A 60 GHz ECRIS For the Beta Beams

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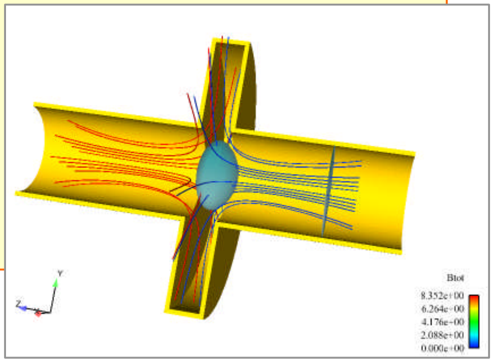
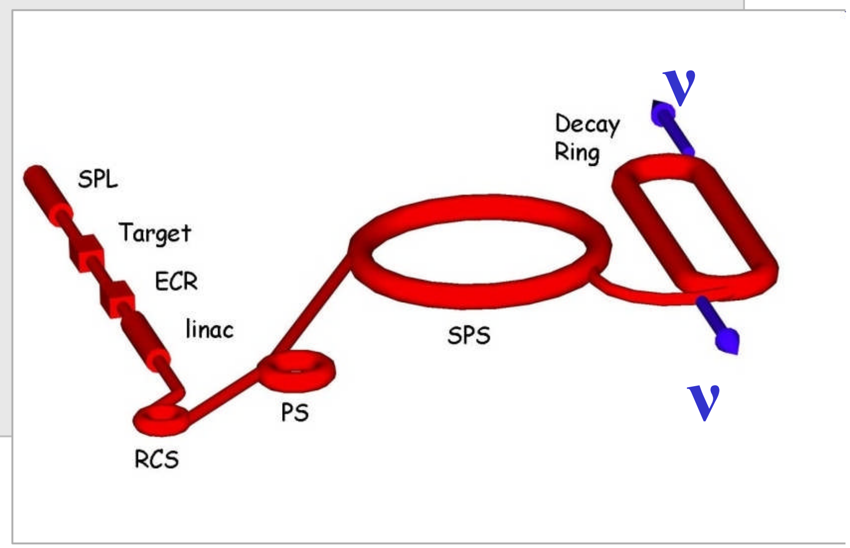
1. The Beta Beams
2. What kind of source for the Beta Beams?
3. 60 GHz R&D with the GHMFL
4. 1st 60 GHz prototype : simulation, CAD
5. Prospects for next years



1. The Beta Beams R&D

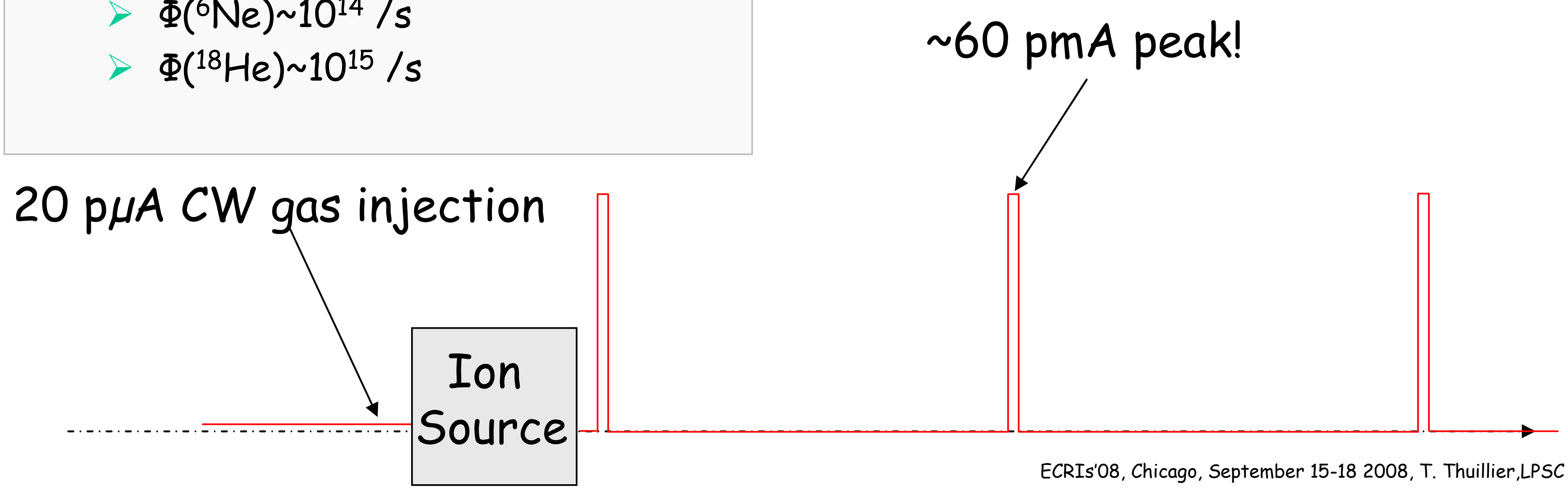
- Produce intense pulsed neutrino beams from ^{6}He and ^{18}Ne decay
  - mixing angle θ_{13} measurement
- Project hold by CERN
  - next generation neutrino factory
- Based on existing technology and machines
  - He and Ne production through ISOL technique
  - Bunching and first acceleration: ECR, linac
  - Rapid cycling synchrotron (RCS)
  - Use of existing machines: PS and SPS
  - Race Track Decay Ring
- γ~100 Lorentz Factor
- Challenging R&D in many fields



1. Ion source R&D initial specifications for Beta Beams

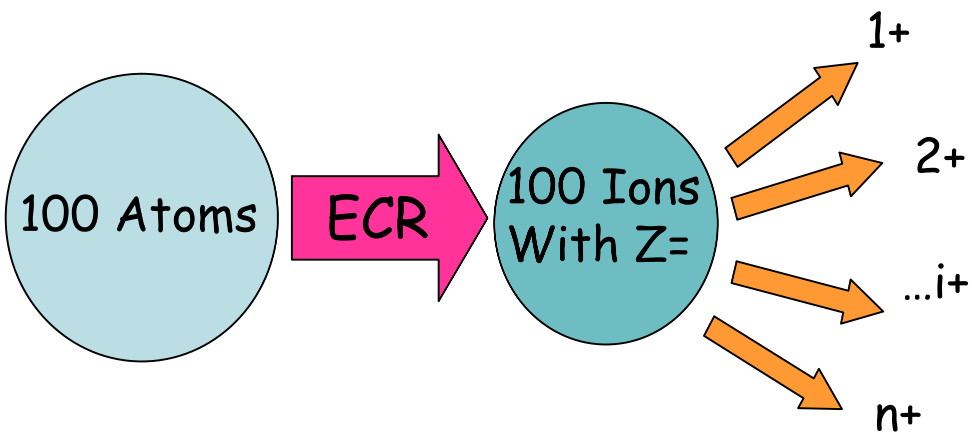
- Source near to the target
  - Highly radioactive environment
  - Source activation
  - Last as long as possible (~1 month)
- Short Half lives :
  - τ (^{6}He)=0.807 s
  - τ (^{18}Ne)=1.67 s
  - Fast ionization and extraction
- Fluxes expected from target:
  - Φ(^{6}Ne)~10^{14} /s
  - Φ(^{18}He)~10^{15} /s

- Bunch ions in range 10-25 Hz
- Pulse width ≤ 100 μs
- <u>As efficient as possible</u>
- Multicharged Ions prefered
- 1+ source not excluded



2. The Charge state spreading : 2 scenarii

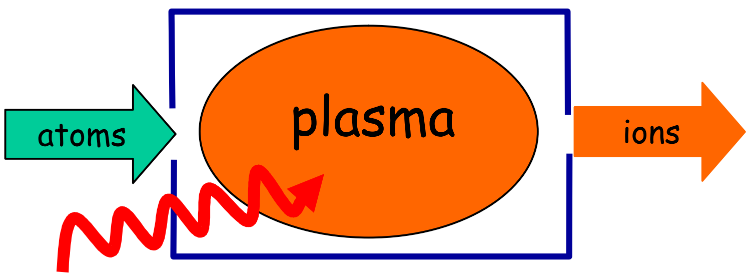
- Tune the ECRIS for N+ optimization => ~20-30% of RIB at best on one charge state
  - Acceleration of 3 charges with special LINAC or FFAG : 50-80%?



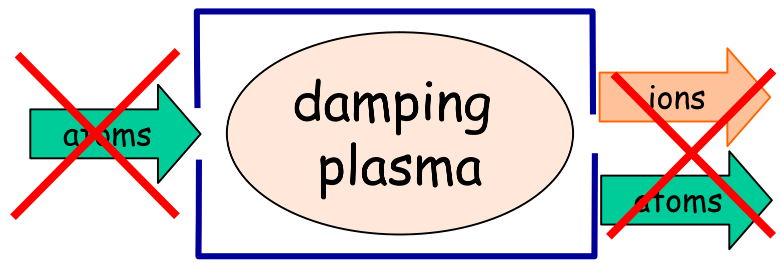
- Tune the ECRIS for 1+ optimization => ~80-99% of RIB at best
  - Provided the plasma has a high density (=> high ionization efficiency)

2. Sources of efficiency loss

- RI gas may be pumped or extracted between RF pulses
  - Pulsed valve at injection
  - Iris (camera like) at extraction



During RF pulse,
plasma ionizes atoms



After RF pulse,
Ion extraction continues
RIB gas can be pumped through
Plasma electrode

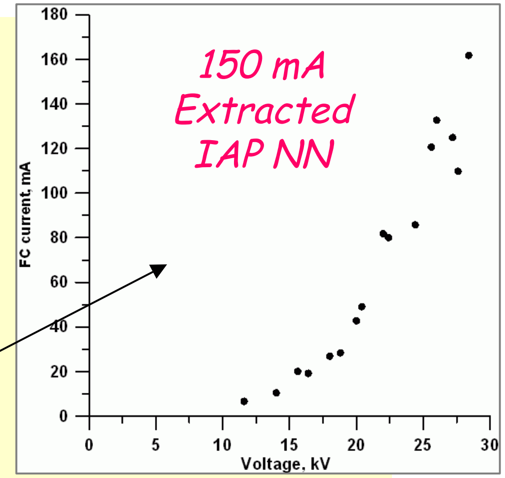
2. Ions source Volume and Ion extraction constraint

- Buffer gas flow
  - To ensure high density plasma condition
  - At 60 GHz : n_e~4.10^{13} /cm^3 => ~10^{16} e$^-$/litre >> RIB flux
- But the higher the buffer gas flow... the higher the total extracted current
- ...And the more difficult the extraction system design

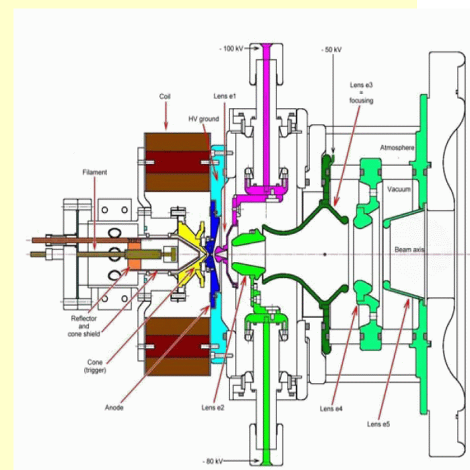
- A small plasma volume is necessary
  - Volume << 1litre
- A high voltage extraction system is mandatory
  - 100 KV
  - Very short accelerating GAP

2. Can an ECRIS Make the job?

- o **High confinement ECRIT at 60 GHz**
  - Pulse time structure (~100 μs)
  - Ionization efficiency
  - High charge state
  - Plasma Volume < 1 litre ..?
  - Total extracted current?



- o **A mirror or CUSP trap @ 60 GHz**
  - High current extraction measured at IAP Nijni Novgorod
  - Short pulses (<100 μs)
  - Medium charge state
  - Ionization efficiency?
- o **A duoplasmatron ?**
  - Pulse Time structure OK
  - High Current extraction OK
  - Pressure in the source…1 mbar (PBM!)
  - Ionization efficiency ??

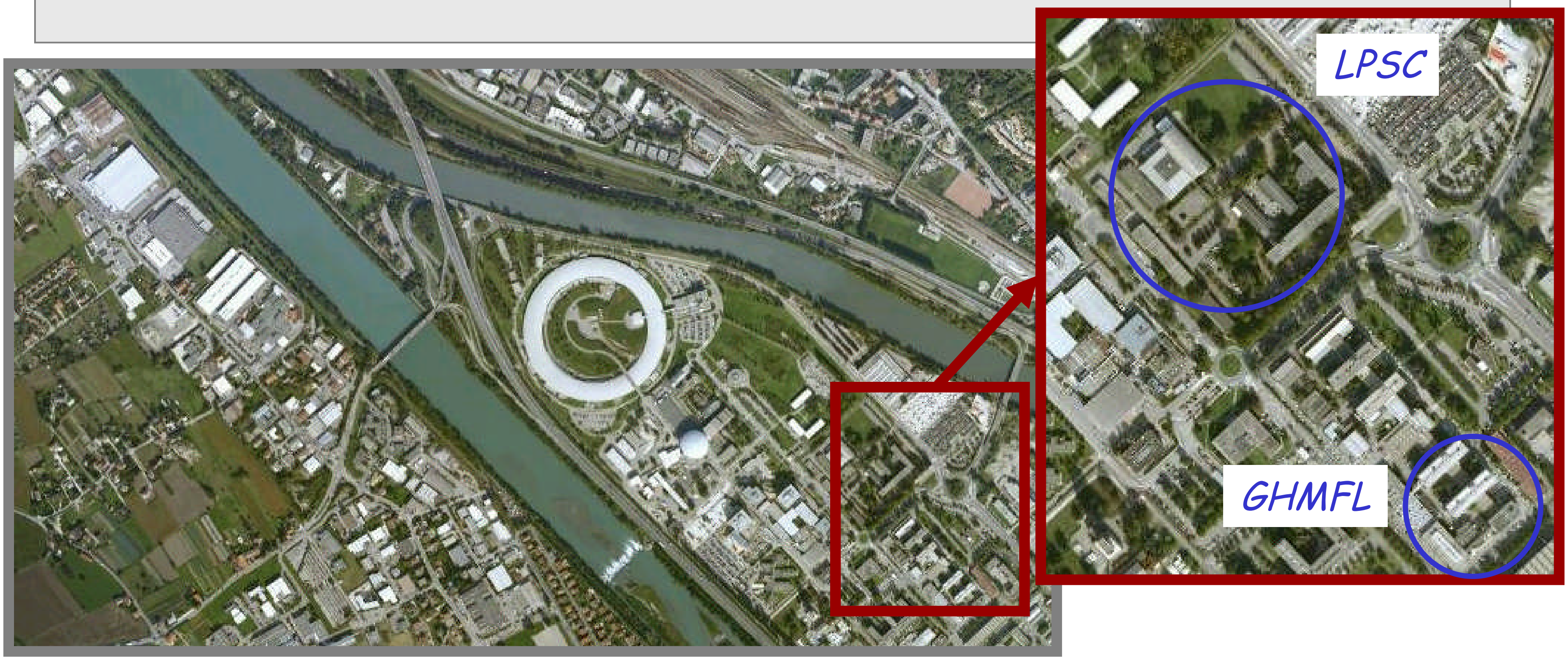


LPSC duoplasmatron

Difficult to choose…each trail is of interest for the project!

3. The 60 GHz R&D program of LPSC

- Build & test prototypes of 60 GHz magnetic structures
- SC is expensive and time consuming
- Collaboration with the Grenoble High Magnetic Field Laboratory (GHMFL)
- Design and build copper based prototypes to be tested in GHMFL
- Fast CAD, fast building

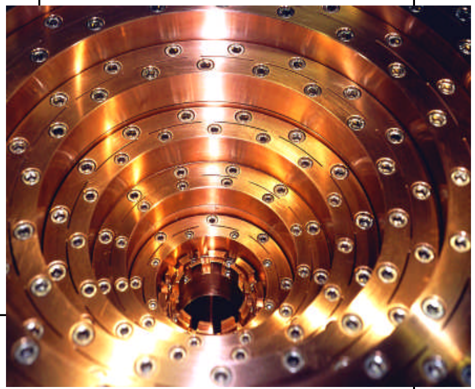


Grenoble Scientific Polygon

Grenoble High Magnetic Field Laboratory

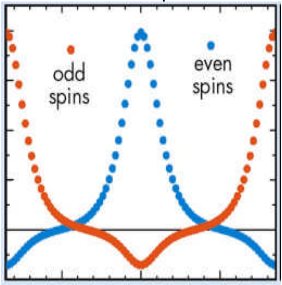
Staff

16 permanent researchers
8 post docs
7 PhD
40 technical staff



Research

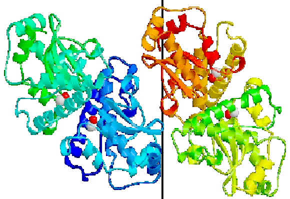
Condensed matter
- Metals
- Superconductors
- Semiconductors
- Magnetic materials
- Nanophysics



Biochemistry and soft matter
- Structural studies
- Magneto-science

Applied Superconductivity
- Superconductor development
- Magnet development

Magnetohydrodynamics
- Basic studies
- Technological studies



Instrumentation under magnetic fields

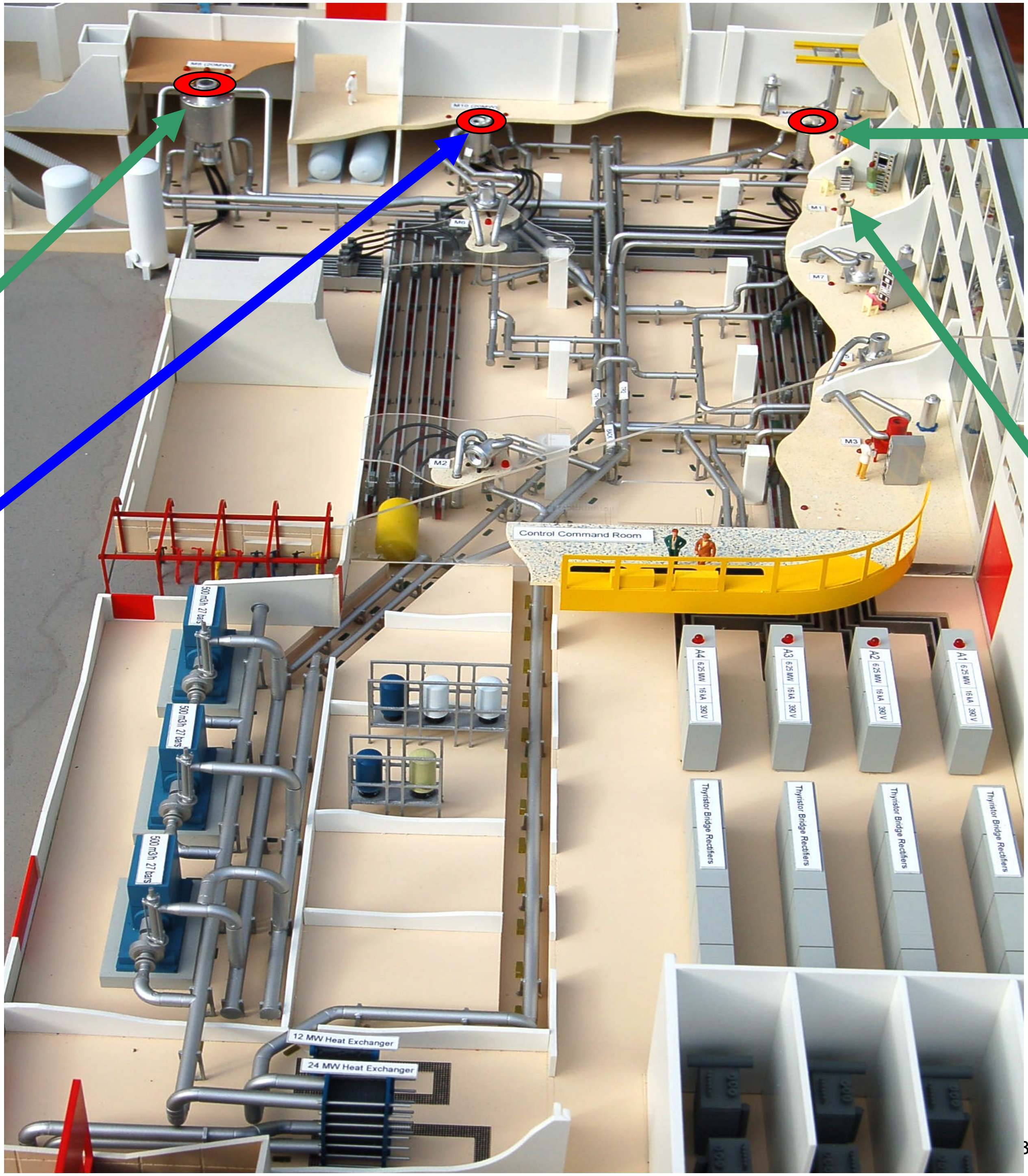
Specific technics

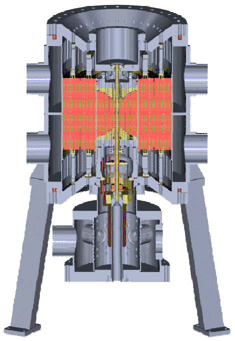
Magnetic field up to 32 T
Low temperatures (> 20 mK)
High pressure (up to 10 kbar)
High field EPR
High field NMR

➔*RESEARCH PROPOSAL FOR MAGNET TIME*
Deadline for 2nd semester 2007
May 25th, 2007

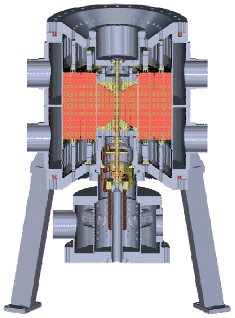
http://ghmfl.grenoble.cnrs.fr/

20 T /160 mm

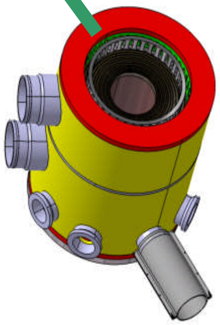




32 T /34 mm
(34 T May 2007)



28 T/50 mm



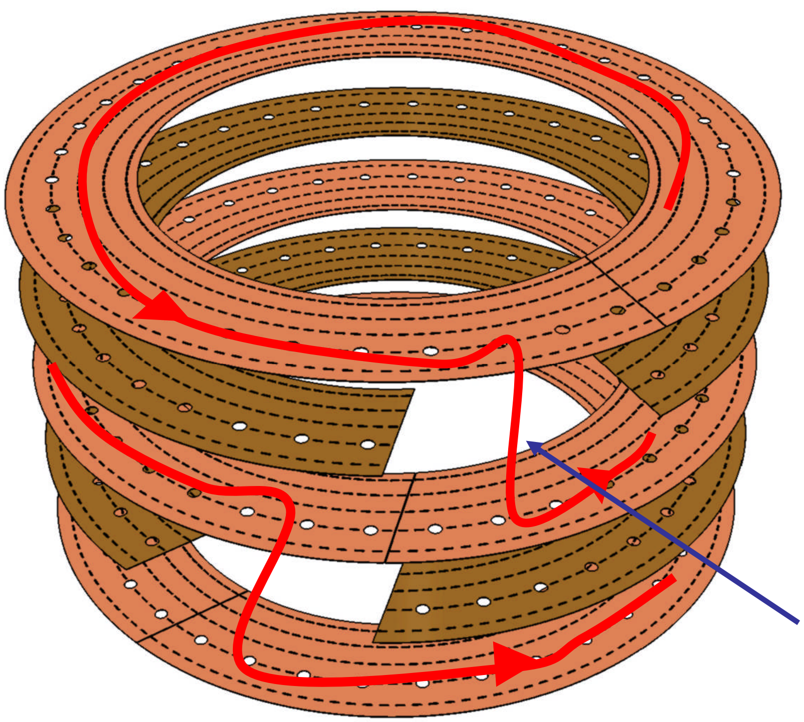
10 MW 25 T
Sept 2007

GHMFL

Magnet Technology

Bitter

Widely used in main high field labs



~ 1000 electric contacts under variable pressure with B

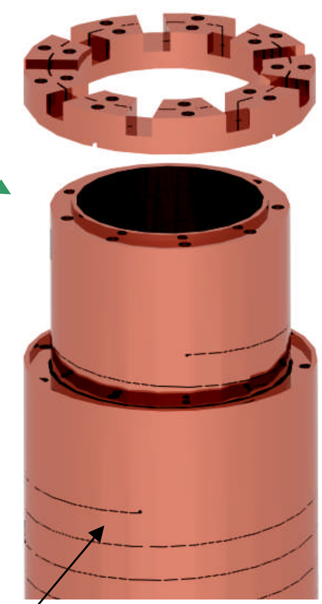
Helix

Longitudinally or Radially cooled

Developed at the GHMFL

~ 10 contacts independant of B

➔ Improved field stability

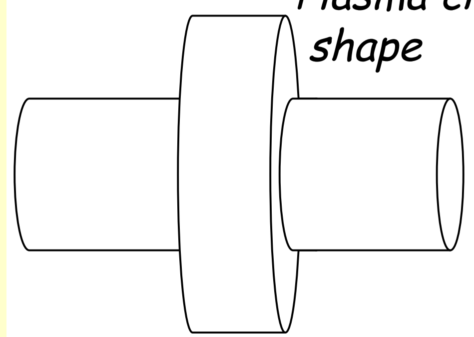


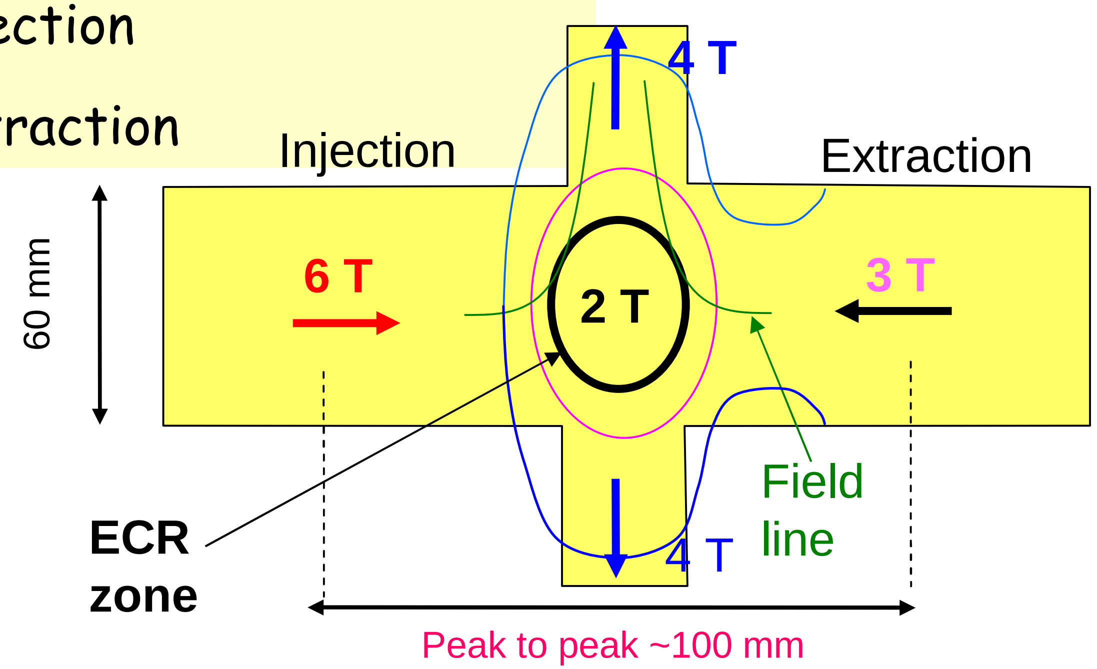
Electrical discharge machining

4. First 60 GHz Prototype - Specifications

- 60 GHz Magnetic CUSP specifications:
  - Compact source (~100 mm long)
  - 2,1 Tesla closed ECR surface
  - 4 Tesla radial confinement
  - 6 Tesla at injection
  - 3 Tesla at extraction

Plasma chamber shape





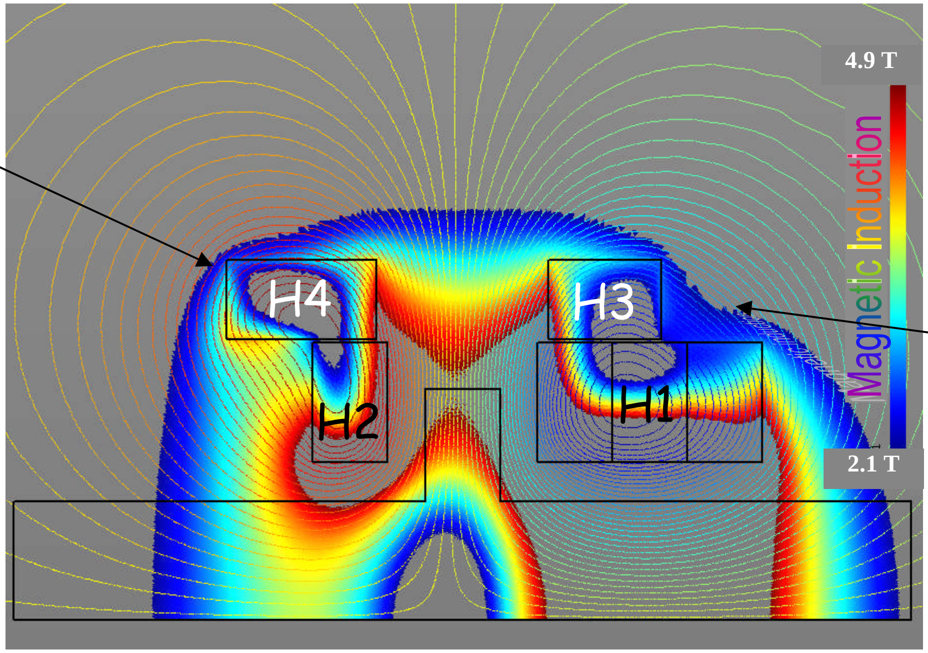
Vchamber~38 cl

Plasma Volume~ 20 cl

o 2D Simulation

- Fast RADIA* calculations to study coils geometry
- Getdp** to adapt coil geometry to Helix techology

Extraction coils H2+H4



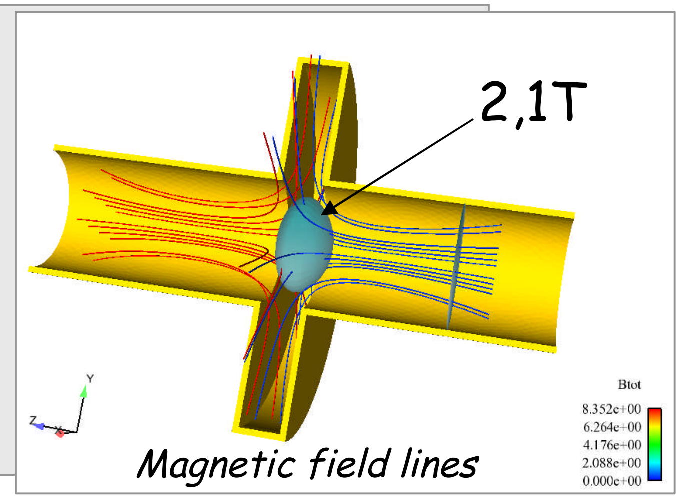
Injection coils H1+H3

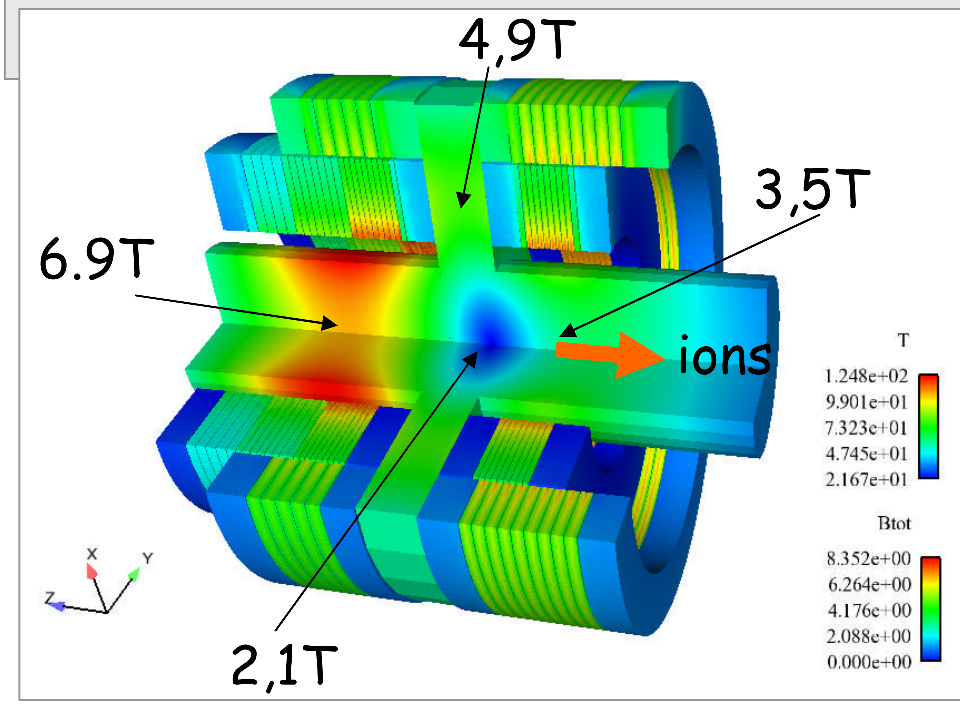
- Solution with 4 helices : H1,H2,H3,H4
- H1 has 3 helix spiral pitches

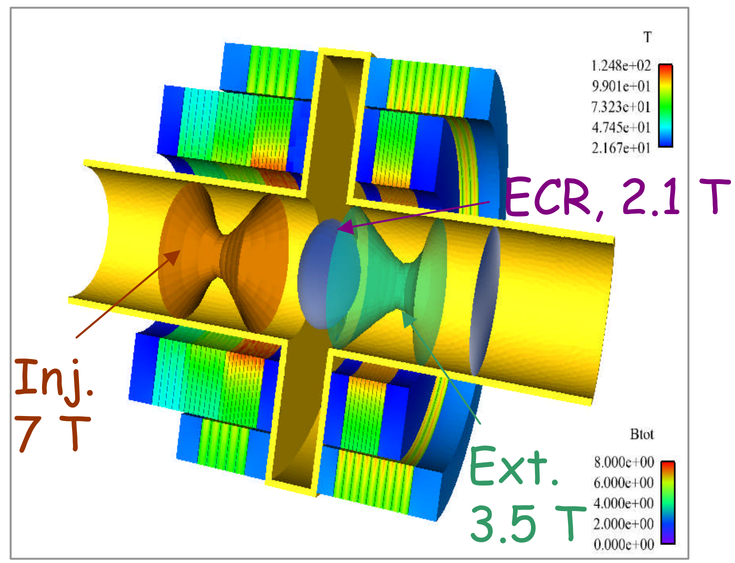
* Mathematica package (ESRF) ** Liege University

4. CUSP Magnetic Simulation

- 3D Simulation with Getdp
  - Exact geometry from CAD
  - Magnetic Field
  - Thermal study
  - Mecanical stress



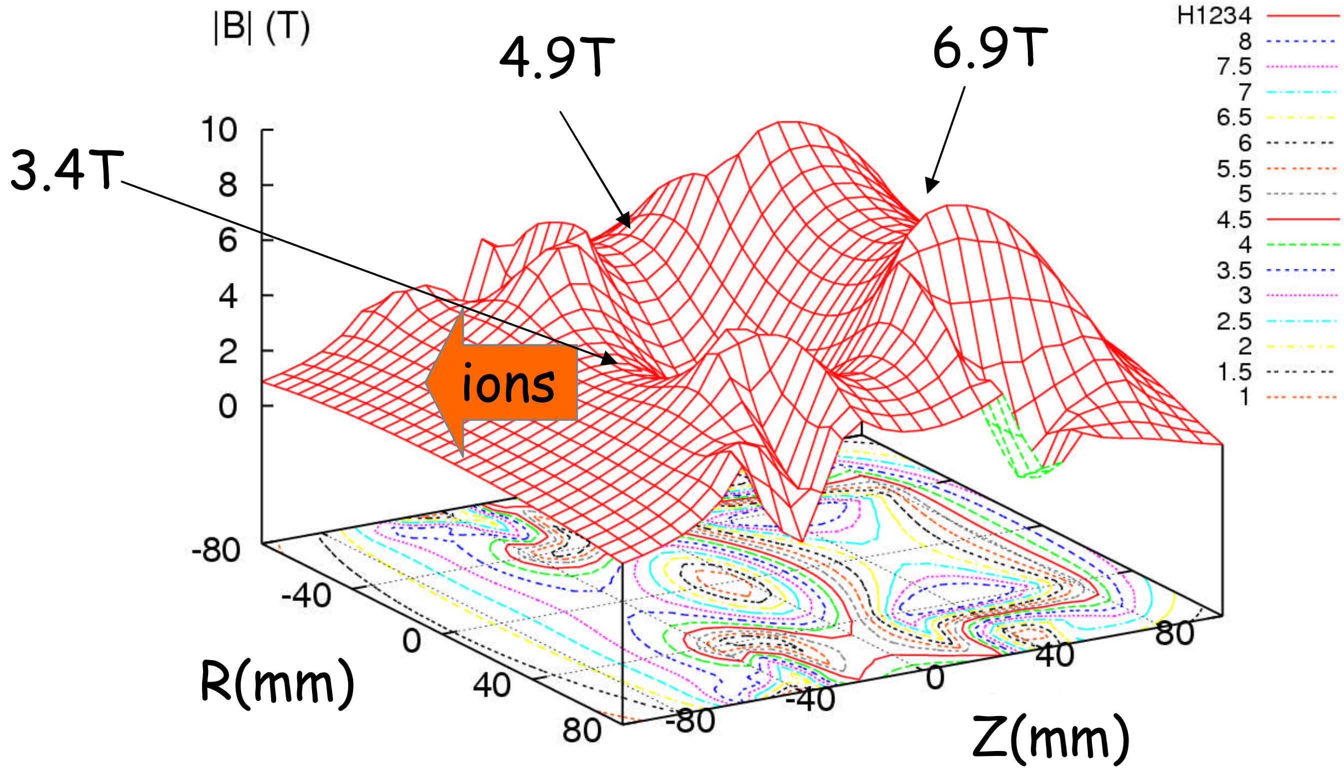


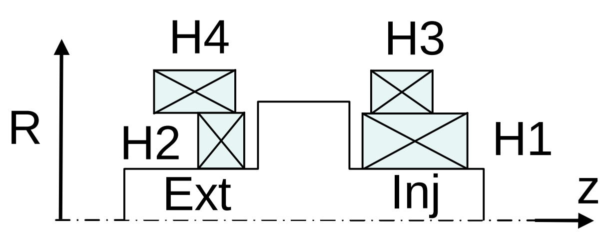


Magnetic Field Above expectation

4. First 60 GHz Prototype - 2D Magnetic Map

(R,Z) plane, |B| surface

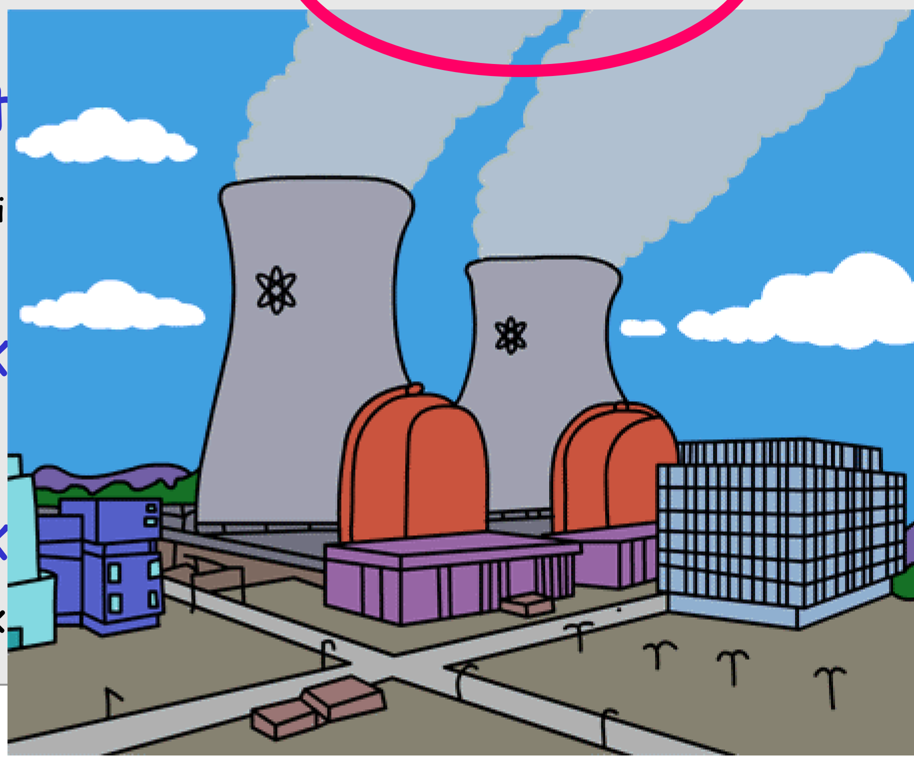




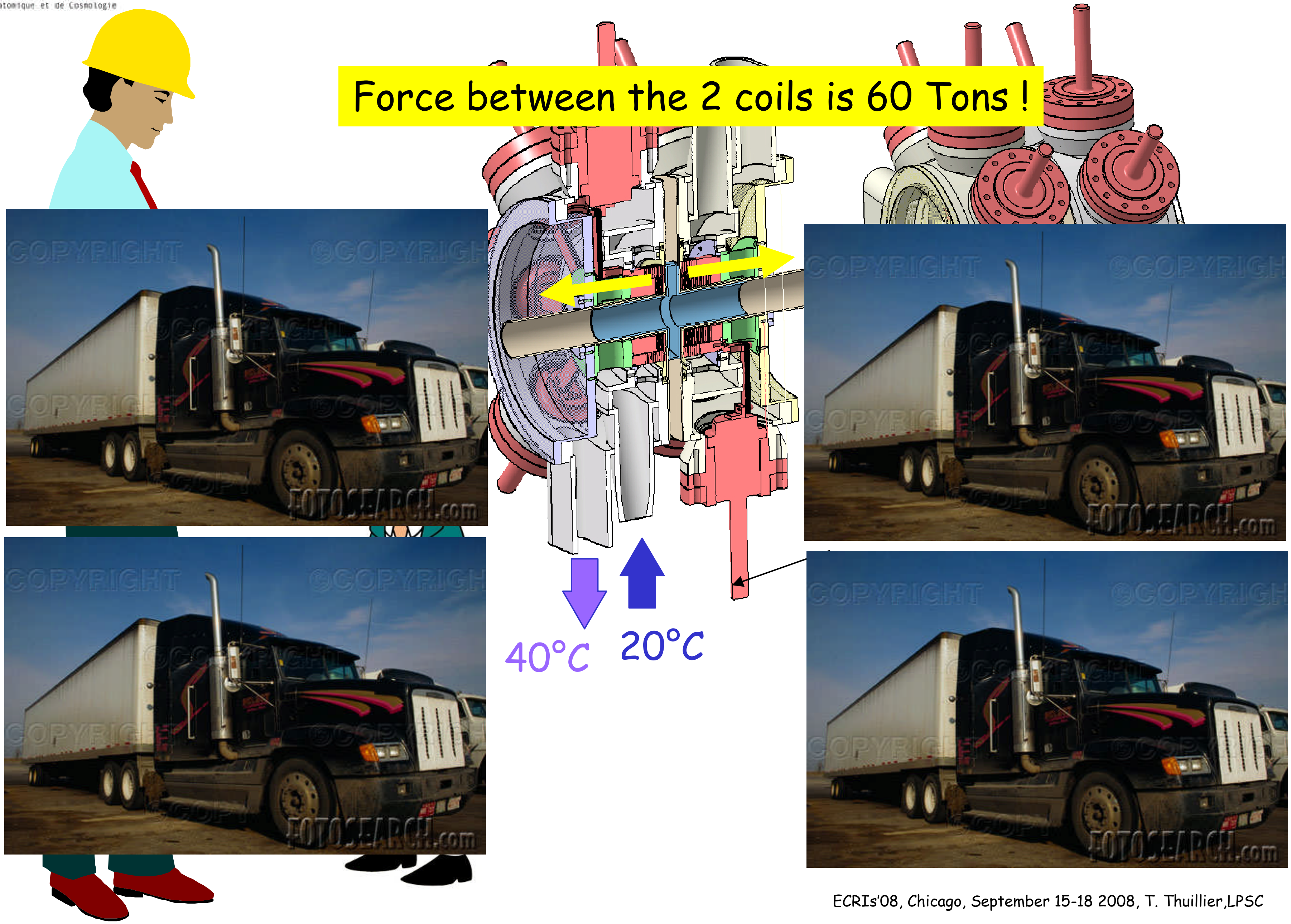
- 6,9 T injection
- 3,4 T ion extraction
- 4,9 T radial mirroir

4. CUSP – order of magnitudes

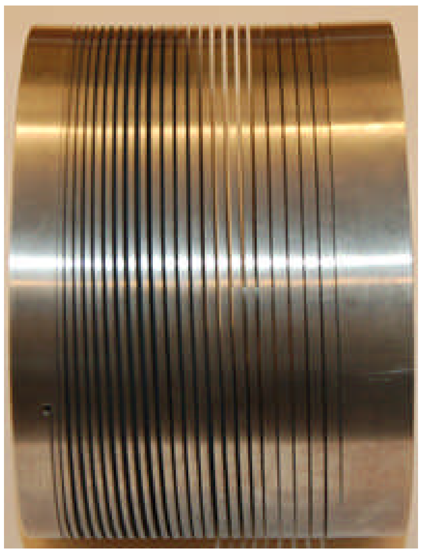
- Current : 30 kA
  - Max density in 2 mm pitch helix part : J~650 A/mm^2
- Electrical Power : P~ 5 MW
- Wat
  - P_i
- Max
- Max
  - <<



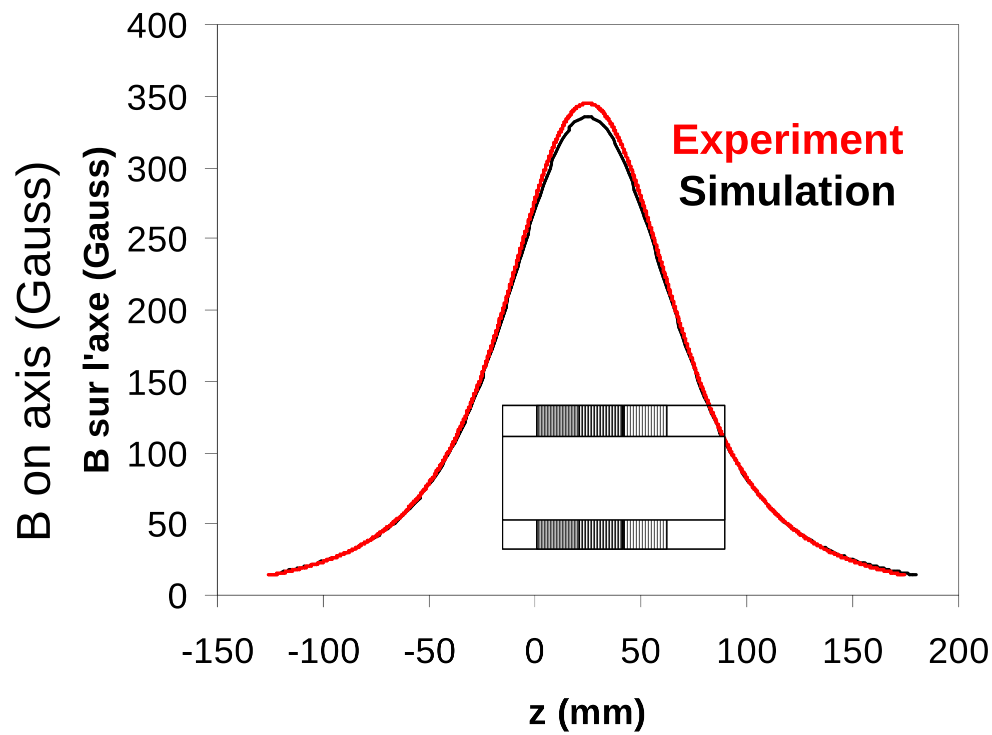
4. CAD Design



o Scale 1 Aluminum model of Coil H1



H1 Aluminum model



- Tested at 140 A (low current)
- Magnetic field measurement
- Comparison with simulation : dB/B~3%
- Magnetic structure validated : OK to build Copper Coils

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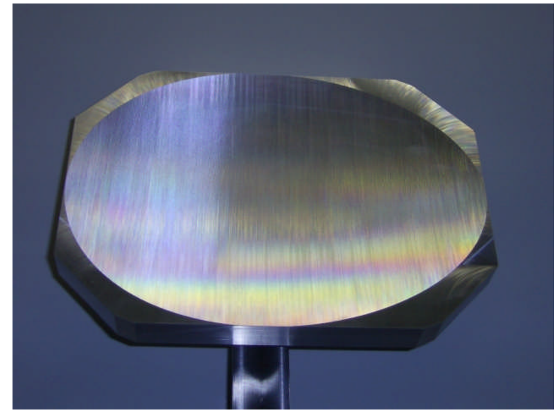
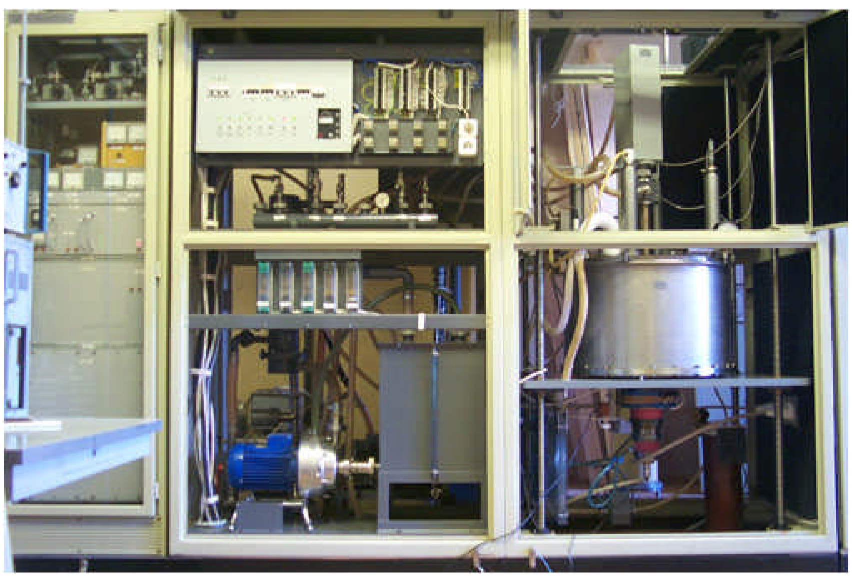
5. 60 GHz Gyrotron

- Order to be placed this year
- Technical specification :
  - **100 kW** / 50-10000 μs pulse / 25 Hz
- Collaboration with IAP under discussion
- Delivery expected end 2009



IAP Focusing Lens



Gycom Gyrotron frame

Gycom Gyrotron
53 GHz
100 kW

5. Planning

- CAD design under progress
  - Validation expected for 10/2008
- Mechanical parts machining
  - Expected for 12/2008
- Magnetic Structure Assembly for 01/2009
  - Deliverable of Eurisol beta beam contract, task 9