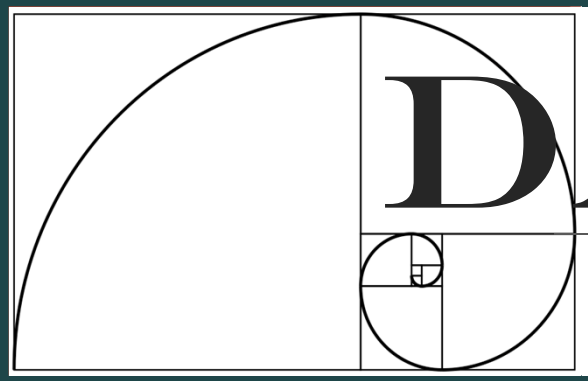


DAEδALUS

DAEδALUS SUPERCONDUCTING RING CYCLOTRON TO DELIVER 10 mA PROTON BEAM AT 800 MeV

ECPM
May, 2012

Alessandra CALANNA
MIT/INFN

DAEδALUS

Decay
At rest
Experiment for
δ_{cp} studies
At the
Laboratory for
Underground
Science

Primary physics goal: searching for

CP-violation in the neutrino sector

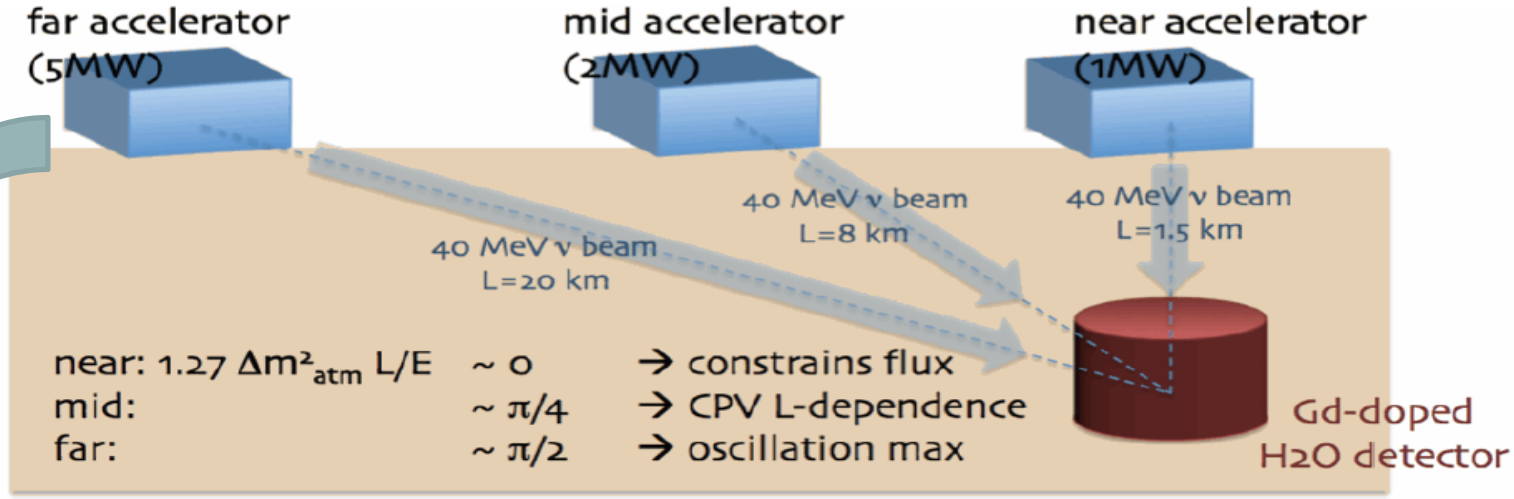
Short baseline $\overline{\upsilon}_\mu \longrightarrow \overline{\upsilon}_e$ experiment with no matter effect

novel design which provides high-statistics and low backgrounds

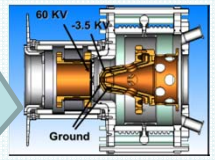
OUTLINE

- Physics Opportunities of DAEδALUS
- Basic Structure of the experiment
- Accelerator requirements
- Status of design
- Critical questions to be answered
- Next steps

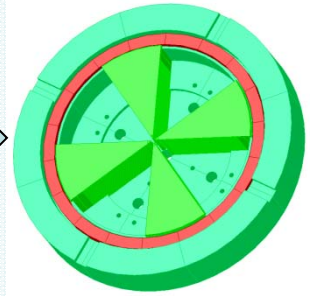
DAEδALUS: experiment overview



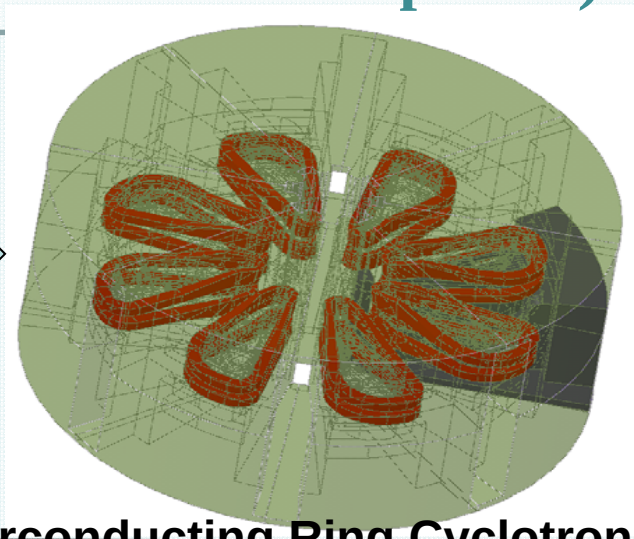
*Accelerator Complex (*LNS-CSFNSM expertise)



VIS source



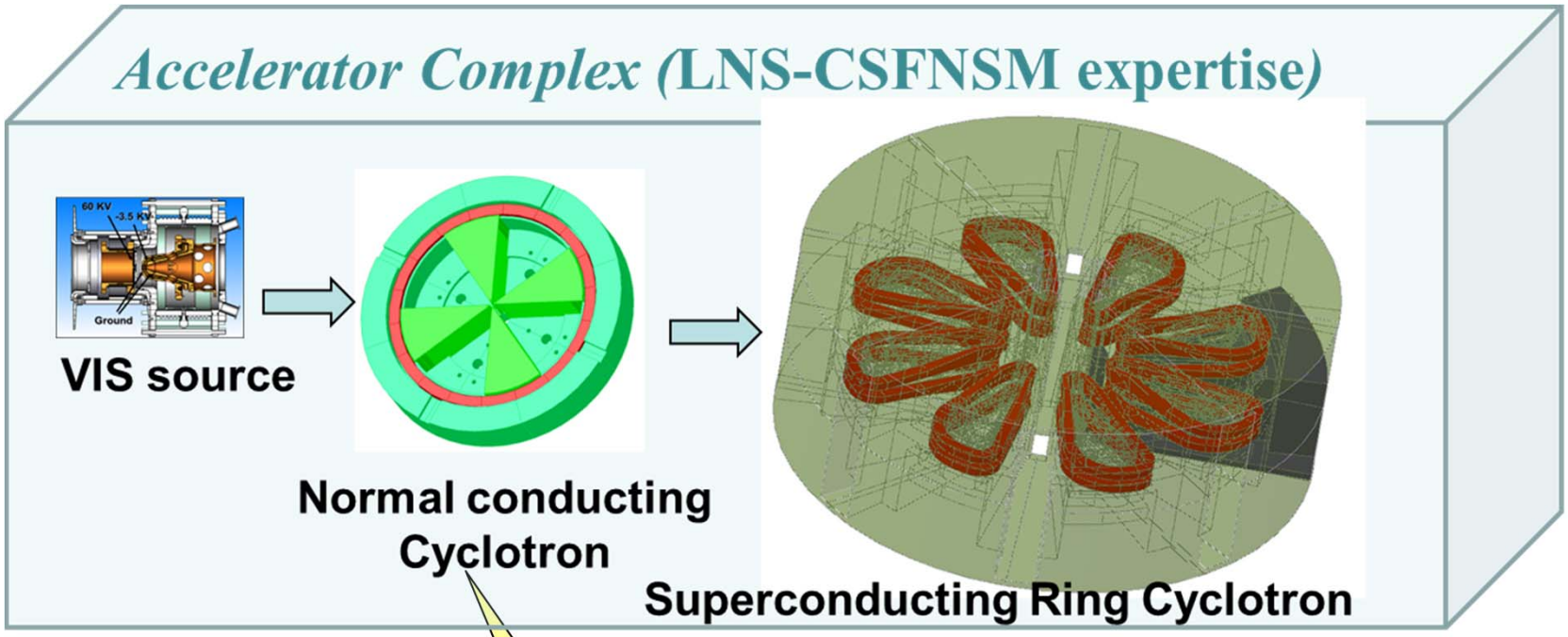
Normal conducting Cyclotron

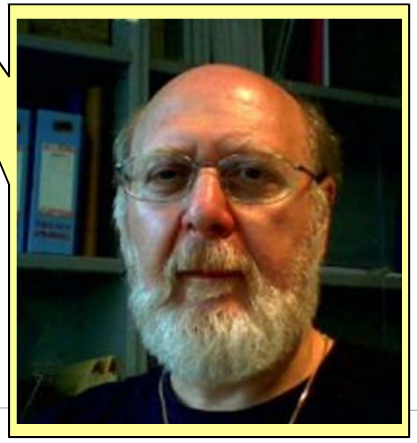


Superconducting Ring Cyclotron

DAEδALUS

SOURCE &INJECTION CHANNEL





Prof. L. Calabretta's talk

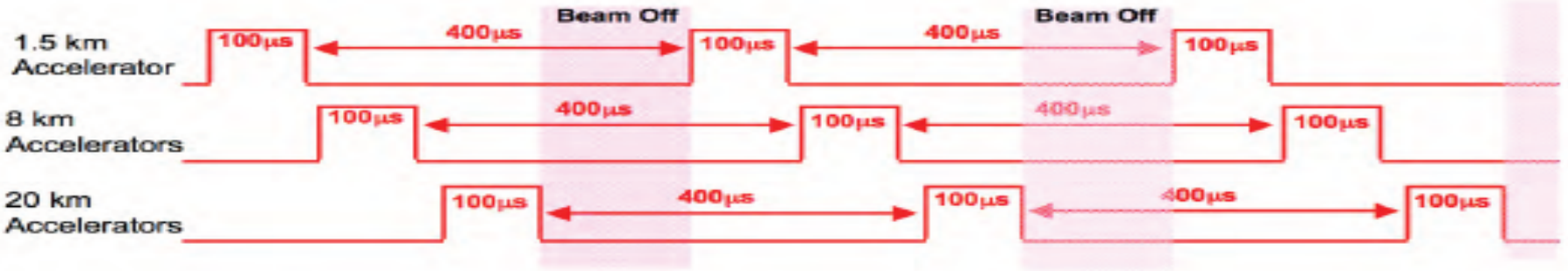
Stay tuned!

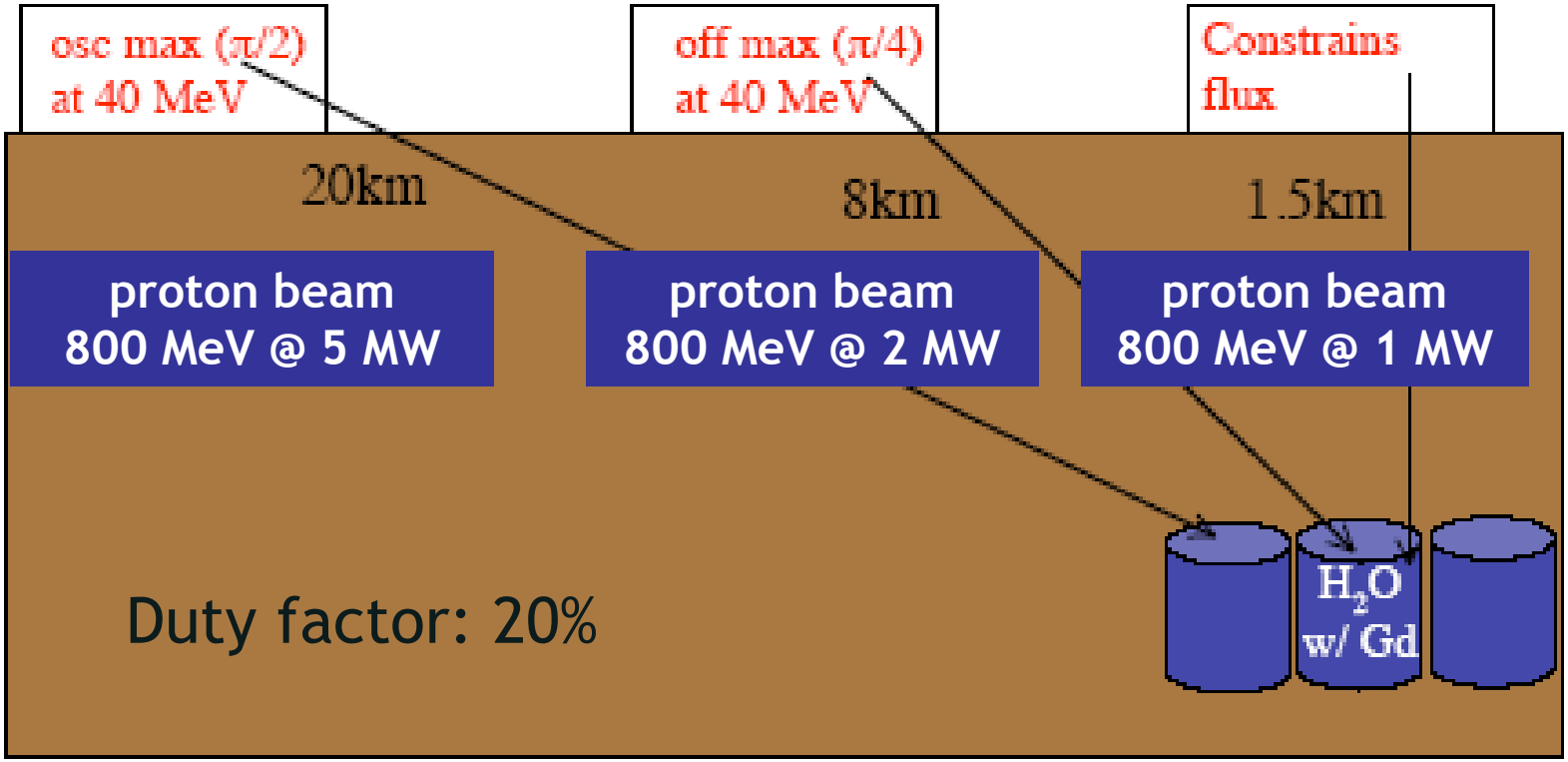
INFN Istituto Nazionale di Fisica Nucleare

Best

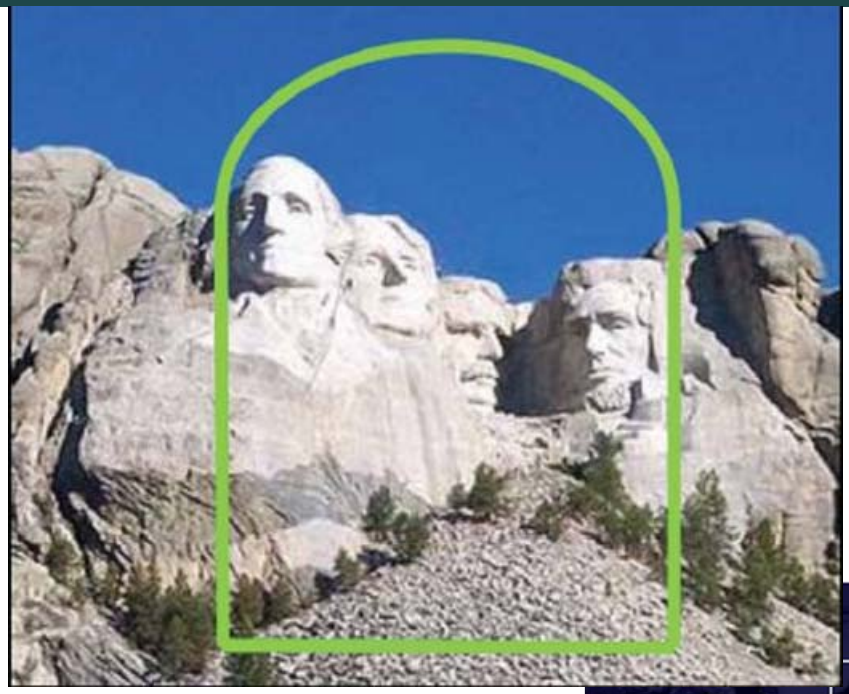
DAEδALUS

DAEδALUS: experiment overview

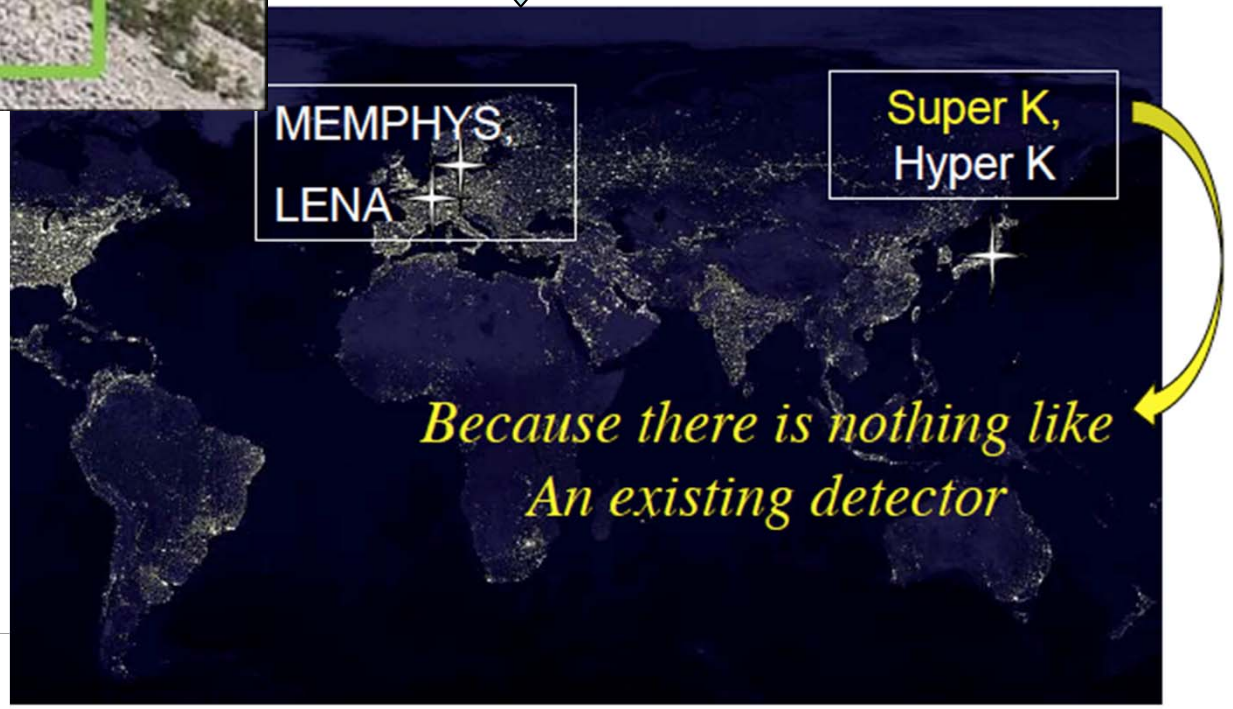




DAEδALUS:idea of dimensions

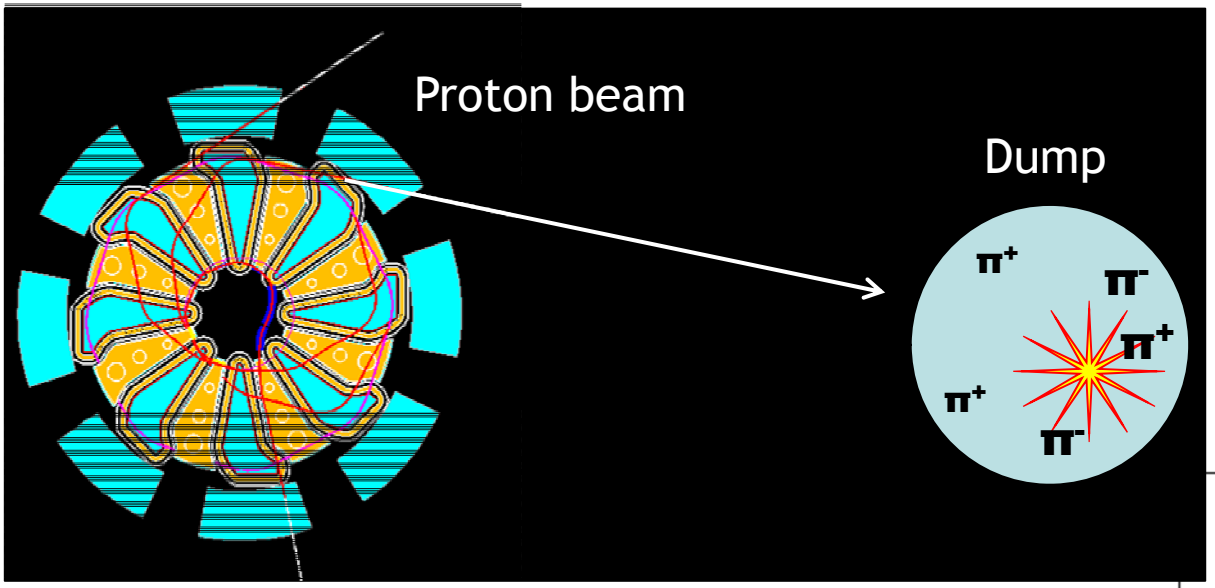


It could be



DAEδALUS

A LITTLE BIT OF PHYSICS (1/4)

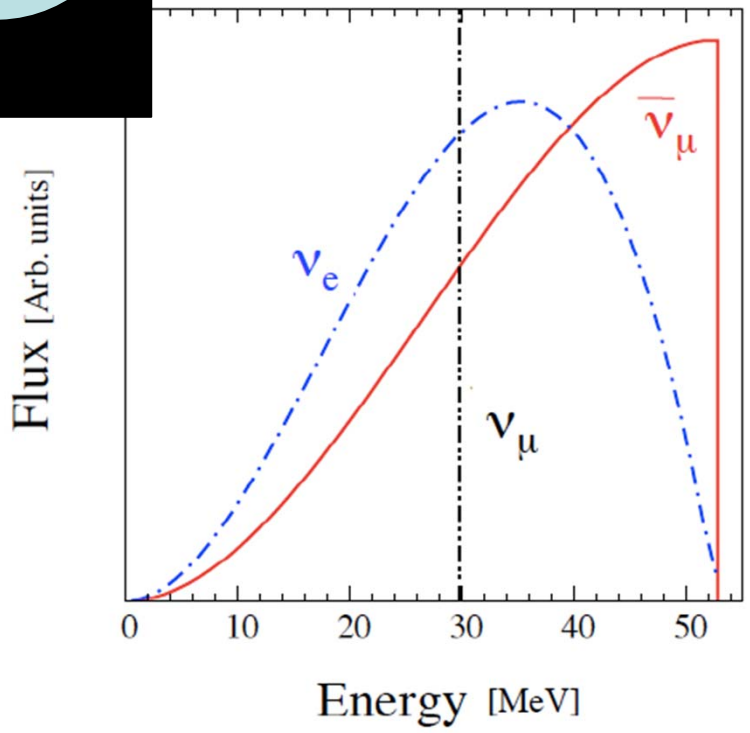


π^- are captured quicky

$$\pi^+ \rightarrow \nu_\mu + \mu^+$$

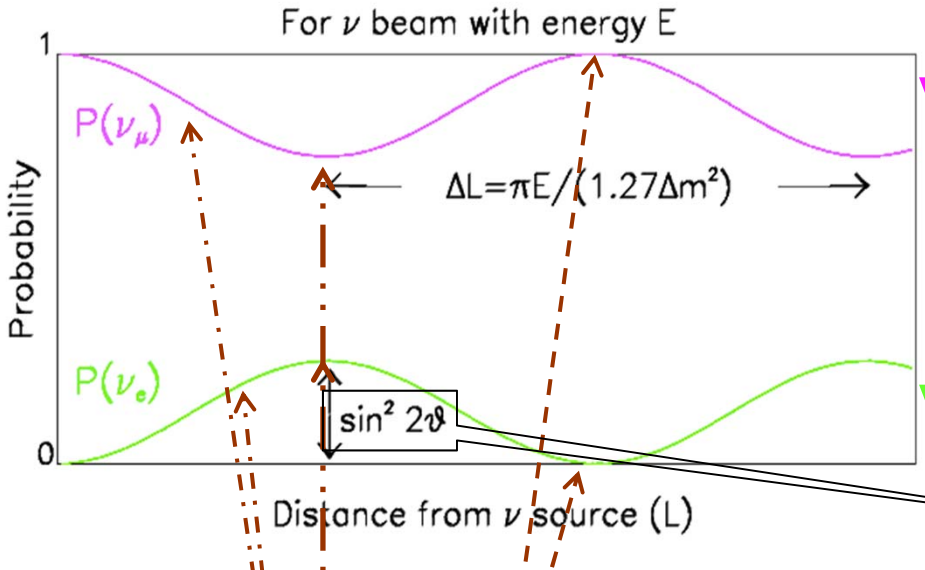
$$\mu^+ \rightarrow e^+ + \overline{\nu}_\mu + \nu_e$$

There is no creation of $\overline{\nu}_e$!

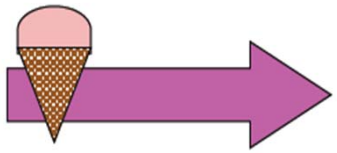


A LITTLE BIT OF PHYSICS (2/4)

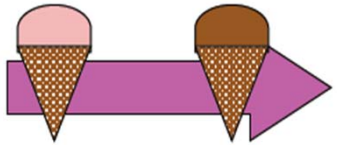
Since neutrinos do not travel as purely electron, muon or tau neutrinos



ν_μ Disappearance



ν_e Appearance



θ=mixing angle

3 distances can provide information on:

Beam-on backgrond → 1.5 km cyclo

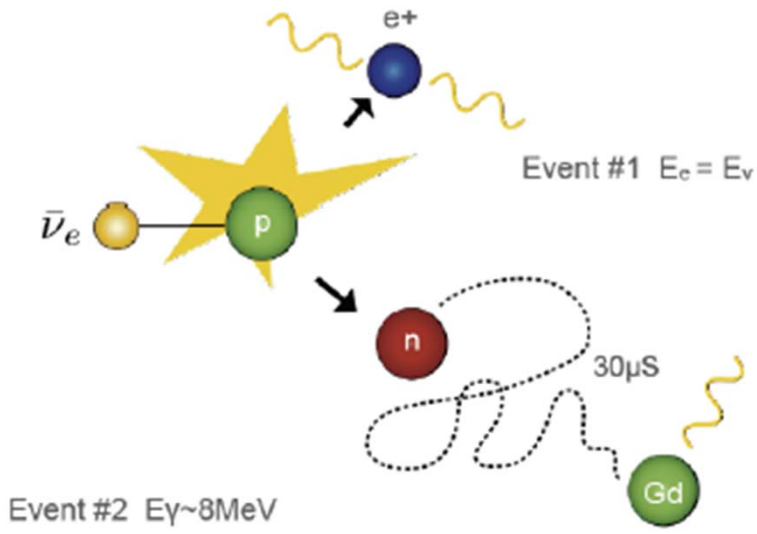
An oscillation wavelength of about π/4 at 50MeV → 8 km cyclo

Oscillation max → 20 km cyclo

A LITTLE BIT OF PHYSICS (3/4)

Water provides target of a free proton for the inverse beta decay (IBD) interaction

$$\overline{\nu}_e + p \rightarrow n + e^+$$



Produces Cherenkov ring

Doped water with Gadolinium enhances the neutron capture signal

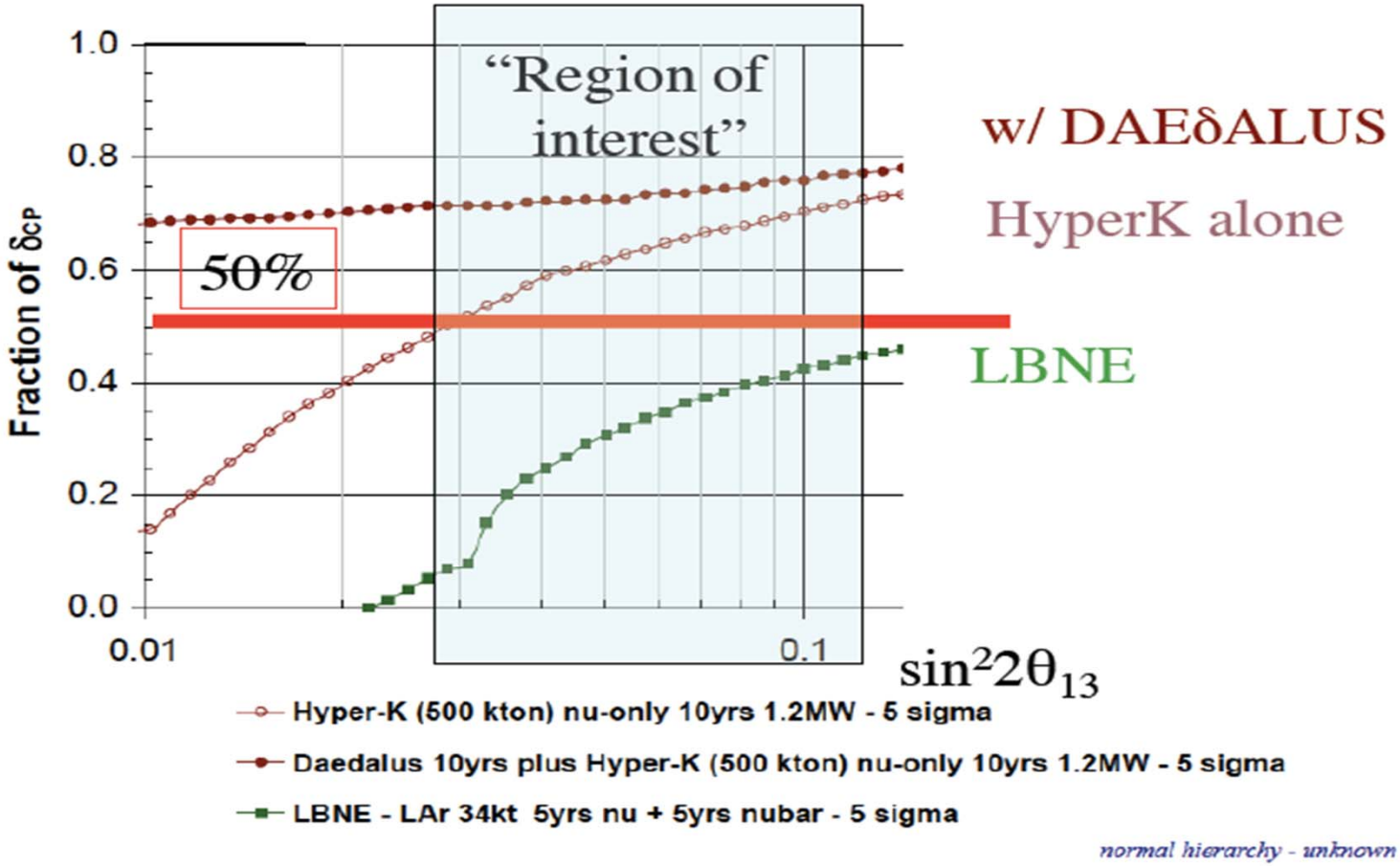
IBD interactions are identified via a coincidence signal

DAEδALUS

A LITTLE BIT OF PHYSICS (4/4)

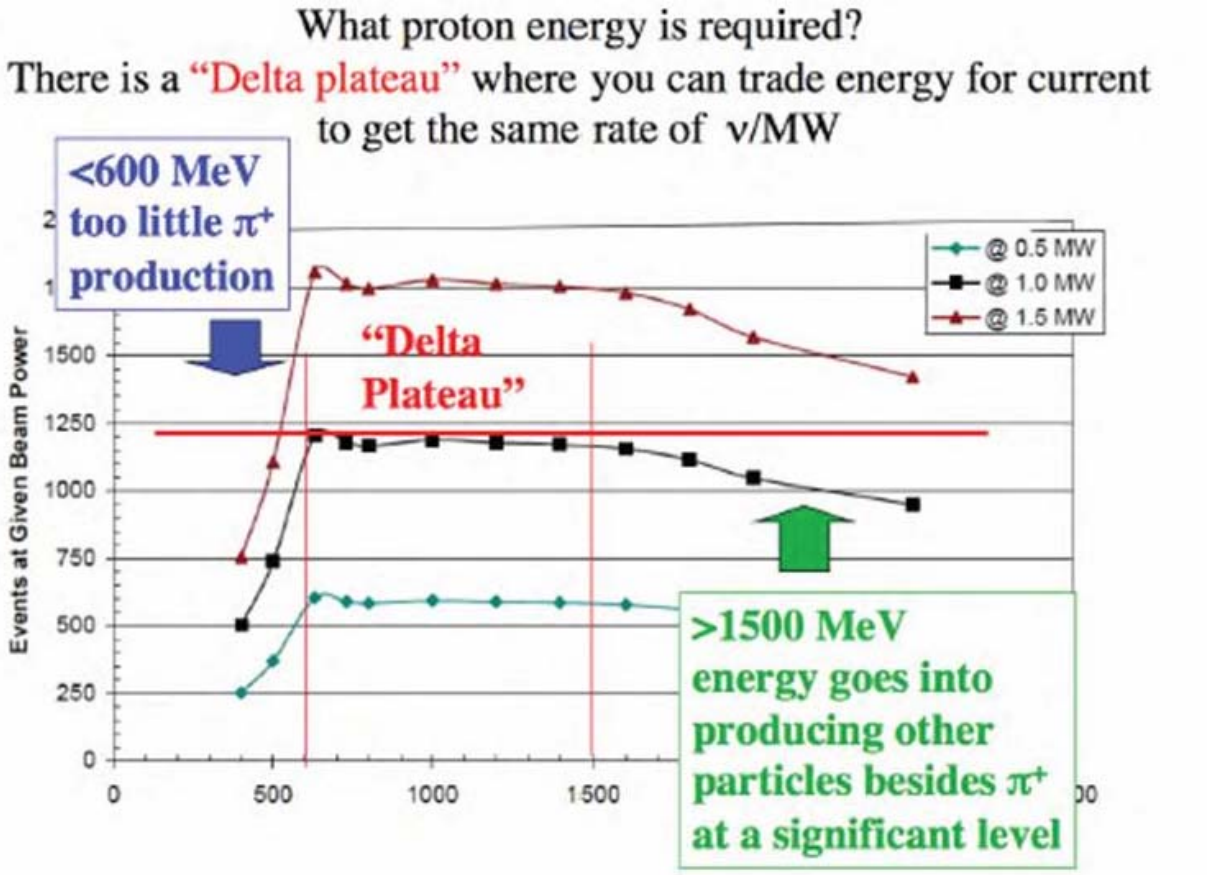
And in the Ultra-large detector era? We are already there!

>70% coverage δ at 5σ!



With the courtesy of Prof. J.Conrad

ACCELERATOR REQUIREMENTS



DAEdALUS needs 1-1.5 MW proton beam @ 800 MeV

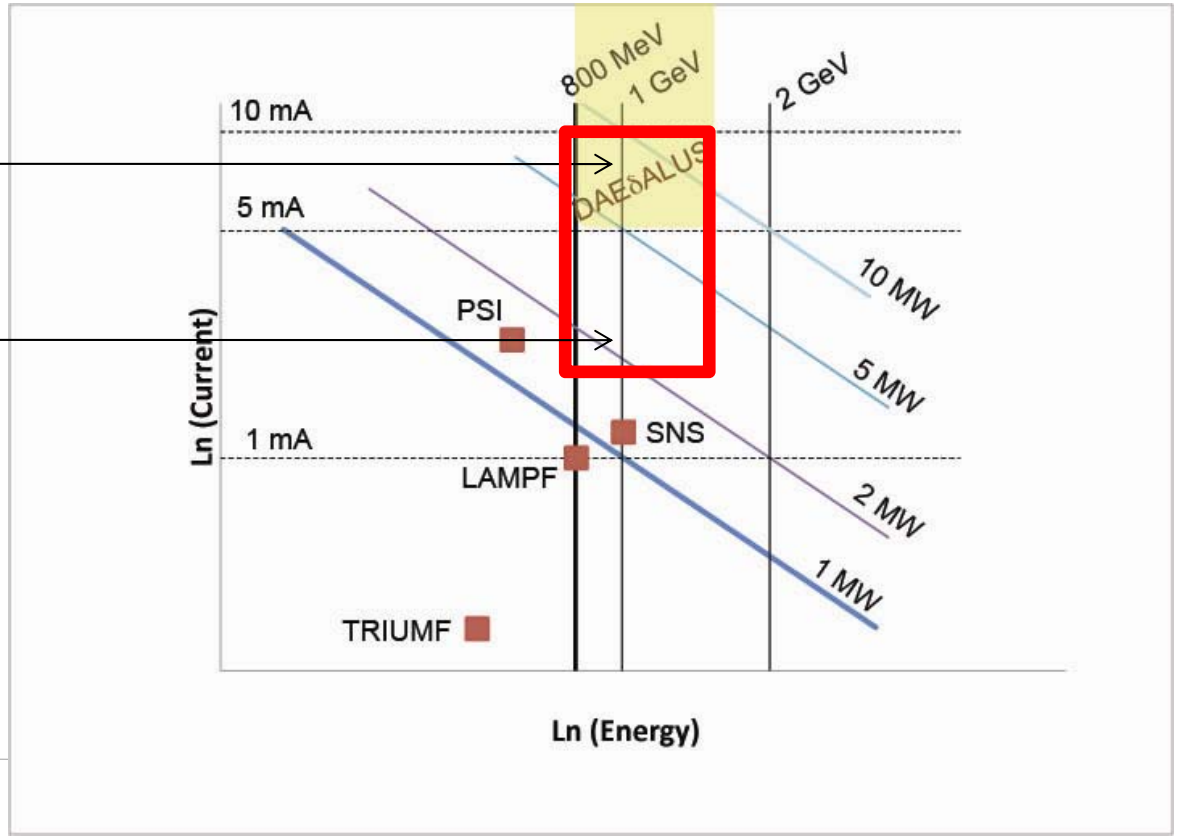
duty cycle= 20% → peak power 5-8 MW → Peak current 6-10 mA

Our Needs vs. Existing Machines

- LAMPF (Linac: 800 MeV, 1 mA)
- PSI (Cyclotron: 590 MeV, 2.3 mA)
- SNS (Linac: 1 GeV, 1 mA)

If we accelerate protons

If we accelerate H2+



DAEδALUS

POSSIBLE TECHNOLOGIES

- Superconducting linacs → the most conservative technology option but they are expensive

- Space and cost constraints suggest that high-power cyclotrons could be a less expensive option.

-Compact cylotrons for protons – MMC – Stacked cyclotrons have been evaluated

-FFAG very interesting, but not yet proven

The Multi Mega Watt Cyclotron (MMC) accelerating H_2^+ has 2 main advantages:

-Space charge effects reduced by a factor of √2 with respect to proton beam

- Extraction by stripping foil

WHY STRIPPER EXTRACTION

Experience at PSI (best performing cyclotron existing).
They have 99.98% of extraction efficiency. Our goal is to match their result (extraction with deflector)

-No interference with injection trajectory

-It is possible to accept an energy spread 0.5-1% .

- No septum needed

- High binding energy, so we can use higher magnetic fields than TRIUMPH

MMC-R Superconducting Ring Cyclotron

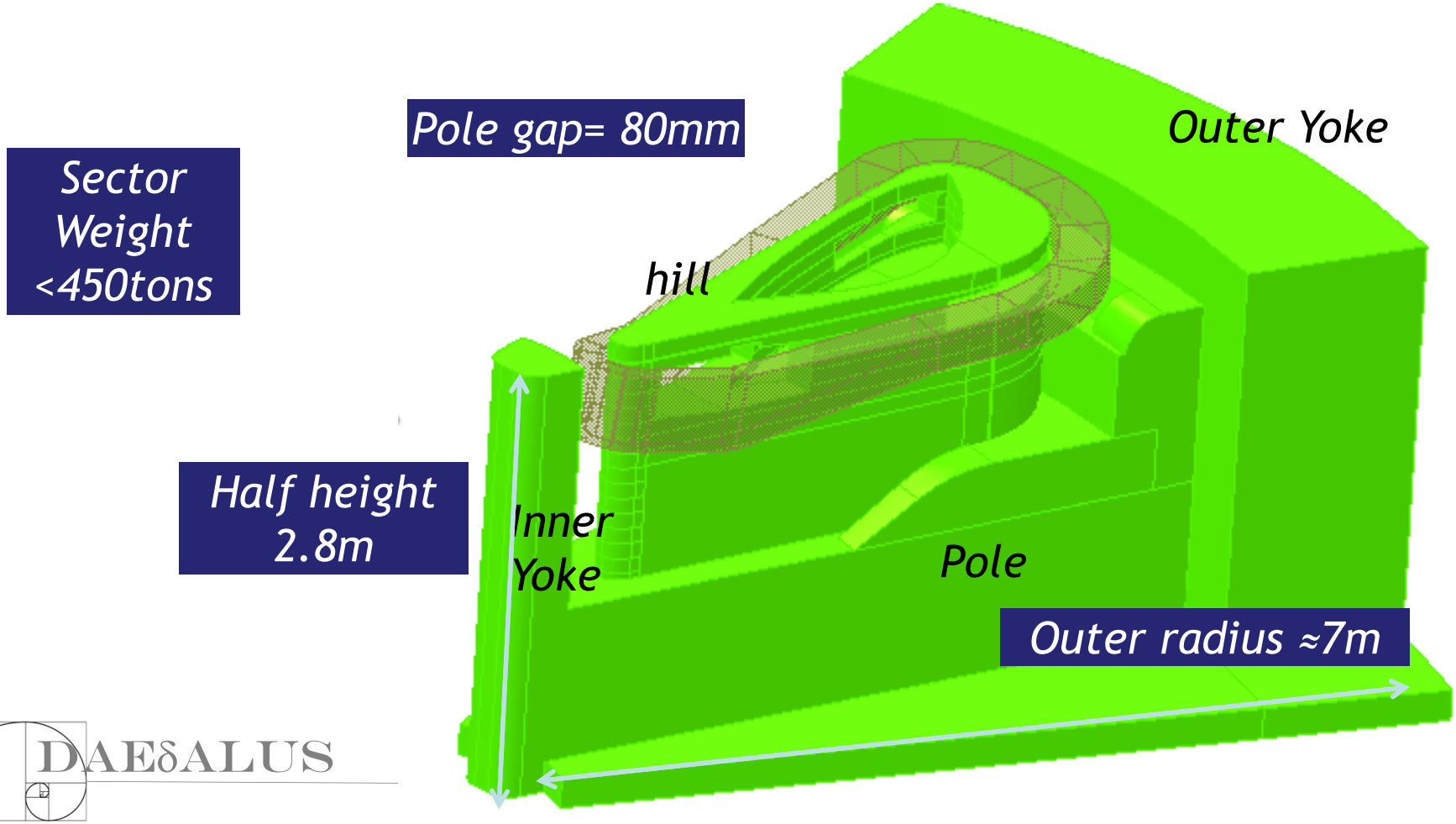
- H2+ injected in the ring cyclotron at 60MeV/n
- Last closed orbit at 800MeV
- Isochronous field. Average field ≈2T
- Simulation done with OPERA3D:
  - Design the structure
  - Define materials
  - Design coils
  - Define mesh
  - Solve through Tosca (FEM)
  - Elaborate and visualize results with Post-Processor
  - Optimization process

- To accelerate H_2^+ the magnetic field is 2 times higher than for protons → superconducting coils
- Losses have to be limited to a few hundred watts in total

MMC-R Superconducting Ring Cyclotron

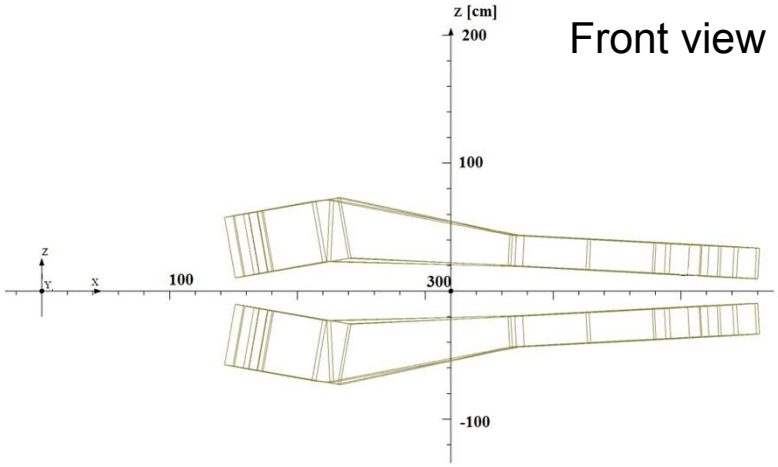
8SUPERCONDUCTING sector magnets:

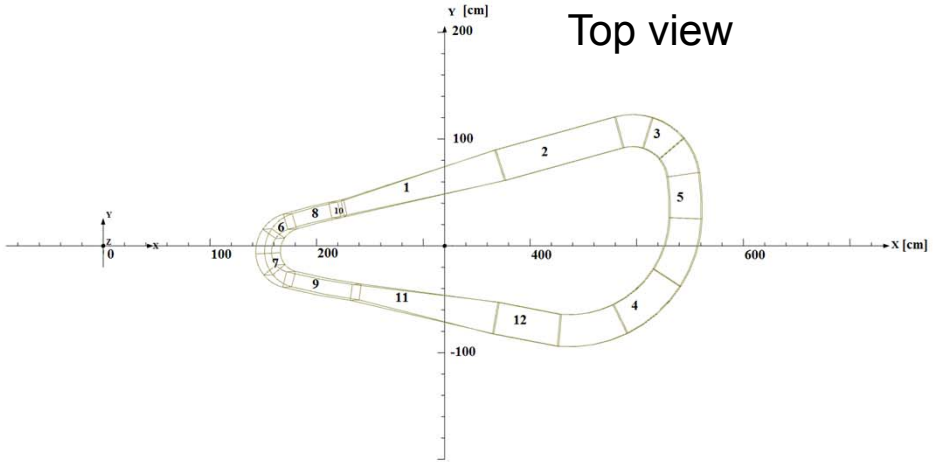
view of1/16 of the cyclotron: median plane is above the upper hill



DAEδALUS

COILS



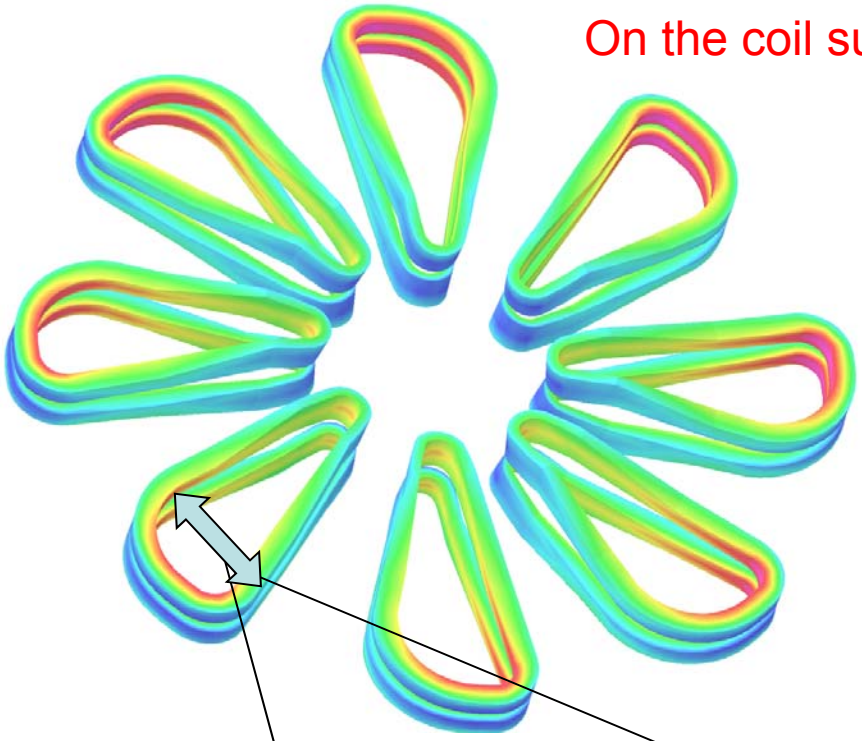


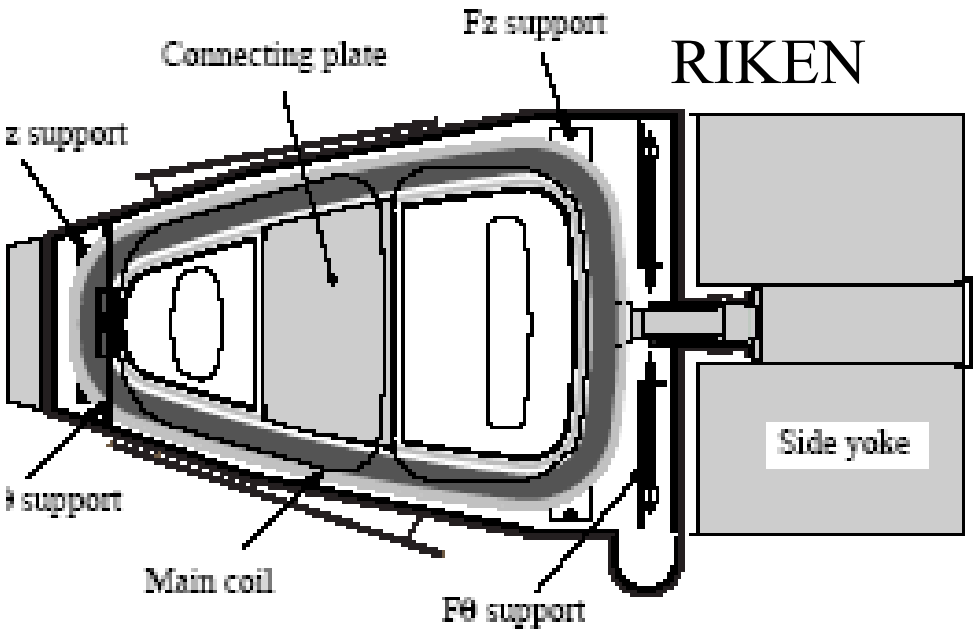
The different cross section is needed to guarantee enough space in the center region for the RF Cavities installation (and maybe is not enough!)

Current density 3400A/cm2
Area 30x24cm2 or 15x48cm2
The winding of the cable could be a blocking point for cooling reasons
Huge forces developped

MMC-R COILS

On the coil surface $Bmod_{max} \approx 6T$



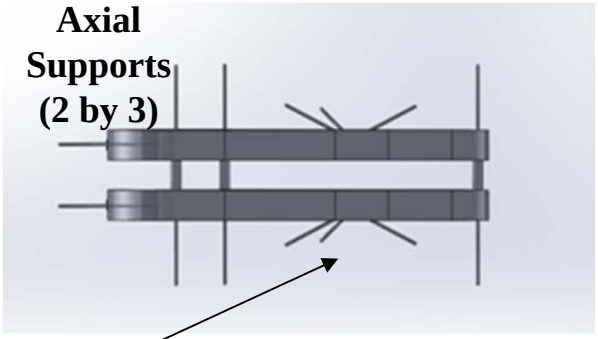


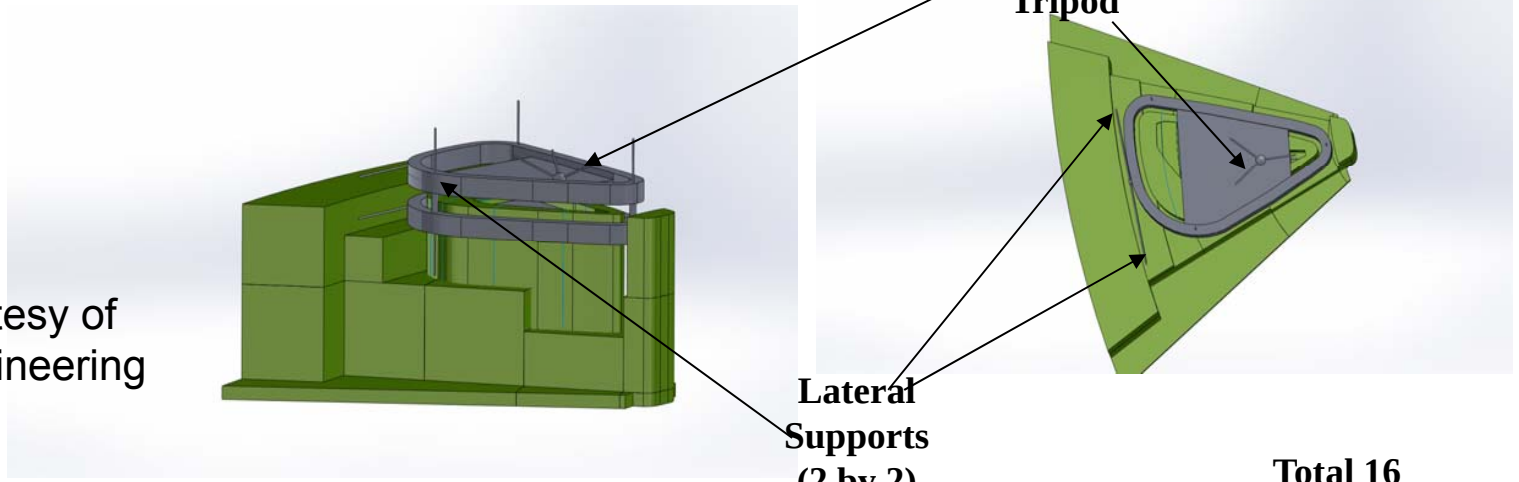
The longest straight arms of the coils will be conncted with a plate passing between the upper and lower hill. This will be necessary to cancel the expansion magnetic forces which tend to make the coil round

MMC-R COILS

	DSRC	RIKEN-SRC	units
Vertical Force *	3.7	3.3	MN
Radial shifthing force *	2.7	0.36	MN
Azimuthal shifthing force *	0.2	0	MN

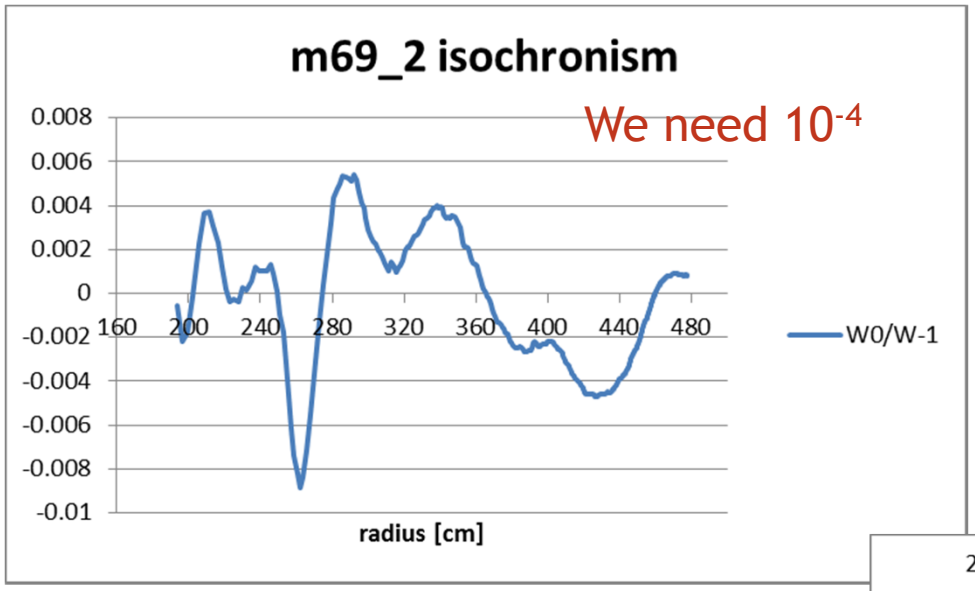
First evaluations on how the cryostat could be constructed



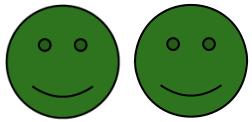


With the courtesy of PSFC MIT Engineering Group

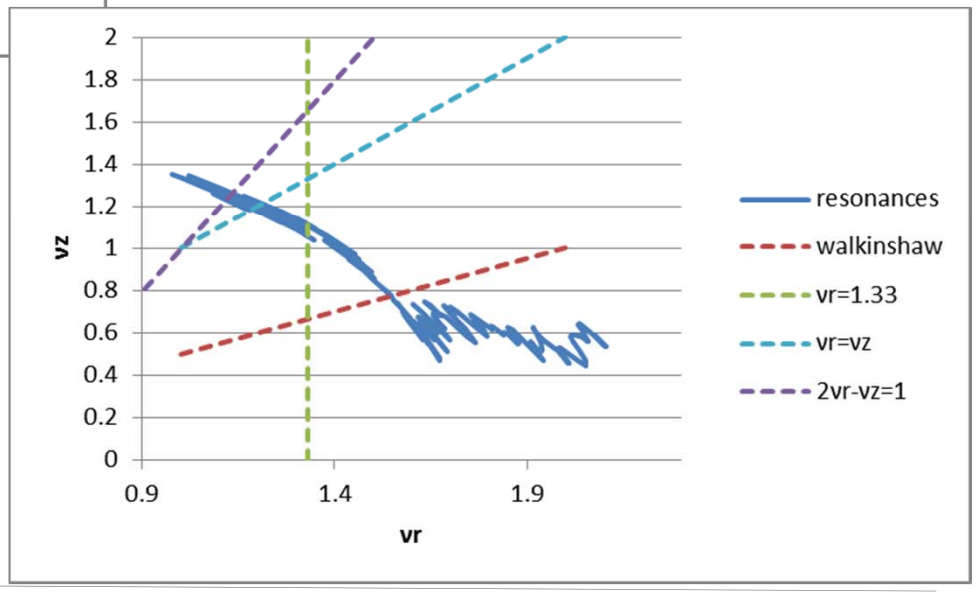
MMC-R OPTIMIZATION RESULTS



±0.5% between isochronous and calculated



All dangerous resonances are crossed quickly
Walkingshaw resonance NOT crossed at the end of acceleration

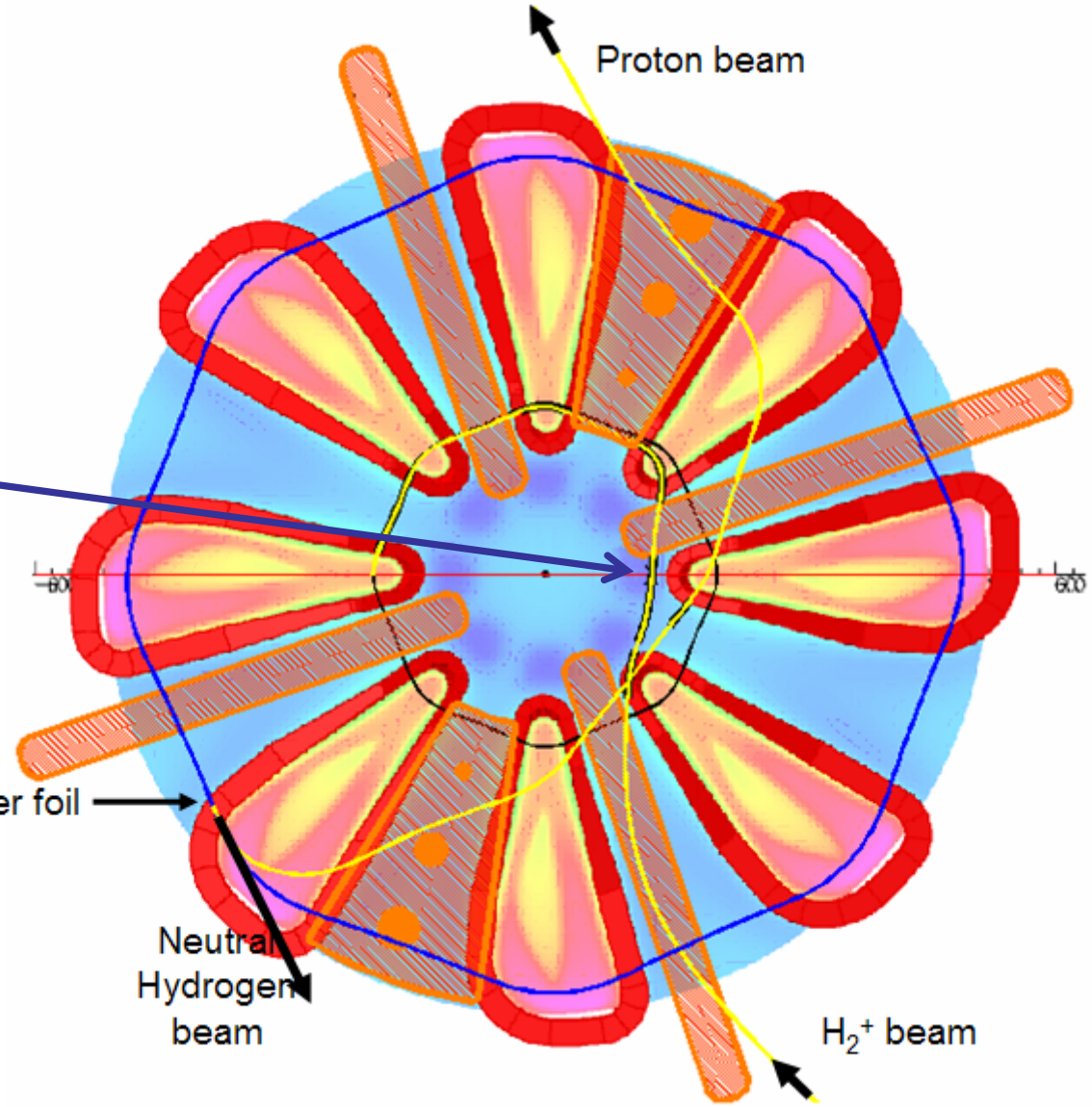


MMC-R LAYOUT

Bmax on a patch on the median plan 6.05T

Bmin on a patch on the median plan -2.5T

1 Electrostatic Deflector + 4 Magnetic channels for the injection



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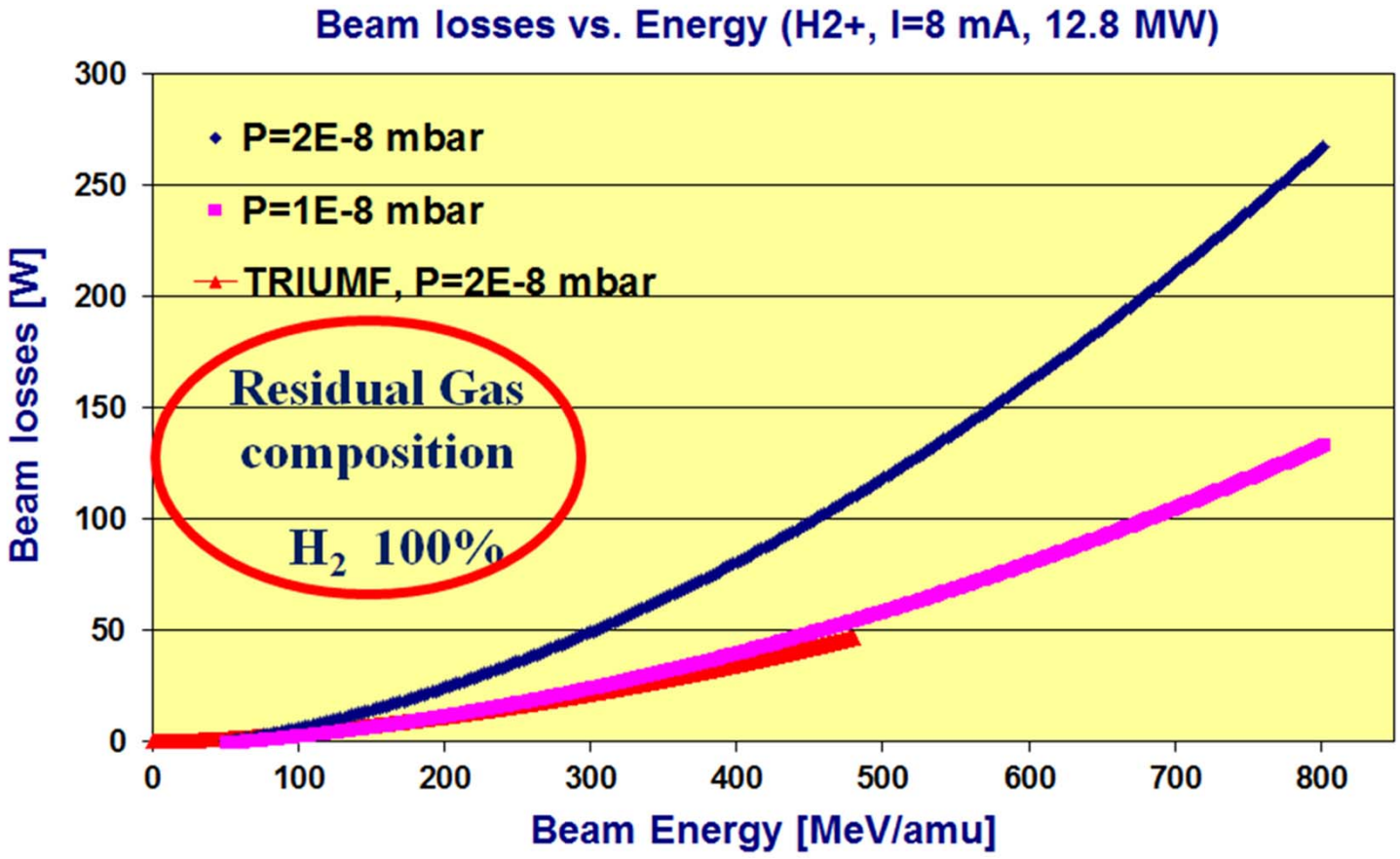
BEAM LOSSES



$$T=N/N_0=\exp(-3.35\ 10^{16} \int \sigma_i(E)\ P\ dl\ )$$

$$\sigma_i(E) \approx 4\pi a_0^{\ 2}\ (v_o/v)^2(Z_t^{\ 2} + Z_t)/Z_i$$

$Z_t=1$

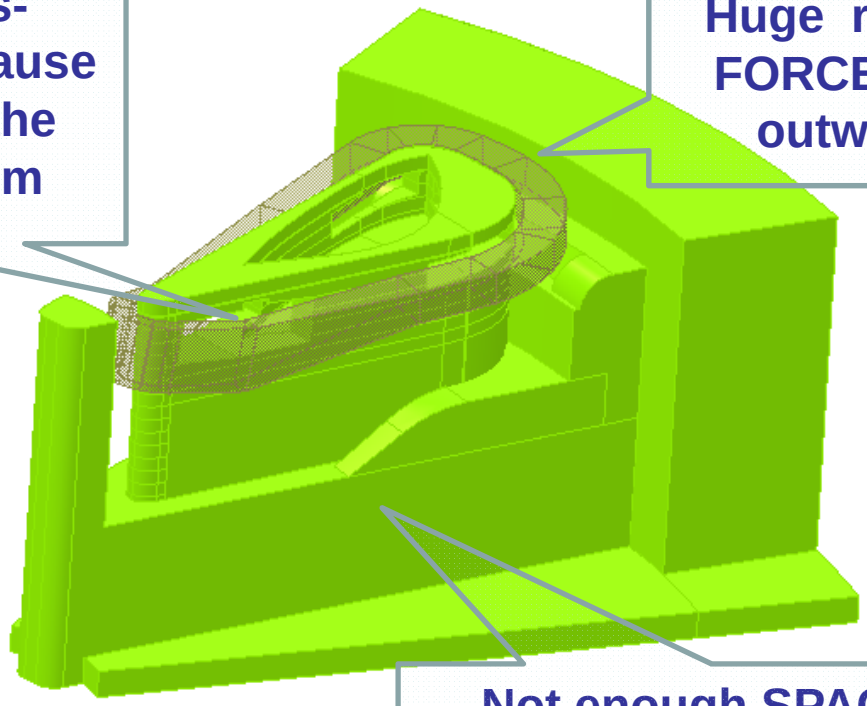
With the courtesy of L. Calabretta INFN-LNL

NEXT DEVELOPEMENT

3 major blocking points in the design

the variable cross-section that could cause complications on the LHe cooling system

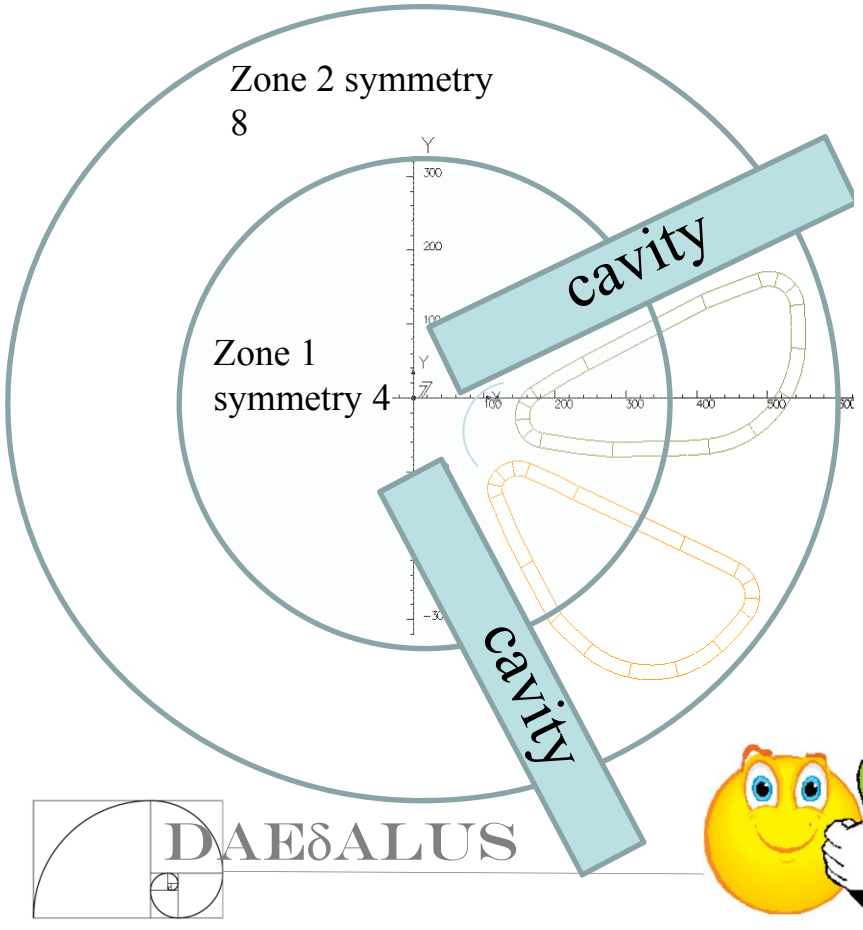
Huge residual radial FORCE that pushed outward the coil

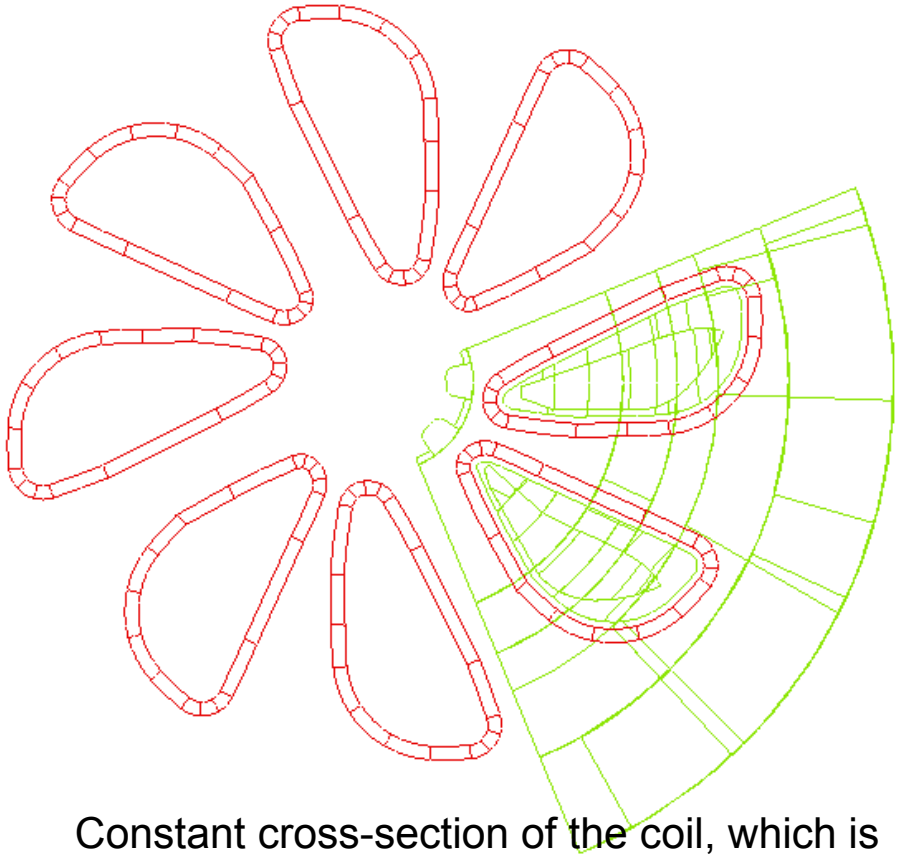


Not enough SPACE left between two contiguous sectors to install RF cavities PSI like

NEXT DEVELOPEMENT

We need an exact symmetry 8 only above 400MeV/amu
-> the coil was divided in two zones. Fixing a point on the center of the hill where there is the last closed orbit, the tip of the coil was tilted by 4deg. Same with the contiguous coil ring, which was tilted by -4deg





Constant cross-section of the coil, which is parallel to the median plane

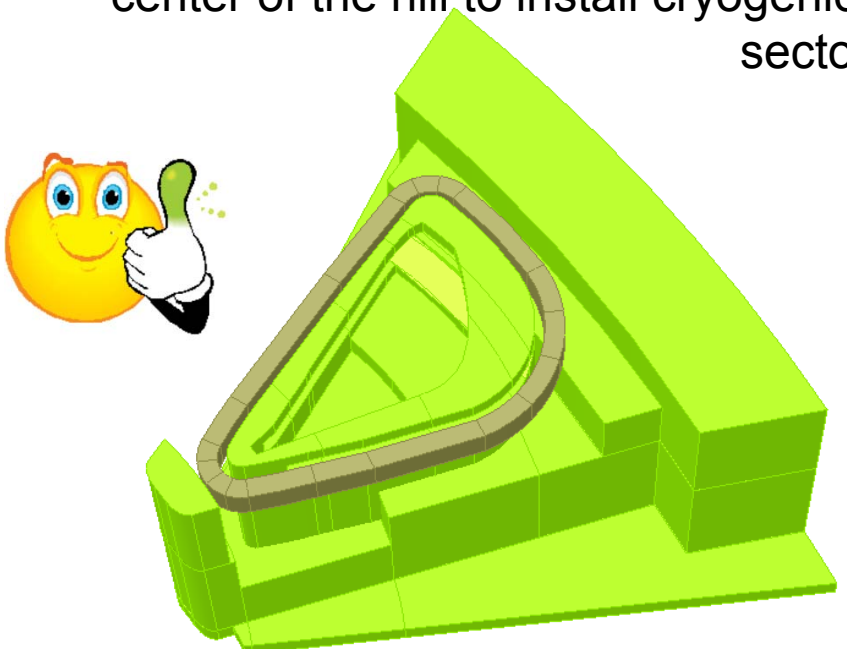
DAEδALUS

NEXT DEVELOPEMENT

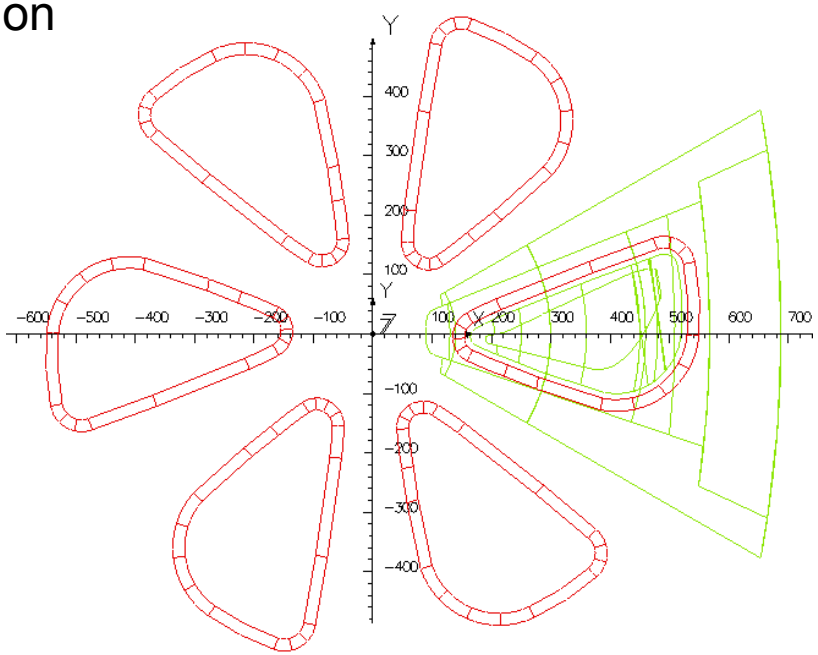
The stopping band resonance for a six sector machine is gamma=3

Why don't use a 6-sector cyclotron?

Before we planned to use SCOILS and 4 empty valleys to install vacuum pumps. Since now we have coils parallel to mp and empty space in the center of the hill to install cryogenic panels, it is possible to explore the 6 sector option

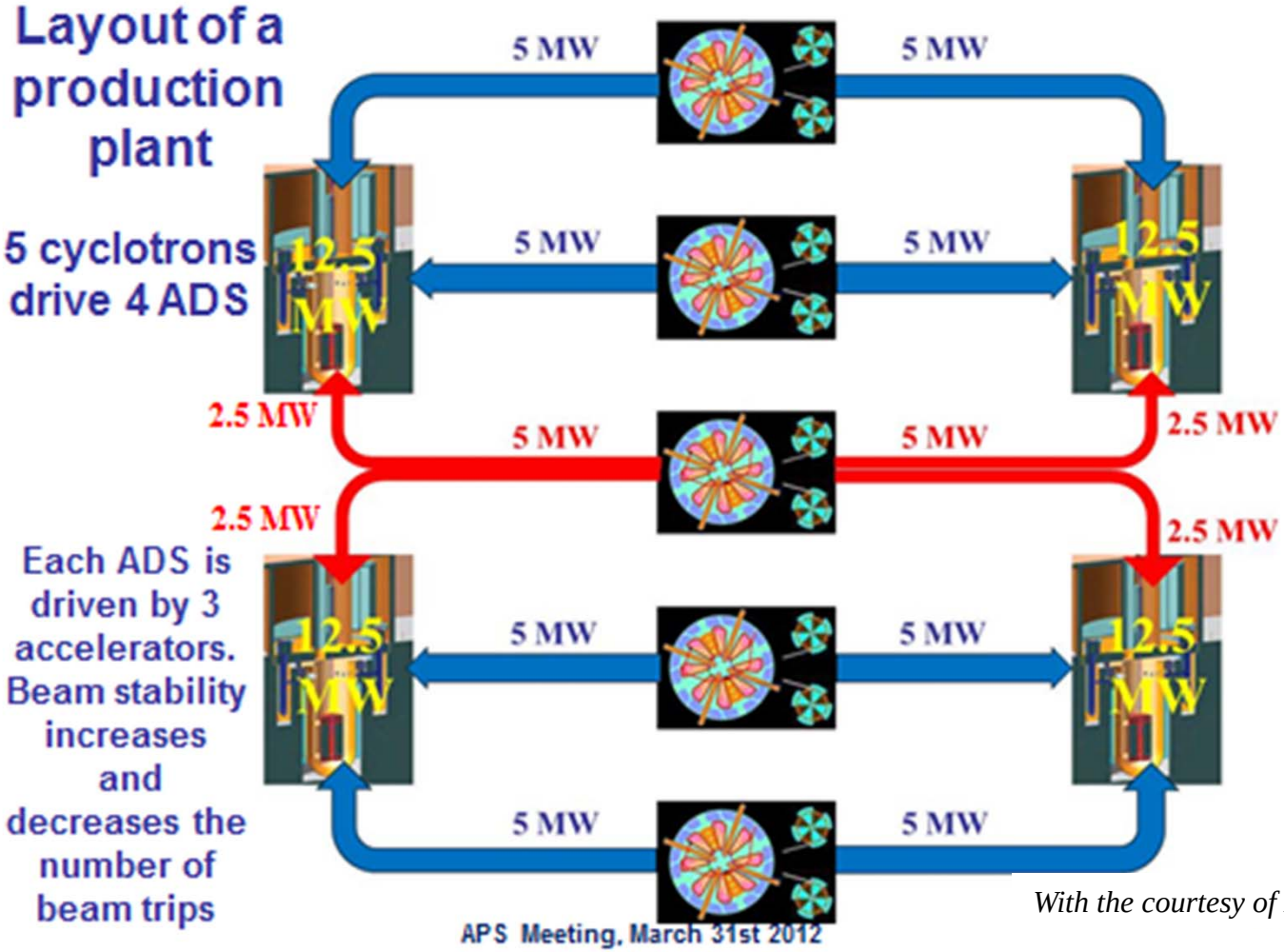


Constant cross-section of the coil, which is parallel to the median plan



- **No more issue for the RF cavities installation**
- **Easier study for injection system**
- **Sector shape similar to Riken**

OTHER APPLICATIONS



With the courtesy of L. Calabretta

SUMMARY

- DAEδALUS is an antineutrino experiment
- DAEδALUS results combined with other experiments will provide real improvement in the knowledge of the of δ_{cp}
- A Supercondicting Cyclotron has studied to produce the proton beam needed
- H_2^+ is the accelerated particle
- Applications in ADS filed

First 2 years of study confirm the feasibility of the project

In Ancient Greece,
DAEδALUS was the mythical patron of those
Who made wonderful things out of objects at hand