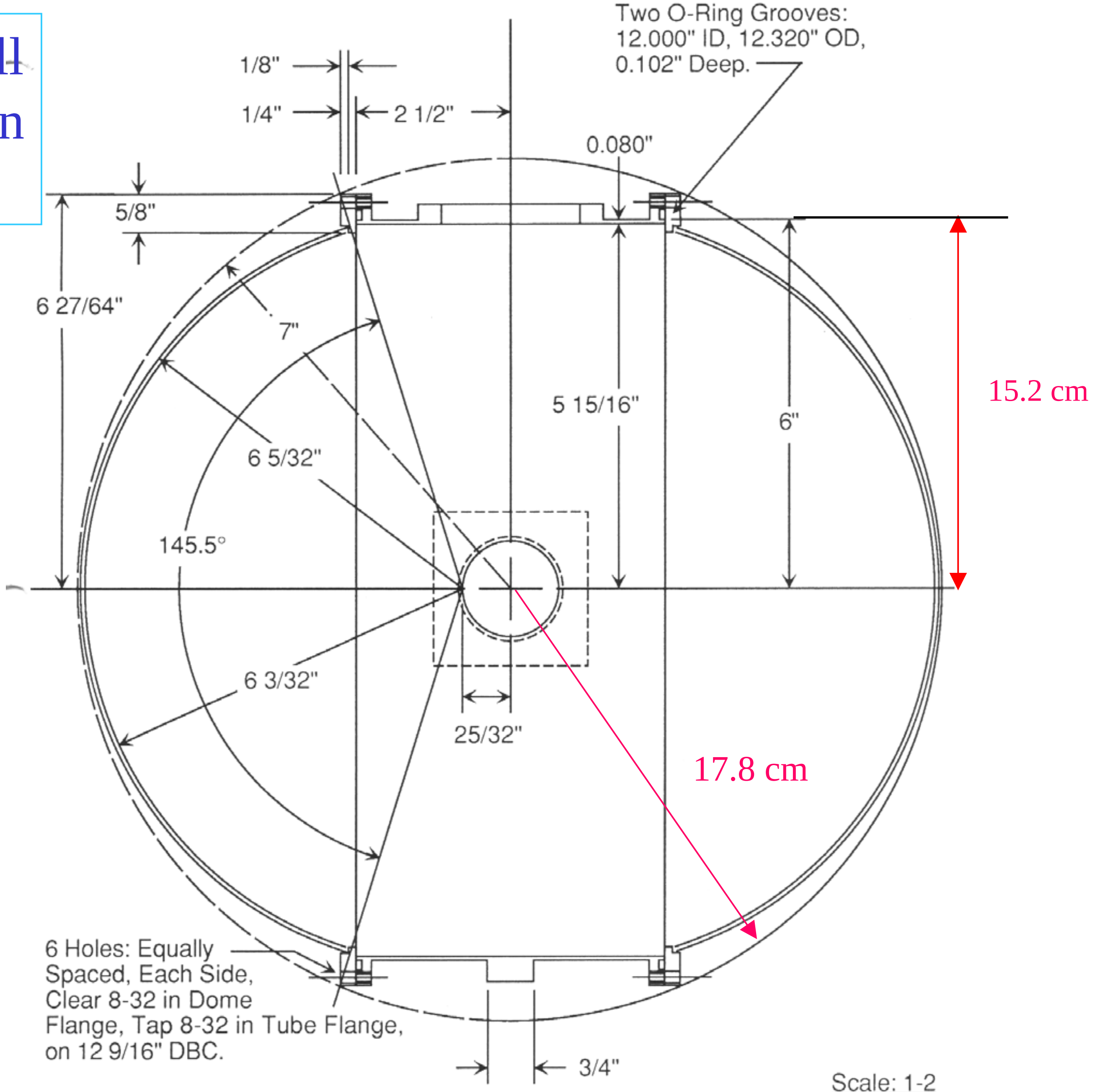


The Washington University MICROBALL

Wash. U. Si Wall + Microball – Crowded !



The Microball Chamber is an Odd oblate



Two O-Ring Grooves:
12.000" ID, 12.320" OD,
0.102" Deep.

6 Holes: Equally
Spaced, Each Side,
Clear 8-32 in Dome
Flange, Tap 8-32 in Tube Flange,
on 12 9/16" DBC.

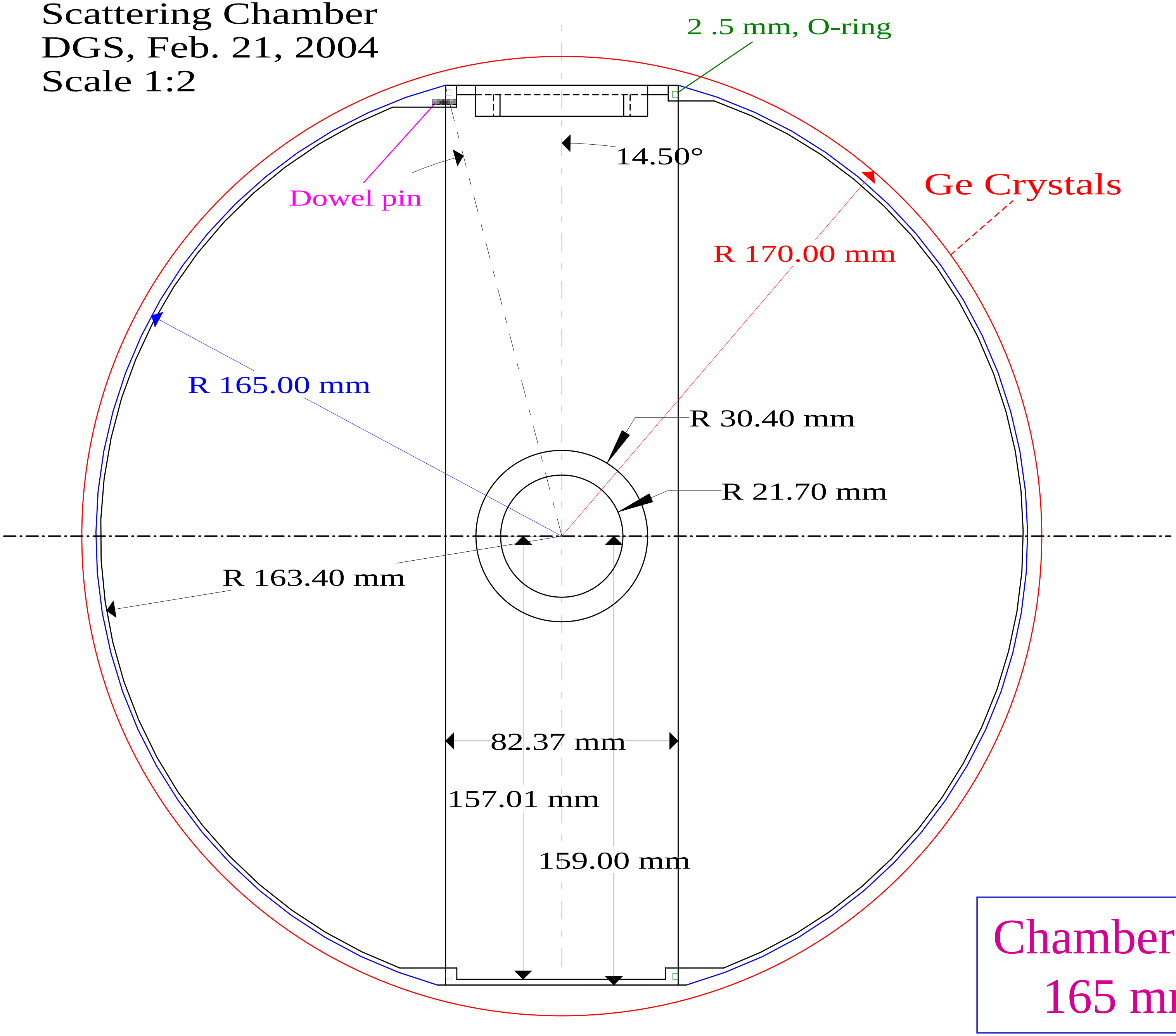
Scale: 1-2

GAMMASPHERE CHAMBER BEAM EXIT VIEW

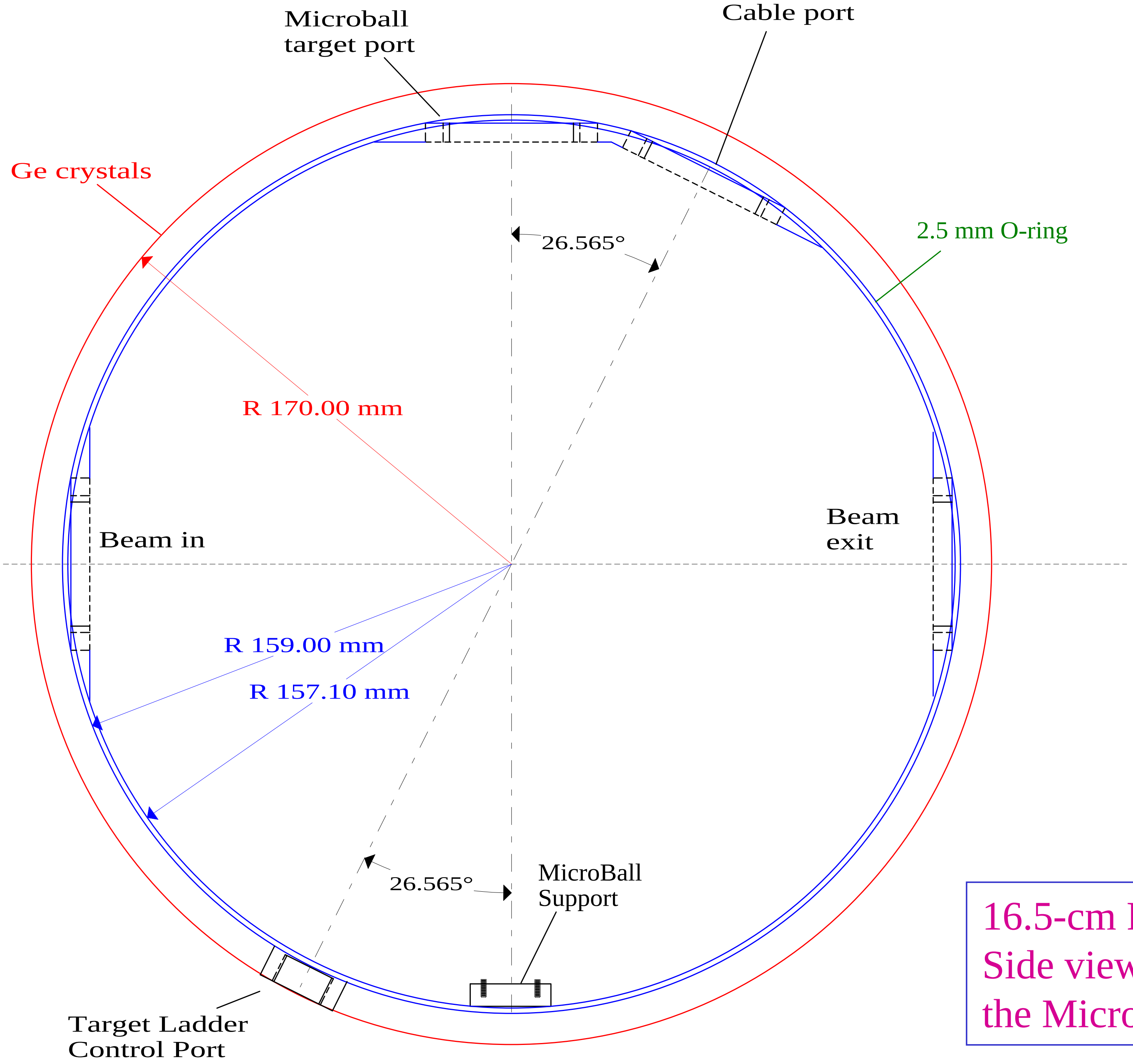
6-14-95
J T Hood

Front view

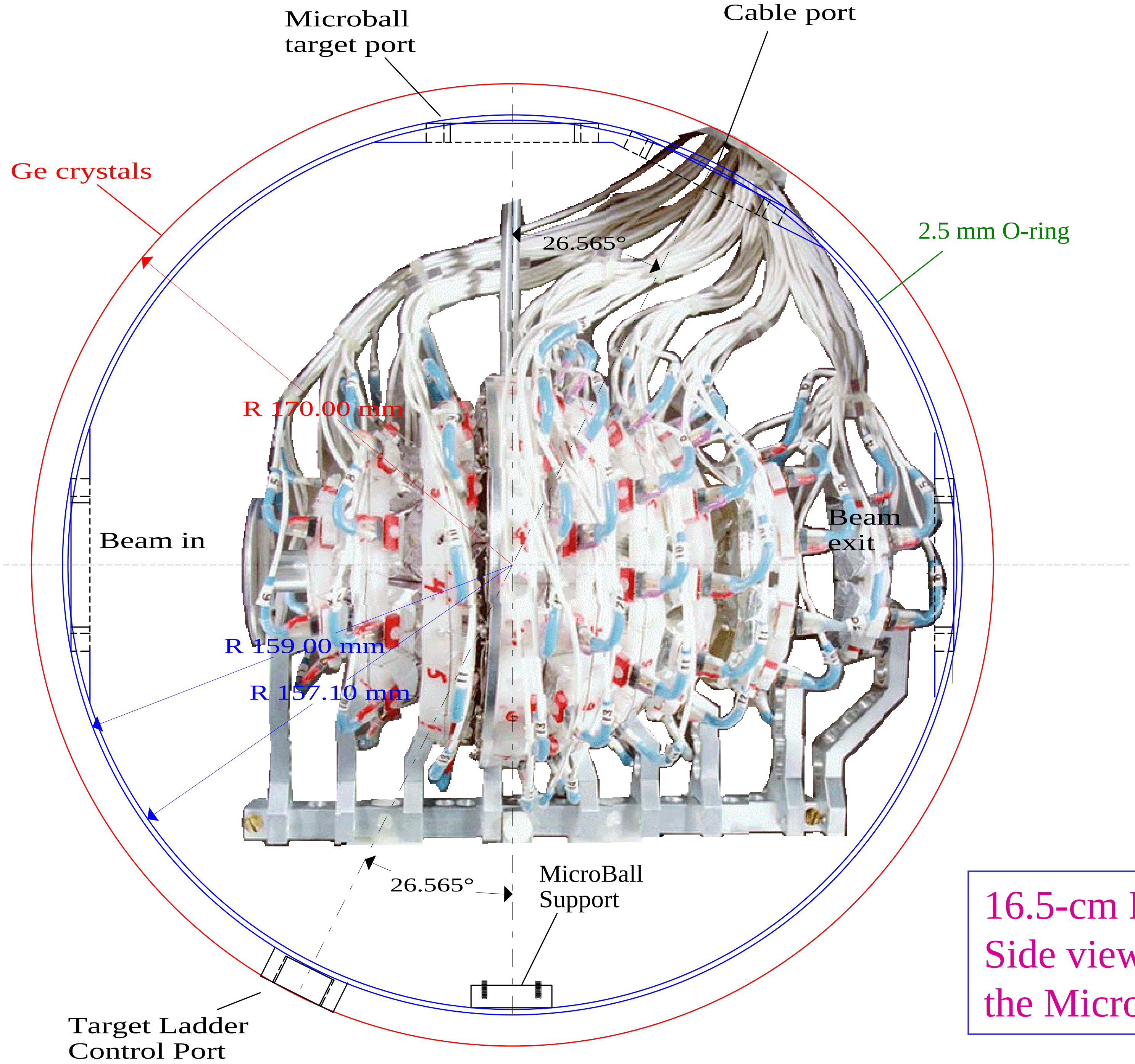
Scattering Chamber
DGS, Feb. 21, 2004
Scale 1:2



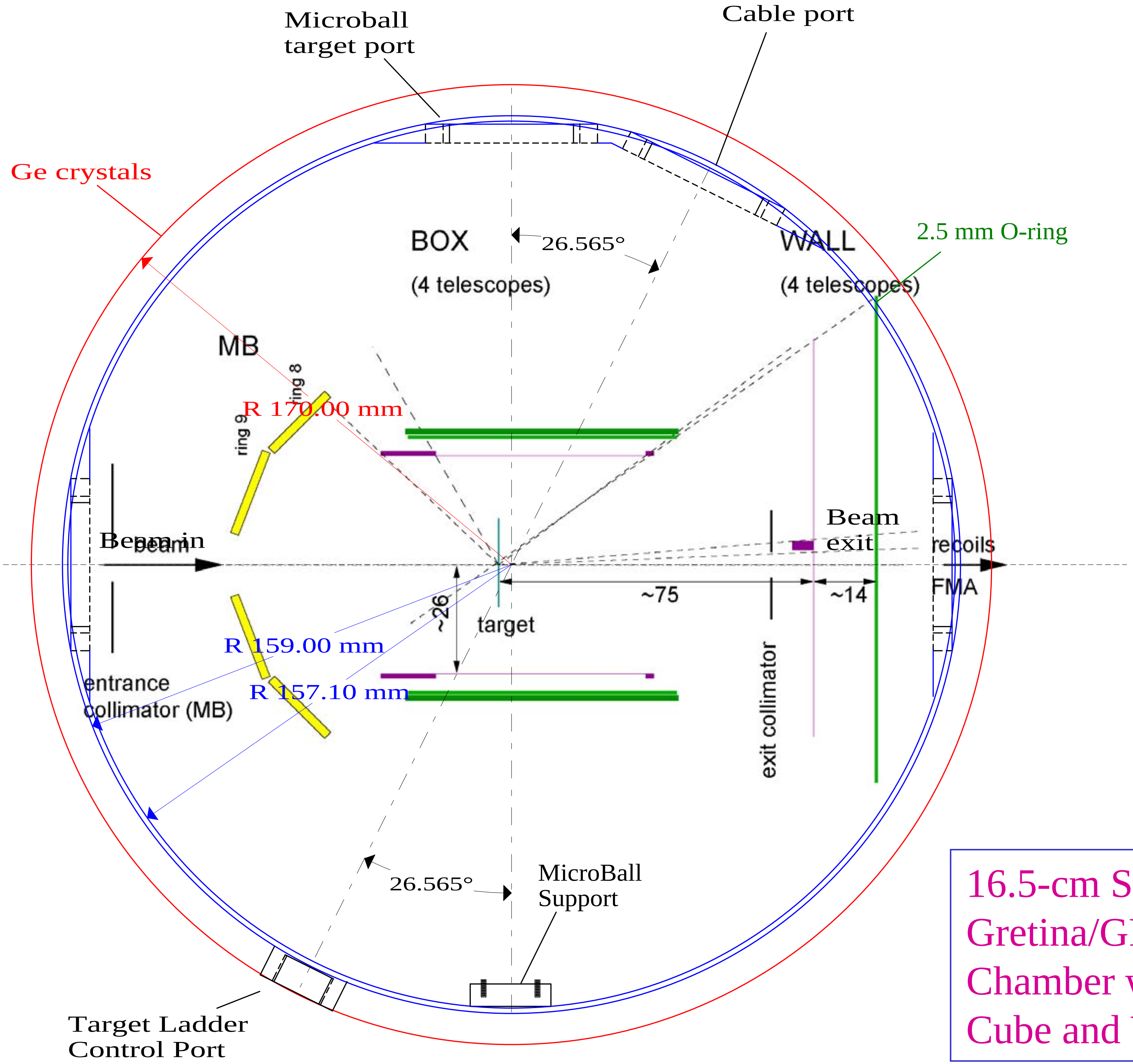
Chamber Radius
165 mm !!!



16.5-cm Radius
Side view with
the Microball



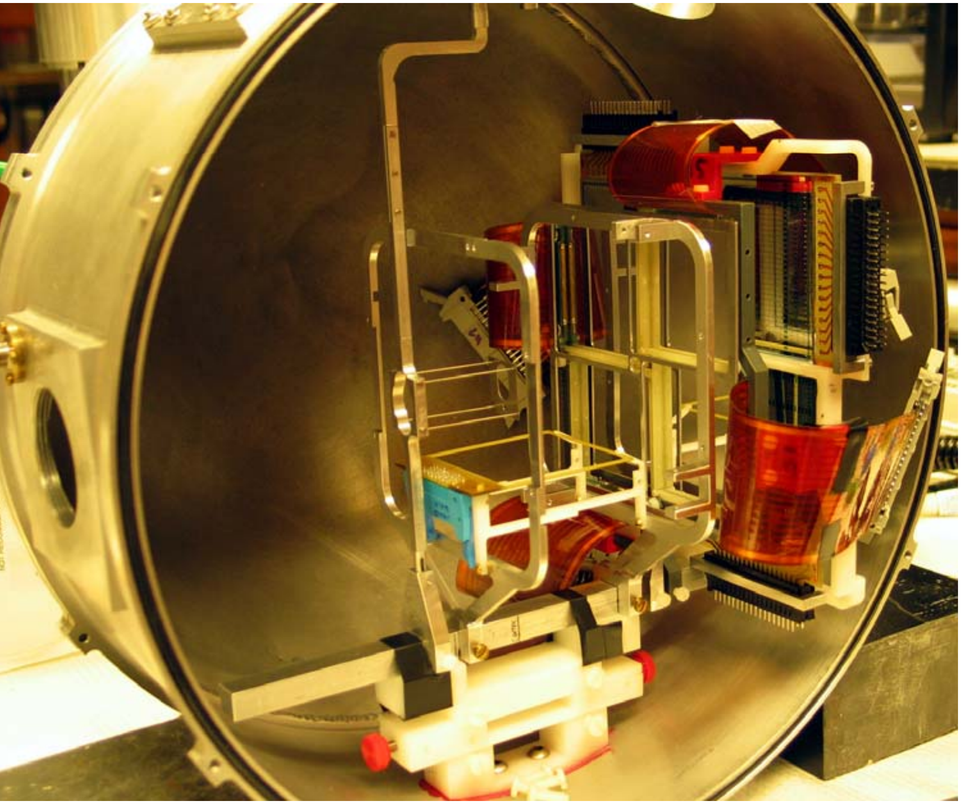
16.5-cm Radius Side view with the Microball

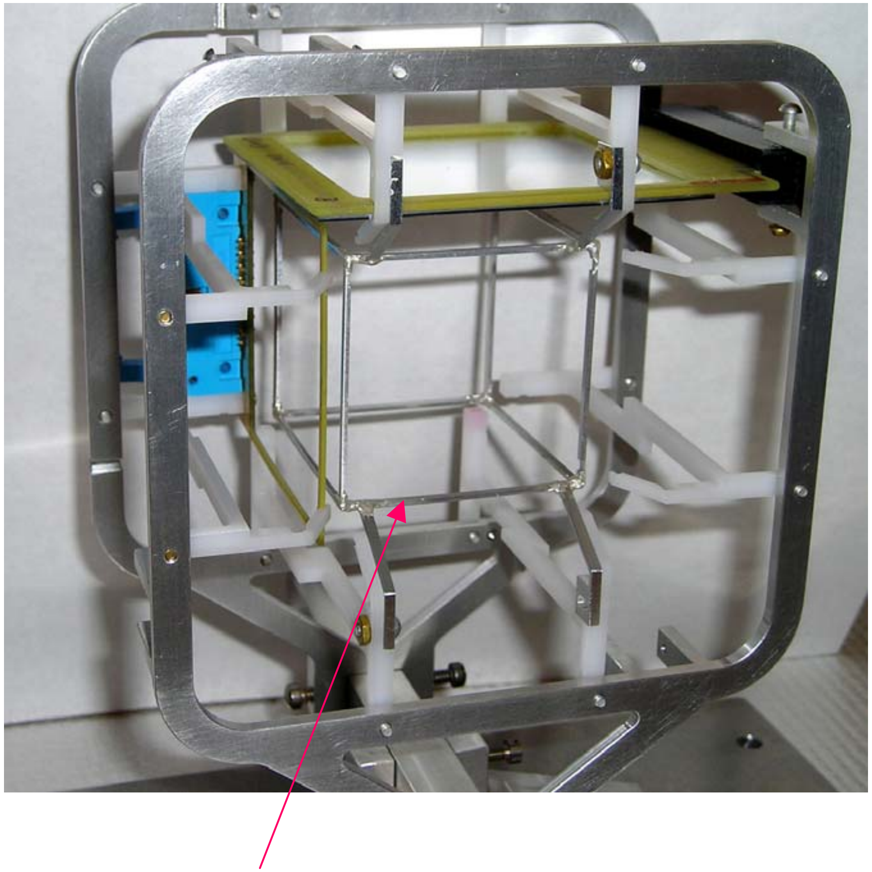


16.5-cm Side view Gretina/GRETA Chamber with Si Cube and Wall

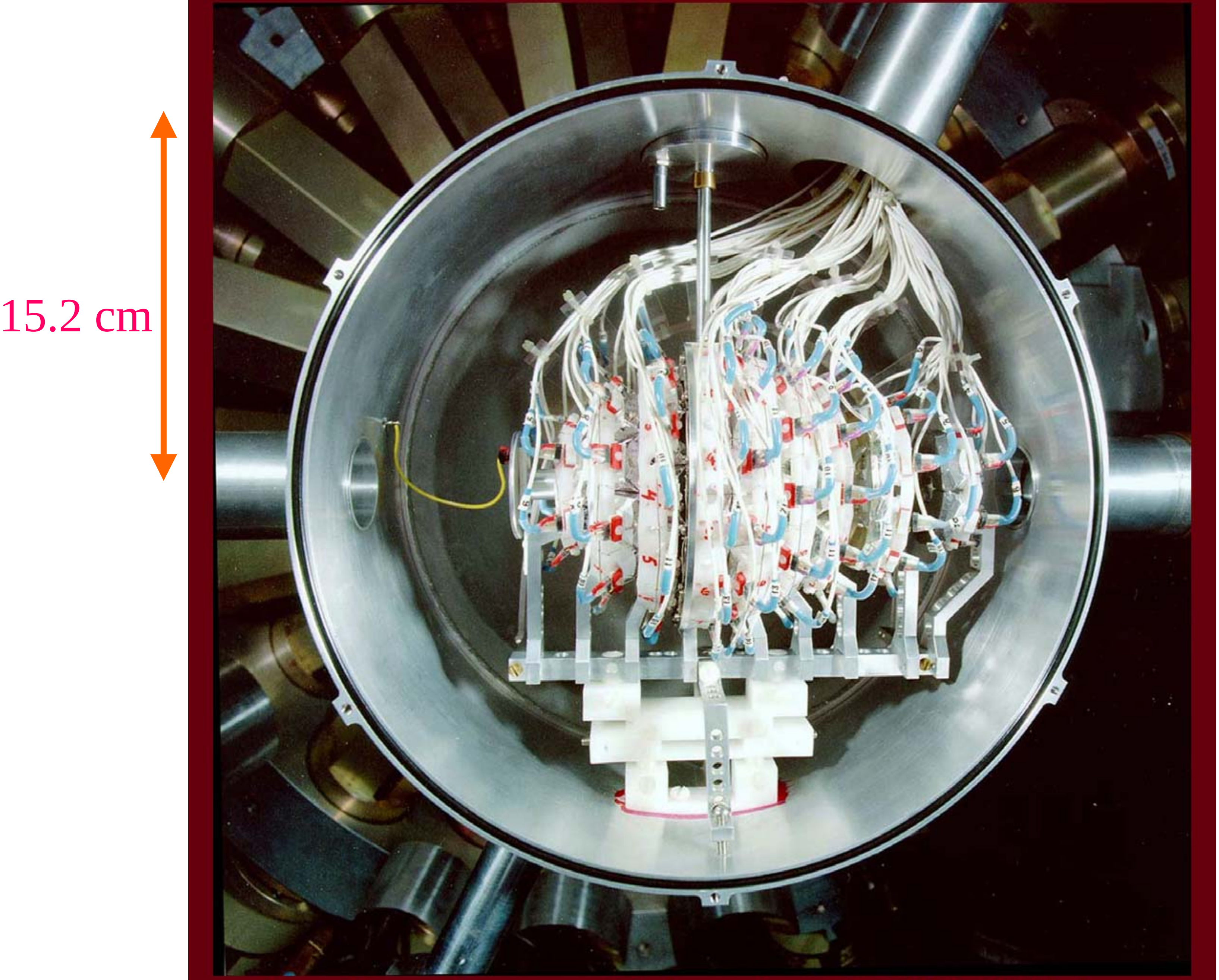
Si Wall and Cube in Microball chamber

The Cube support



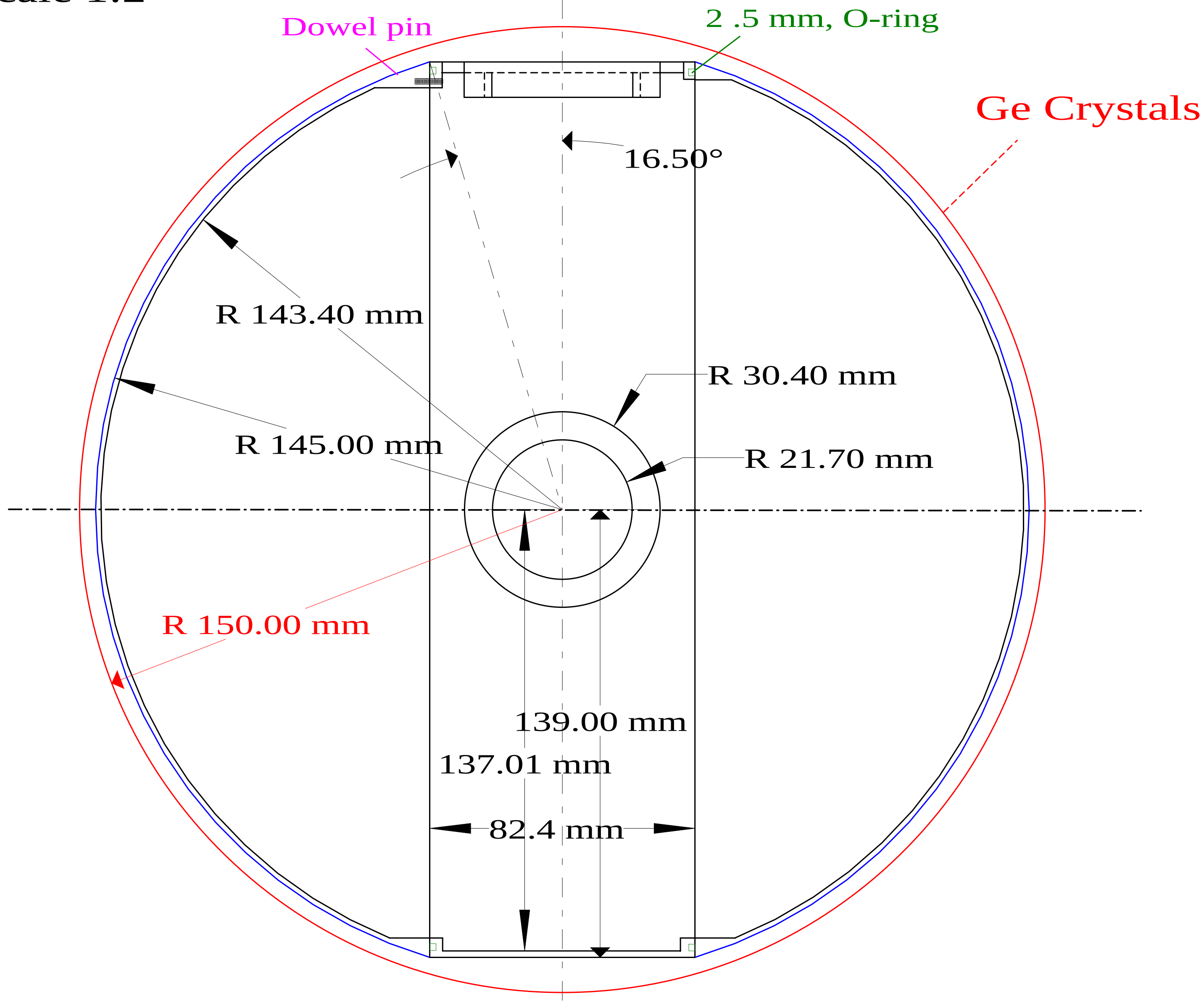


The End,
Thanks

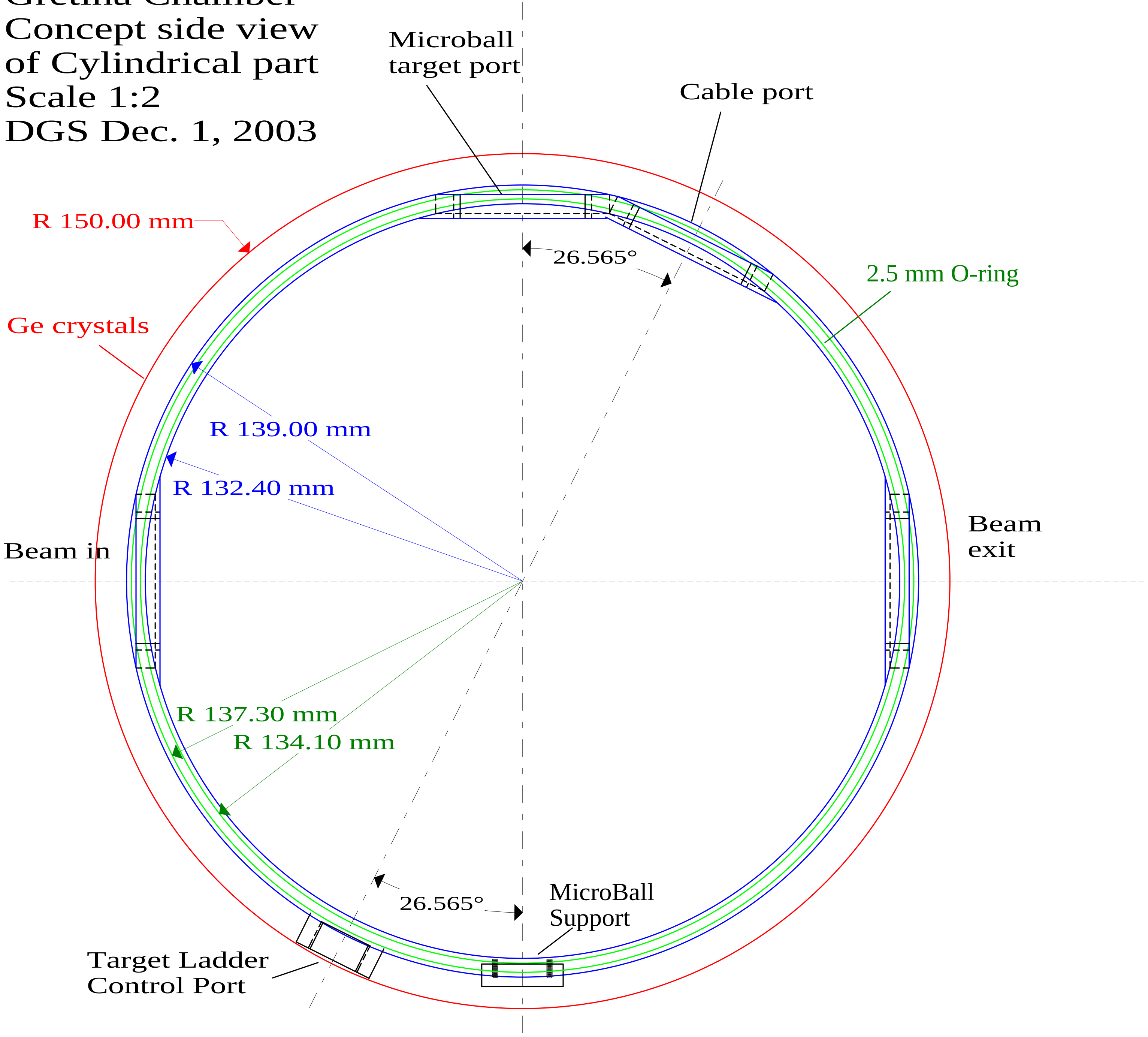


The Washington University MICROBALL

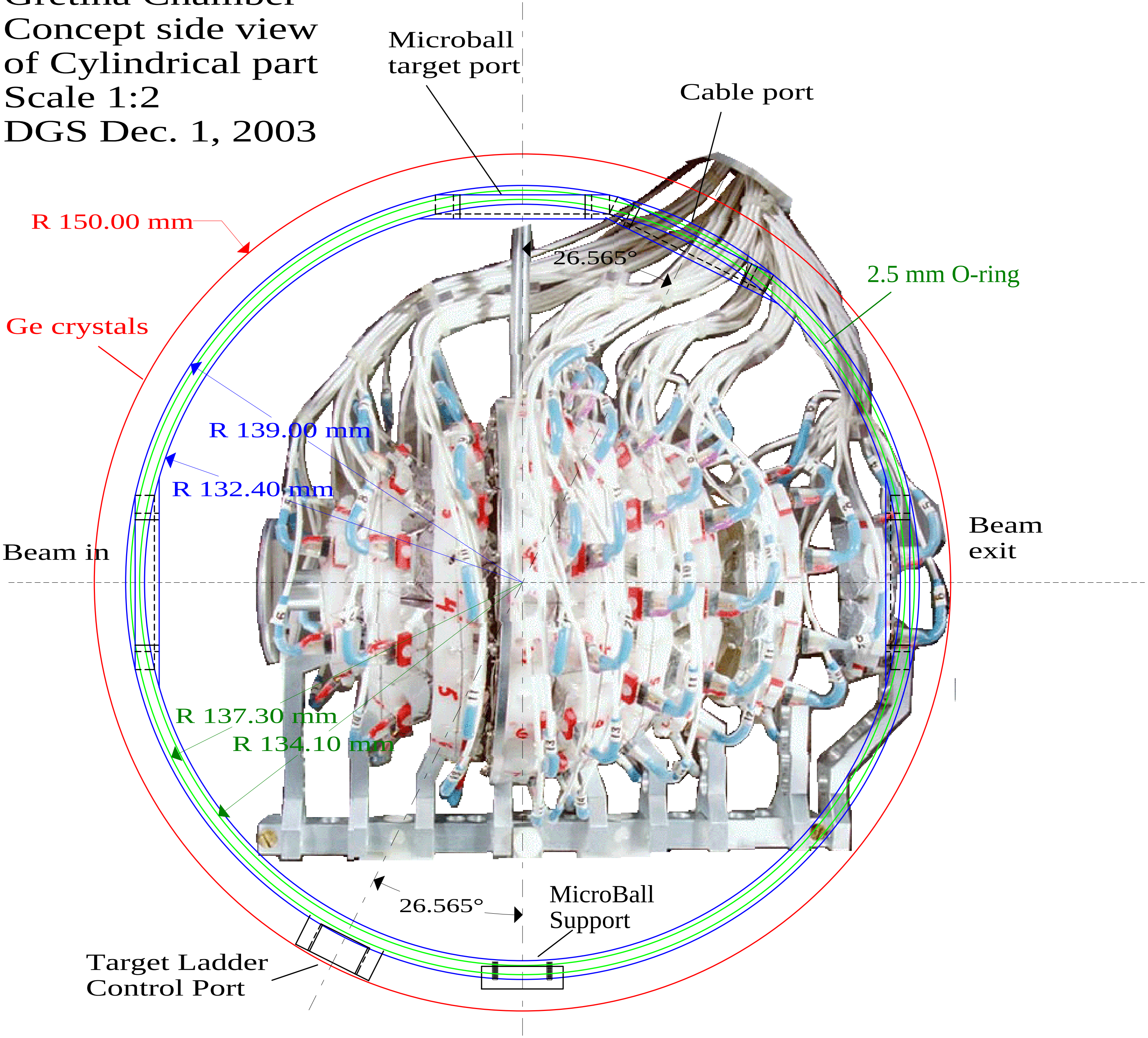
Concept Front View
of the Gretina
Scattering Chamber
DGS, Dec. 1, 2003
Scale 1:2



Gretina Chamber
Concept side view
of Cylindrical part
Scale 1:2
DGS Dec. 1, 2003



Gretina Chamber
Concept side view
of Cylindrical part
Scale 1:2
DGS Dec. 1, 2003



Gretina Chamber
Concept side view
of Cylindrical part
Scale 1:2
DGS Dec. 1, 2003

Crowded Silicon
Wall + Cube !!
256 strips (cables)