Design of thin high field magnets for polarised solid targets

1.- Thin High Field Superconducting Coils

2.- (Thin Polarized Solid Targets)

Polarization in PANDA
17. March 2008
Ferrara, Italy
Andreas Thomas
A2- and CBall@MAMI- Collaborations

Bonn Polarized Solid Target

[C.Bradtke et al., NIM **A436**, 430 (1999)]

„Frozen Spin Mode“

- Polarization : DNP at high B-Field (2.5 T)
- Measurement : very low T ($\leq 50\,mK$)

´freeze´ up the spin (>0.4 Tesla)

relaxation time $T \approx 200\,h$

New Technology: horizontal cryostat with integrated solenoid (holding field)

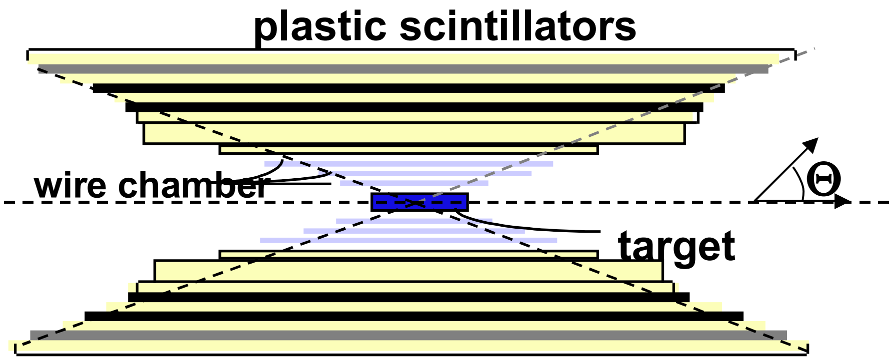
1.2 Kelvin

0.42 Tesla

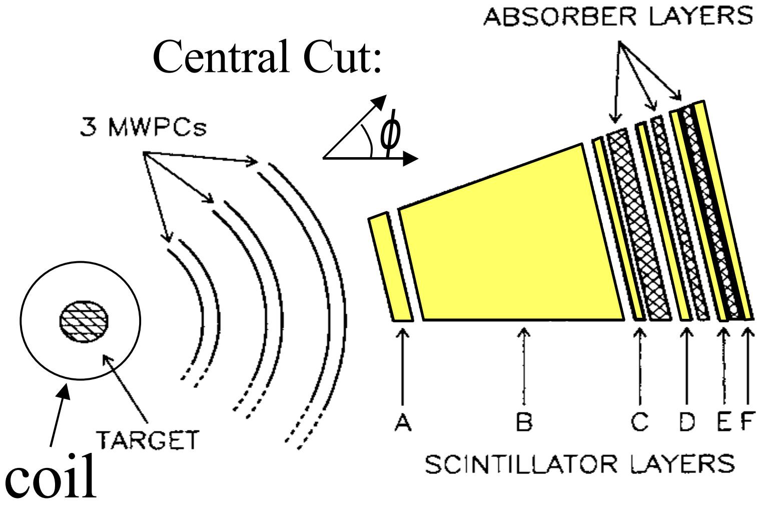
equiv. 780µm Cu (100µm NbTi)

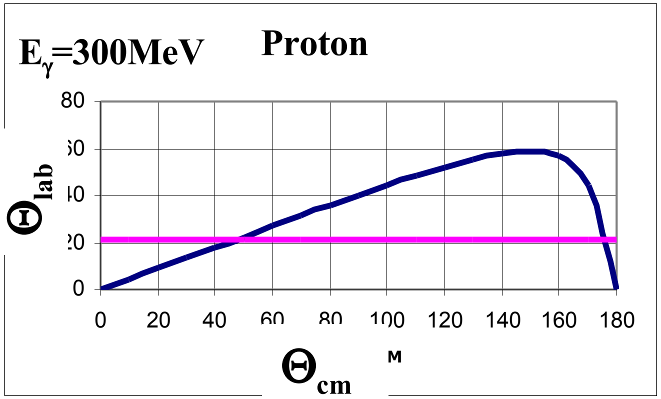
4π detector → sec. particles punch through coil

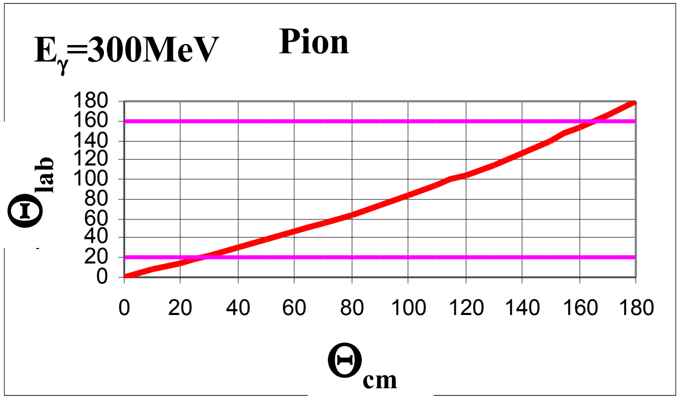
DAPHNE Sideview Cut:



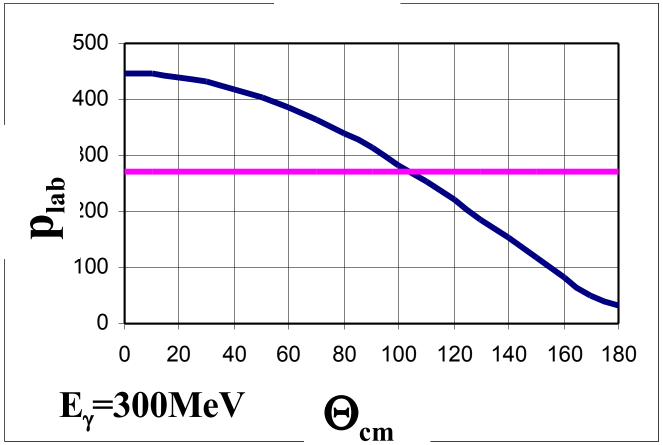
Central Cut:

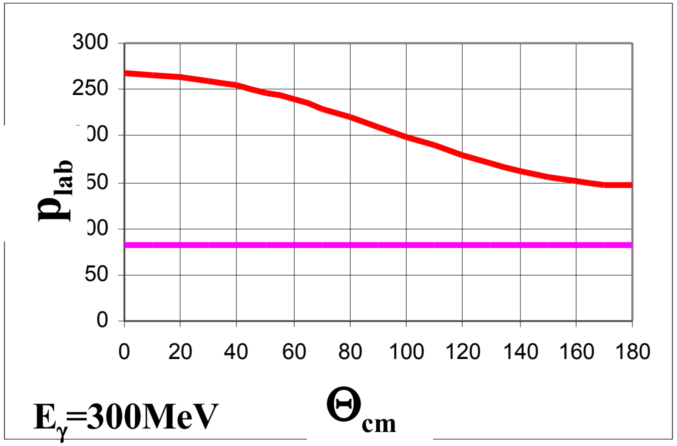






$$21^0<\theta<159^0$$
$$0^0\leq\phi\leq 2\pi$$
$$D\,\Omega=0.94*4p$$





$$273\frac{MeV}{c}\leq p_p$$
$$81\frac{MeV}{c}\leq p_\pi$$

! Thin holding coil important!

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Nuclear Instruments and Methods in Physics Research A 356 (1995) 111–115

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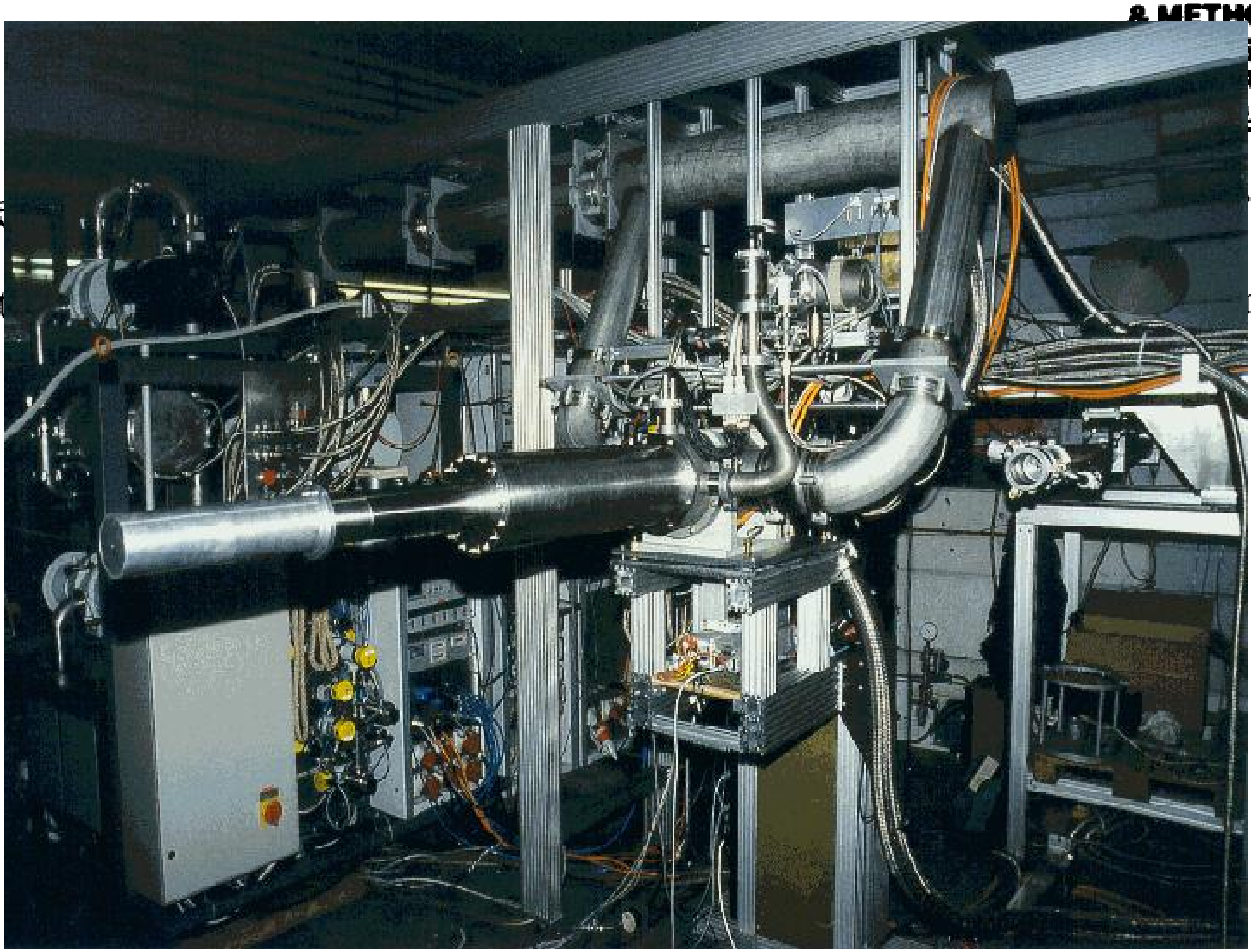
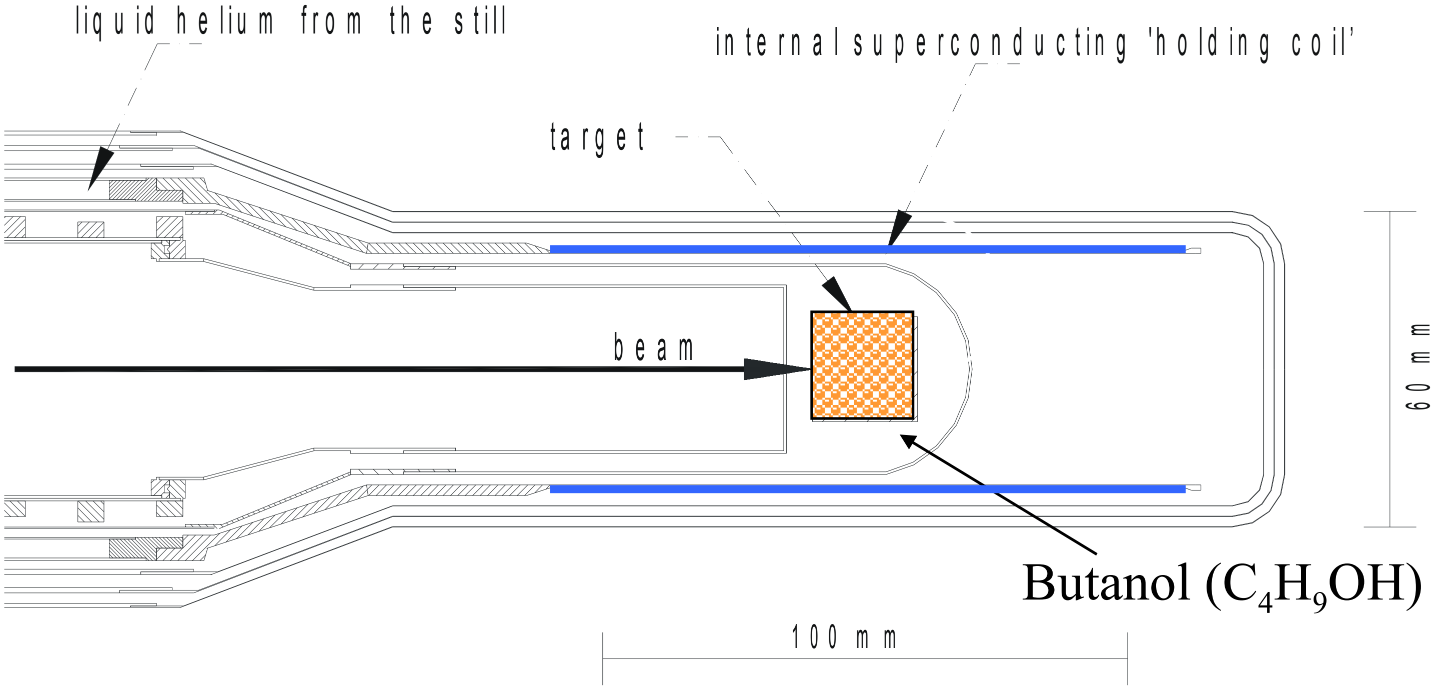
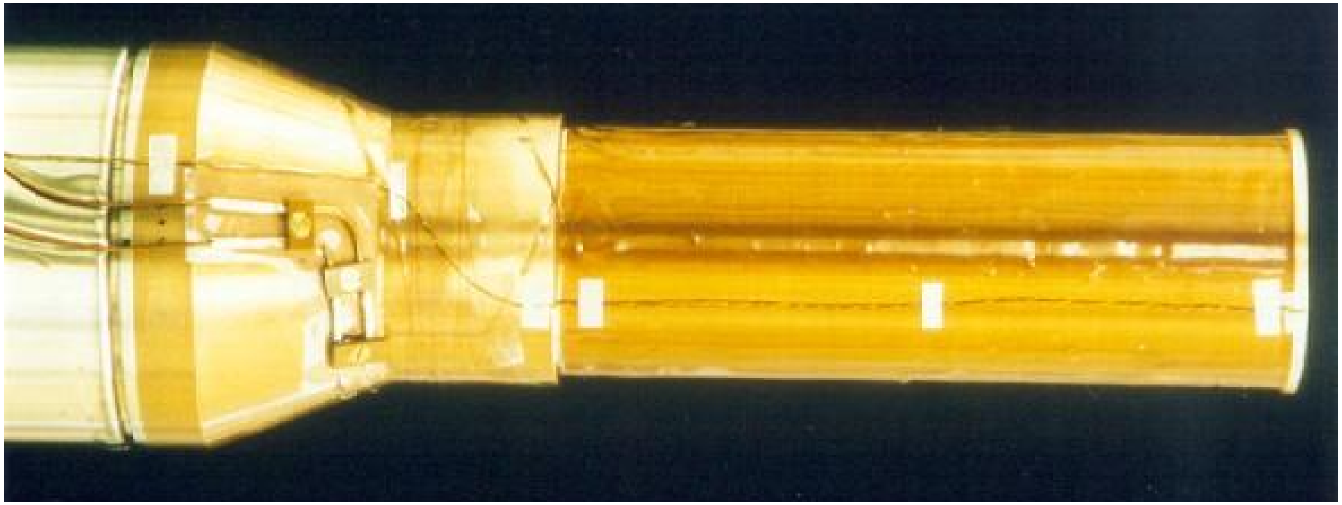


Bonn Frozen Spin Target at A2 / MAMI

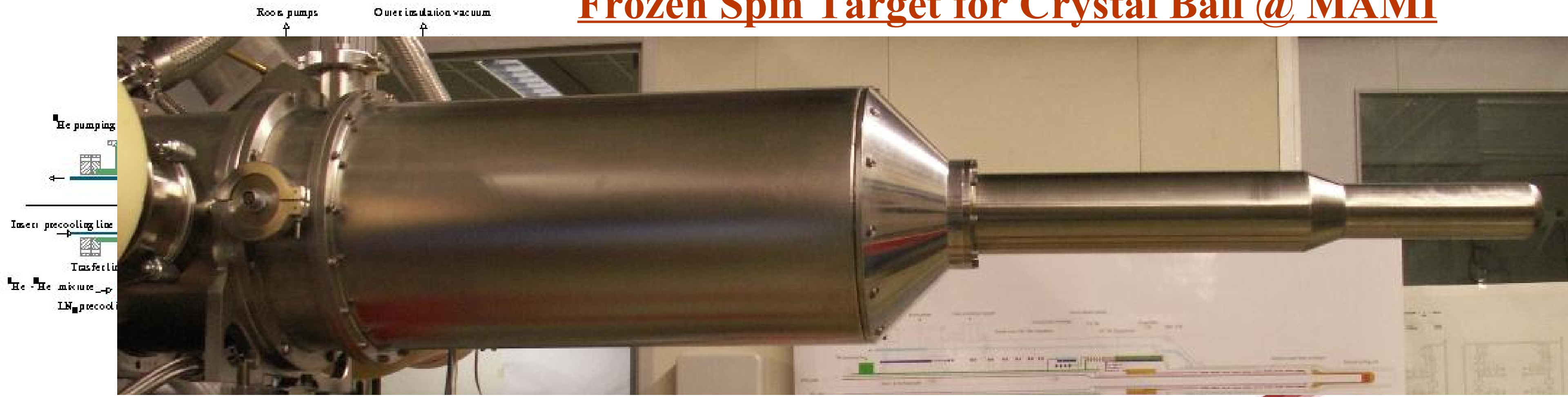
[H.Dutz et al., NIM **A356** (1995)111]


liquid helium from the still
internal superconducting 'holding coil'
target
beam
60 mm
Butanol (C_4H_9OH)
100 mm



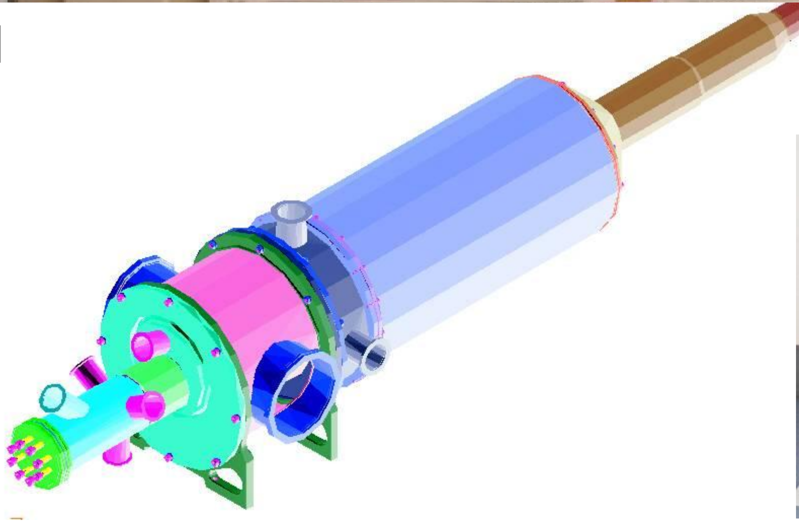
B =0.6T

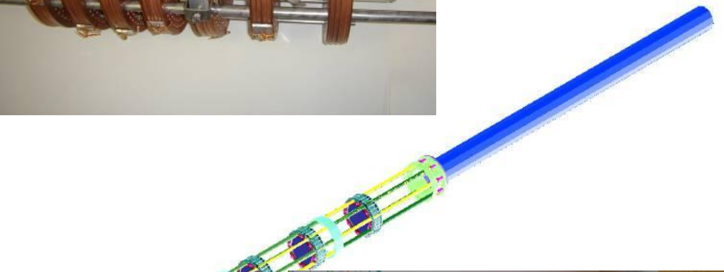
Frozen Spin Target for Crystal Ball @ MAMI

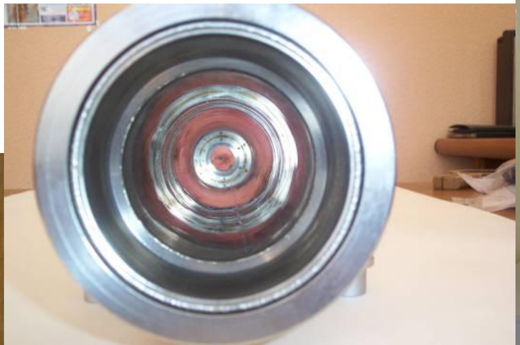


^{3}He/^{4}Helium Dilution cryostat [JINR Dubna] with ^{4}Helium-evaporator as precooler:

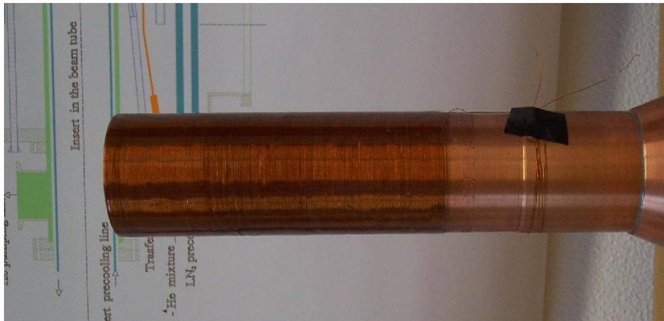
T<30mK; P_p=90%; P_d=70%.







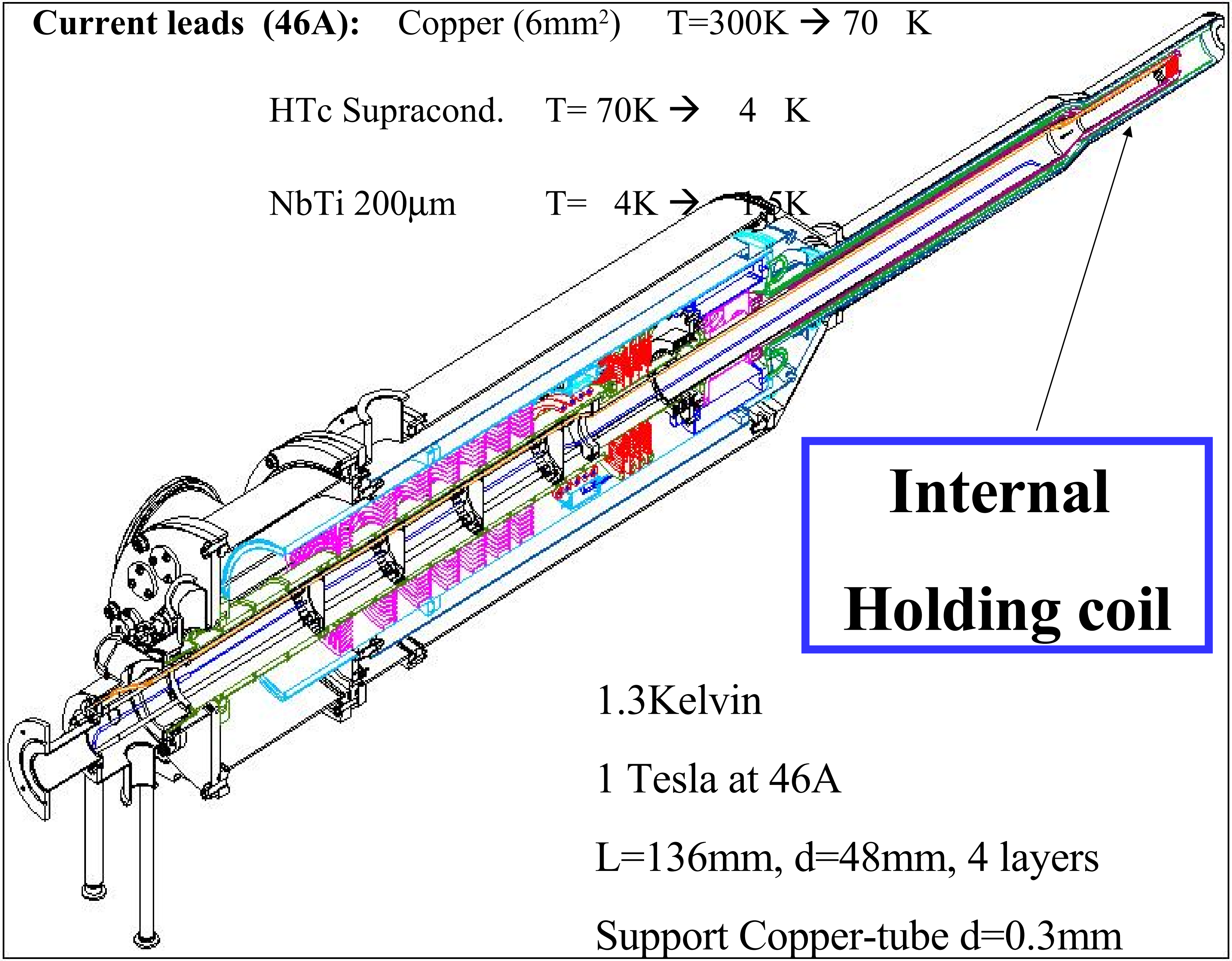
Coil production in the Mechanics workshop



Current leads (46A): Copper ($6 mm^2$) T=300K → 70 K

HTc Supracond. T= 70K → 4 K

NbTi 200µm T= 4K → 1.5K



Internal
Holding coil

1.3Kelvin

1 Tesla at 46A

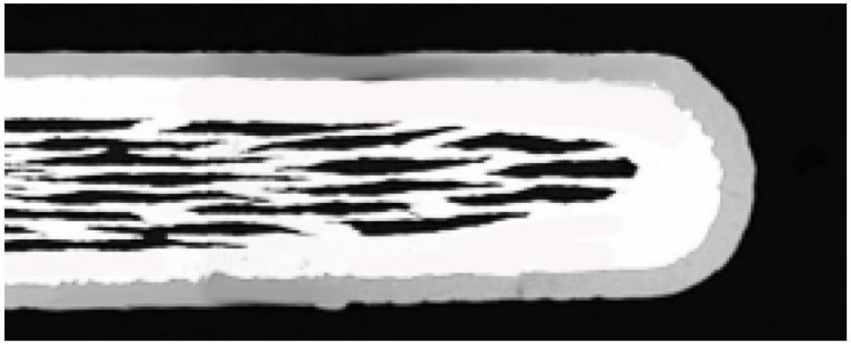
L=136mm, d=48mm, 4 layers

Support Copper-tube d=0.3mm

HTc Supraconductor
T= 70K → 4 K

SPECIFICATIONS FOR TT-GOLD HTS WIRES:

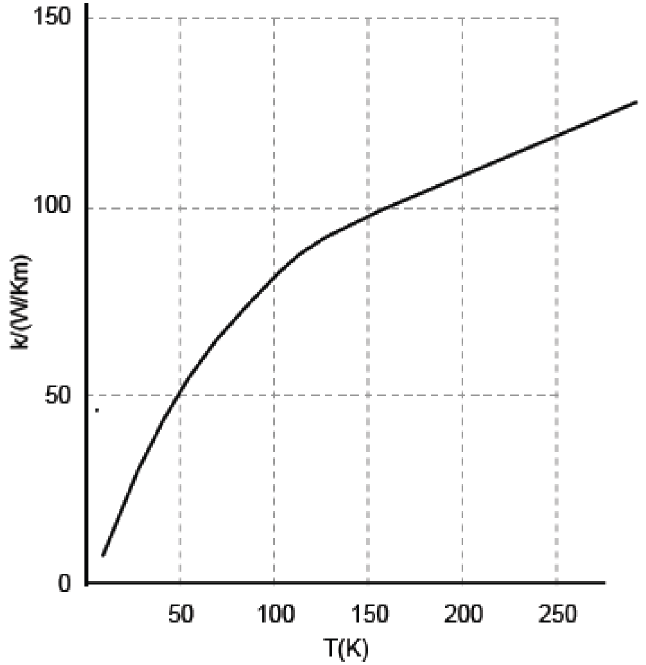
Material TT-gold	Material of superconducting filaments	BSCCO ceramic
	Material of inner matrix	AgAu
	Material of outer sheath	Reinforced AgAu alloy
Superconducting Properties	Critical current	40 A, 50 A, 60 A, 70 A (1µV/cm criterion, 77K, in selffield)
Dimensions	Width	4.0 mm
	Thickness	0.25 mm
Thermal Parameters	Fill Factor	34% argentometric
	Gold Content	4.6% by weight
Certifications to be provided (bare HTS wire)	Protocol of critical current over the length (resistive measurements for the total lenght, in increments of about 1 m) and the n-value	Protocol of width and thickness over the lenght for the bare conductor



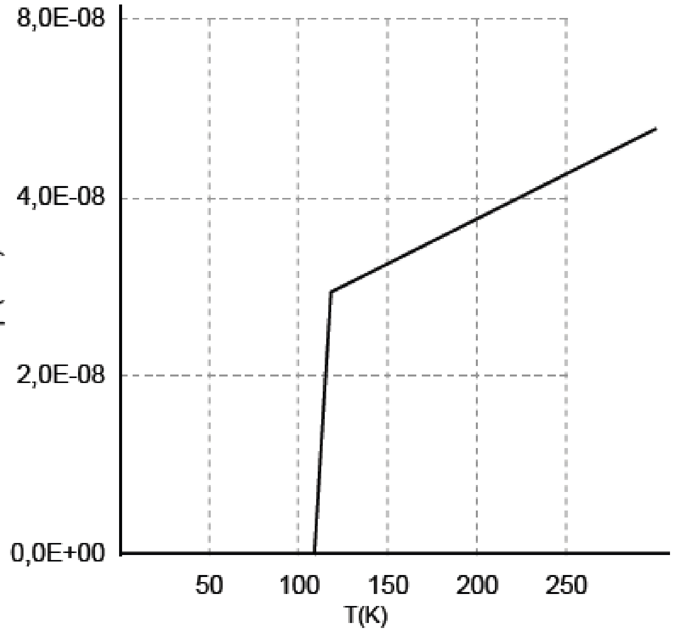
http://www.trithor.de

IEEE TRANSACTIONS ON APPLIED SUPERCONDUCTIVITY 15 (2): 2522-2525 Part 3, JUN 2005

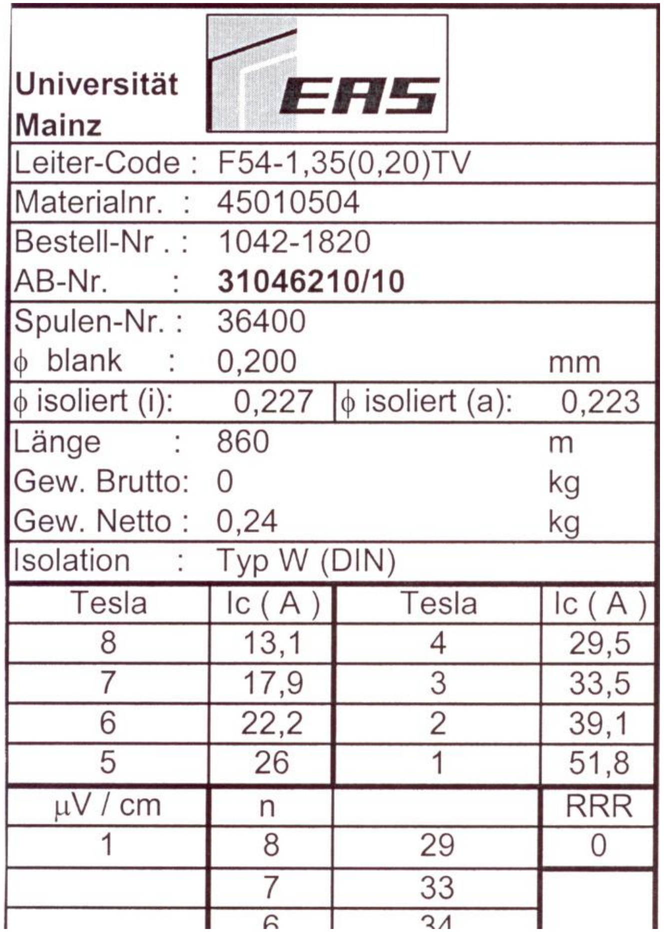
Thermal Conductivity of TT-Gold Current Leads Wire



Electrical Resistivity of TT-Gold Current Leads Wire



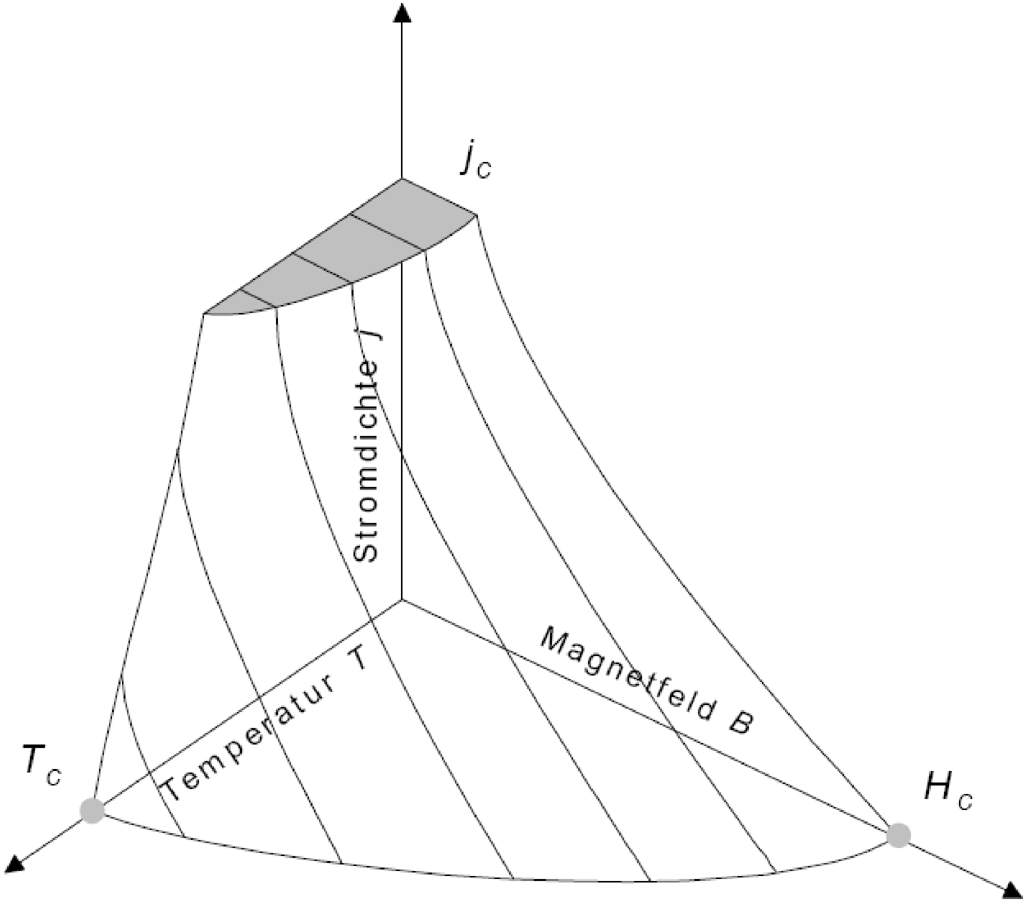
NbTi 200µm
(T=1.2*K*)



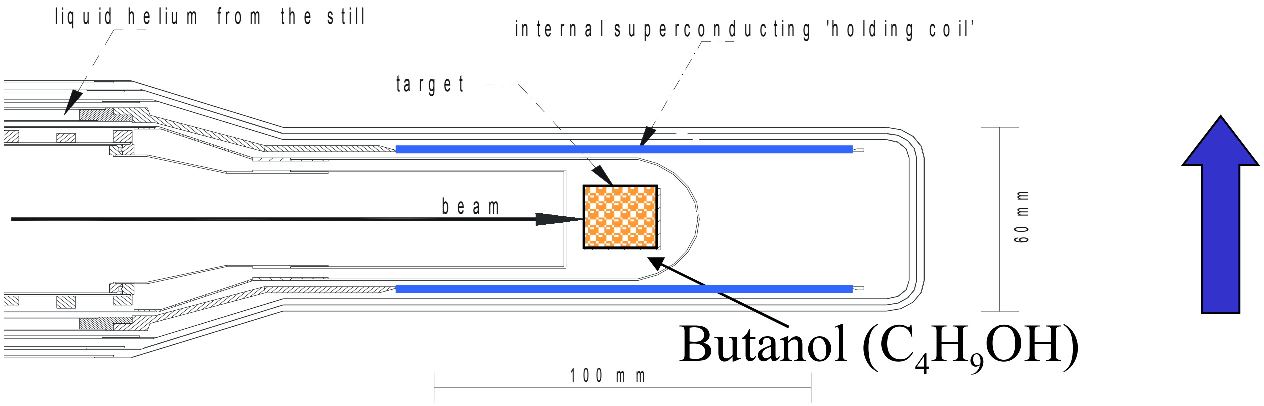
Universität
Mainz

Leiter-Code :	F54-1,35(0,20)TV		
Materialnr. :	45010504		
Bestell-Nr . :	1042-1820		
AB-Nr. :	**31046210/10**		
Spulen-Nr. :	36400		
ϕ blank :	0,200		mm
ϕ isoliert (i): 0,227		ϕ isoliert (a):	0,223
Länge :	860		m
Gew. Brutto:	0		kg
Gew. Netto :	0,24		kg
Isolation :	Typ W (DIN)		

Tesla	Ic (A)	Tesla	Ic (A)
8	13,1	4	29,5
7	17,9	3	33,5
6	22,2	2	39,1
5	26	1	51,8
µV / cm	n		RRR
1	8	29	0
	7	33	
	6	34	



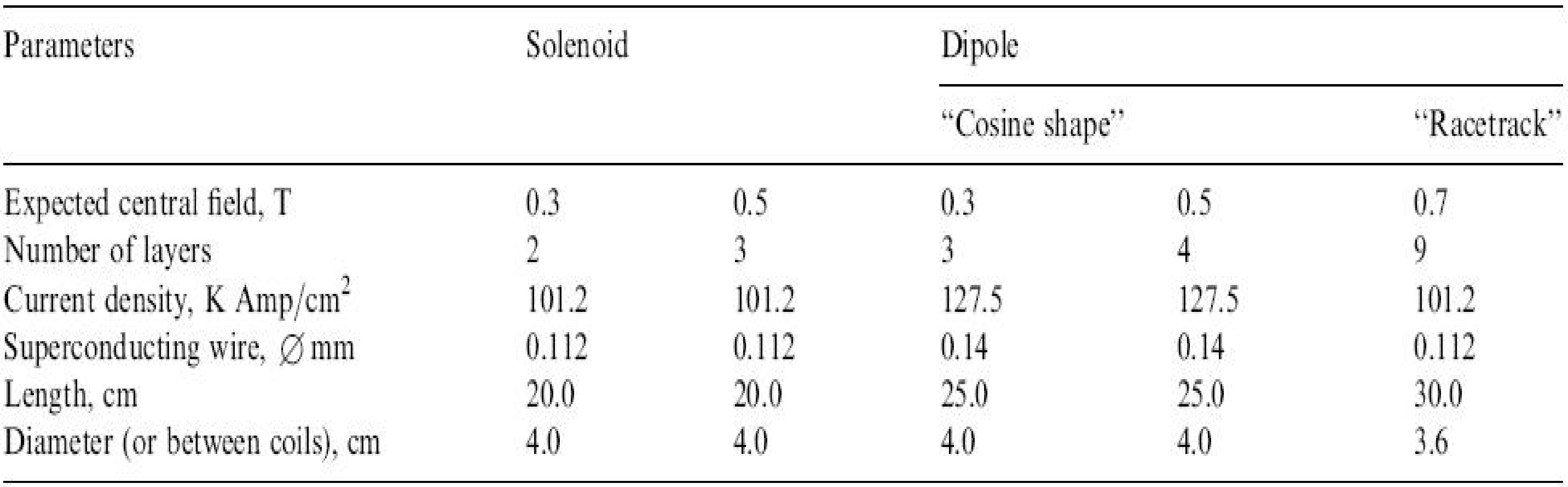
Technical Realisation of a Transverse Magnet in a longitudinal target



B = 0.5T

[E.Dzyubak et al., NIM A 526 (2004) 132-137, OPERA3D calculations]

Table 1
Models of holding magnet system



Parameters	Solenoid		Dipole		
			"Cosine shape"		"Racetrack"
Expected central field, T	0.3	0.5	0.3	0.5	0.7
Number of layers	2	3	3	4	9
Current density, K Amp/cm^2	101.2	101.2	127.5	127.5	101.2
Superconducting wire, ∅ mm	0.112	0.112	0.14	0.14	0.112
Length, cm	20.0	20.0	25.0	25.0	30.0
Diameter (or between coils), cm	4.0	4.0	4.0	4.0	3.6

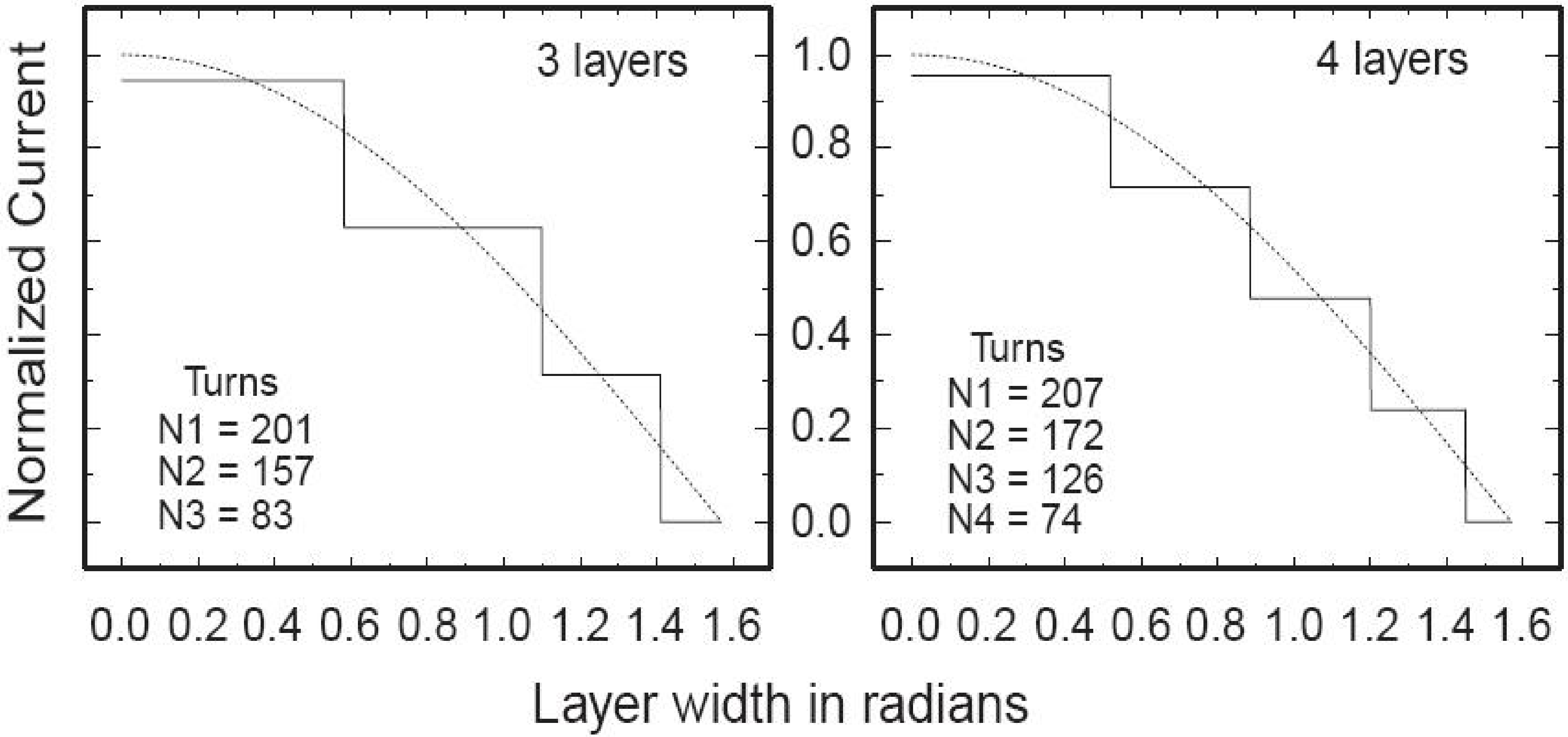


Fig. 1. Cosine shape dipoles.

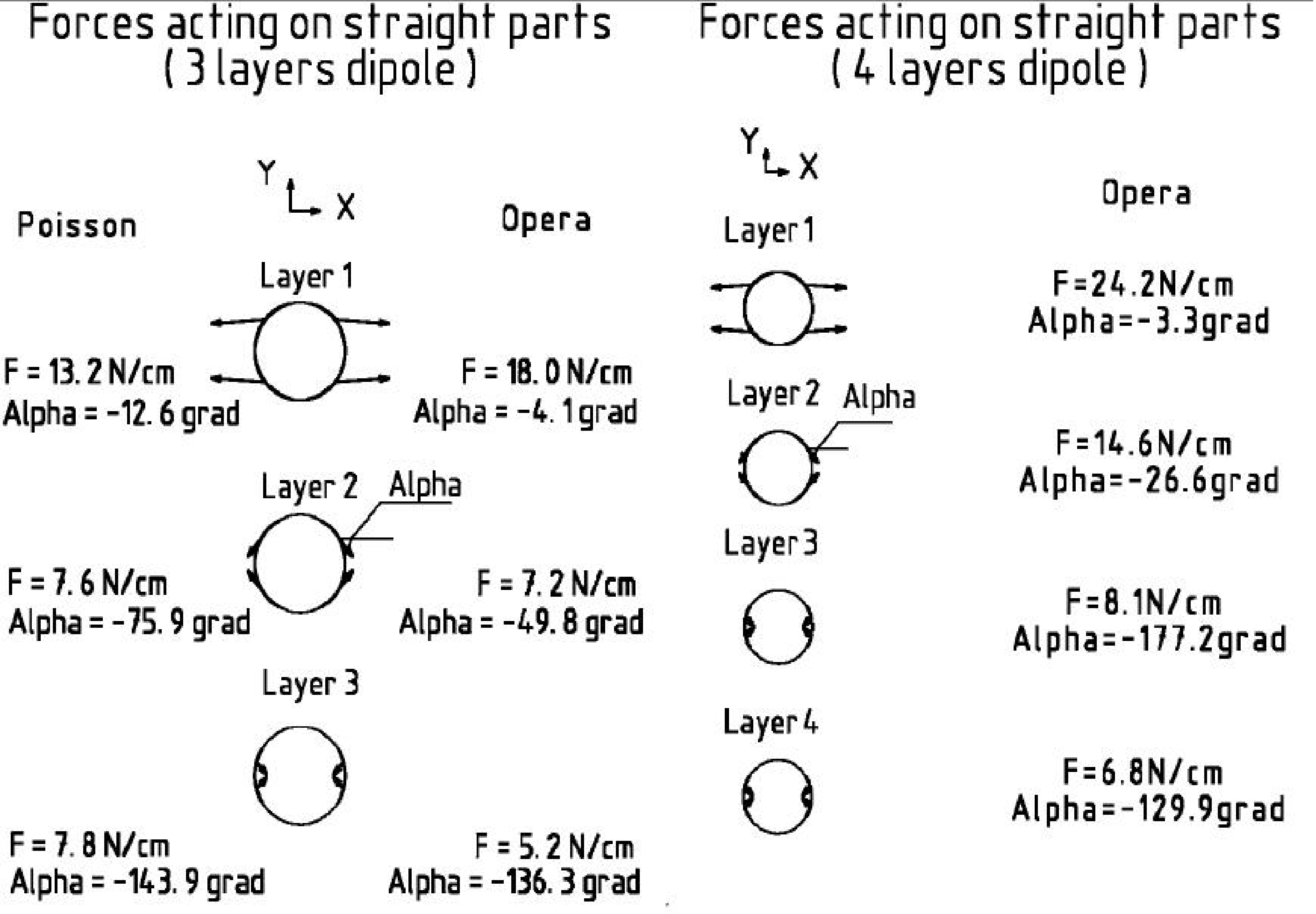
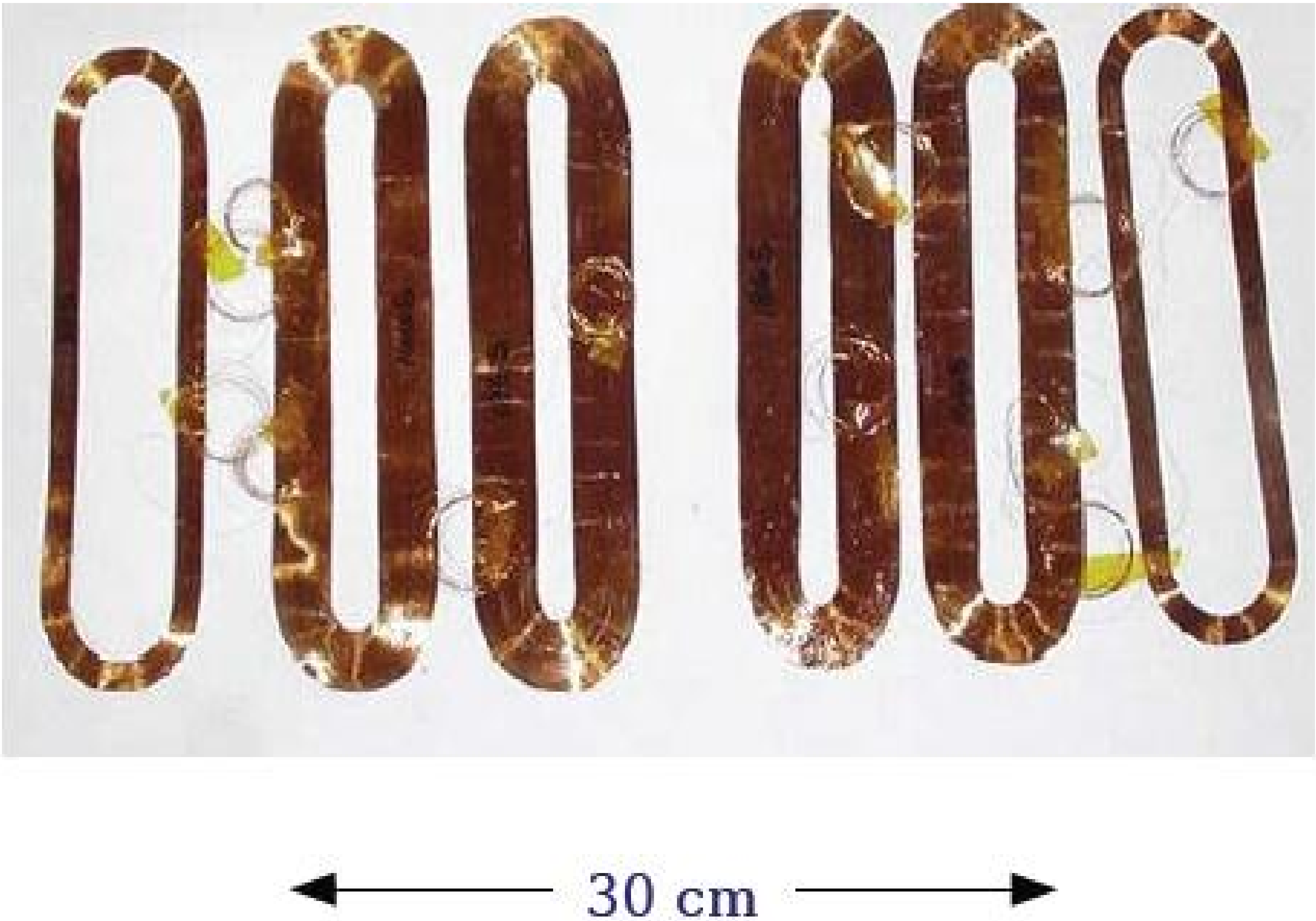
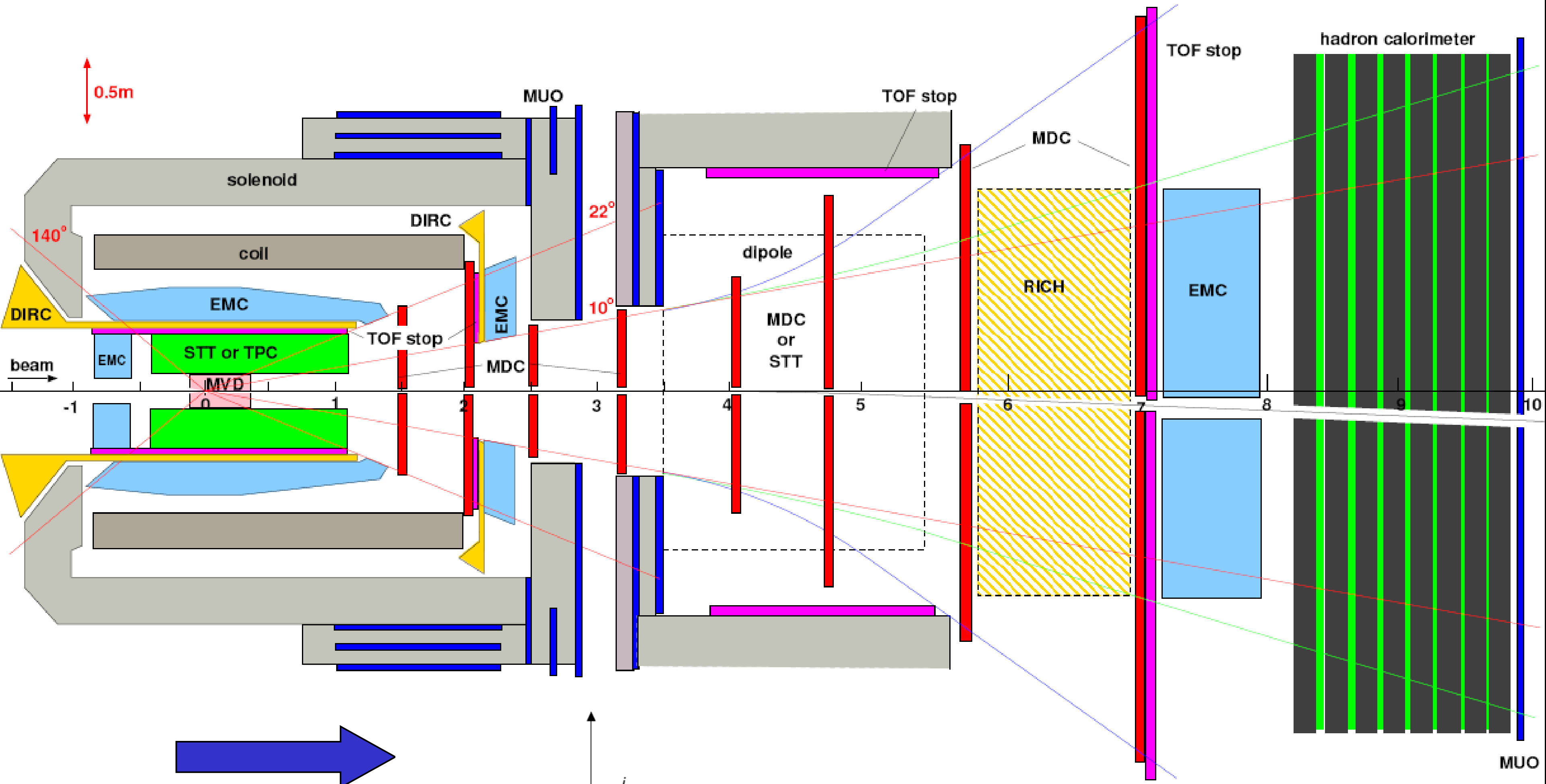


Fig. 5. Dipole forces at the center.

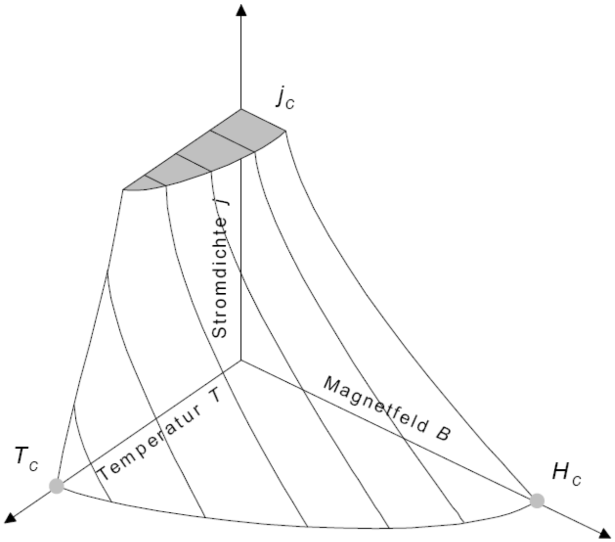
[talk Ch. Keith EU-Workshop Rech 2005]

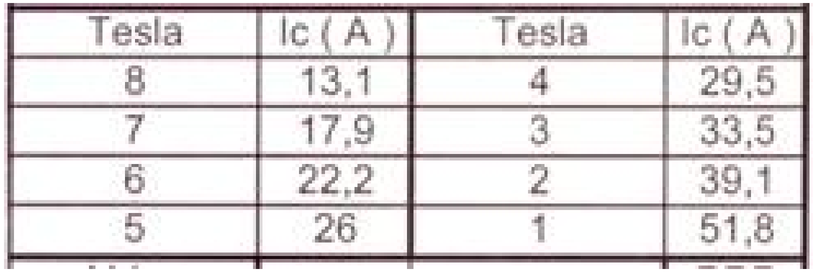


Epoxy Impregnated, Elasticity → Vibration → Quench?



B=2T





Tesla	Ic (A)	Tesla	Ic (A)
8	13,1	4	29,5
7	17,9	3	33,5
6	22,2	2	39,1
5	26	1	51,8

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Nuclear Instruments and Methods in Physics Research A 418 (1998) 233–240

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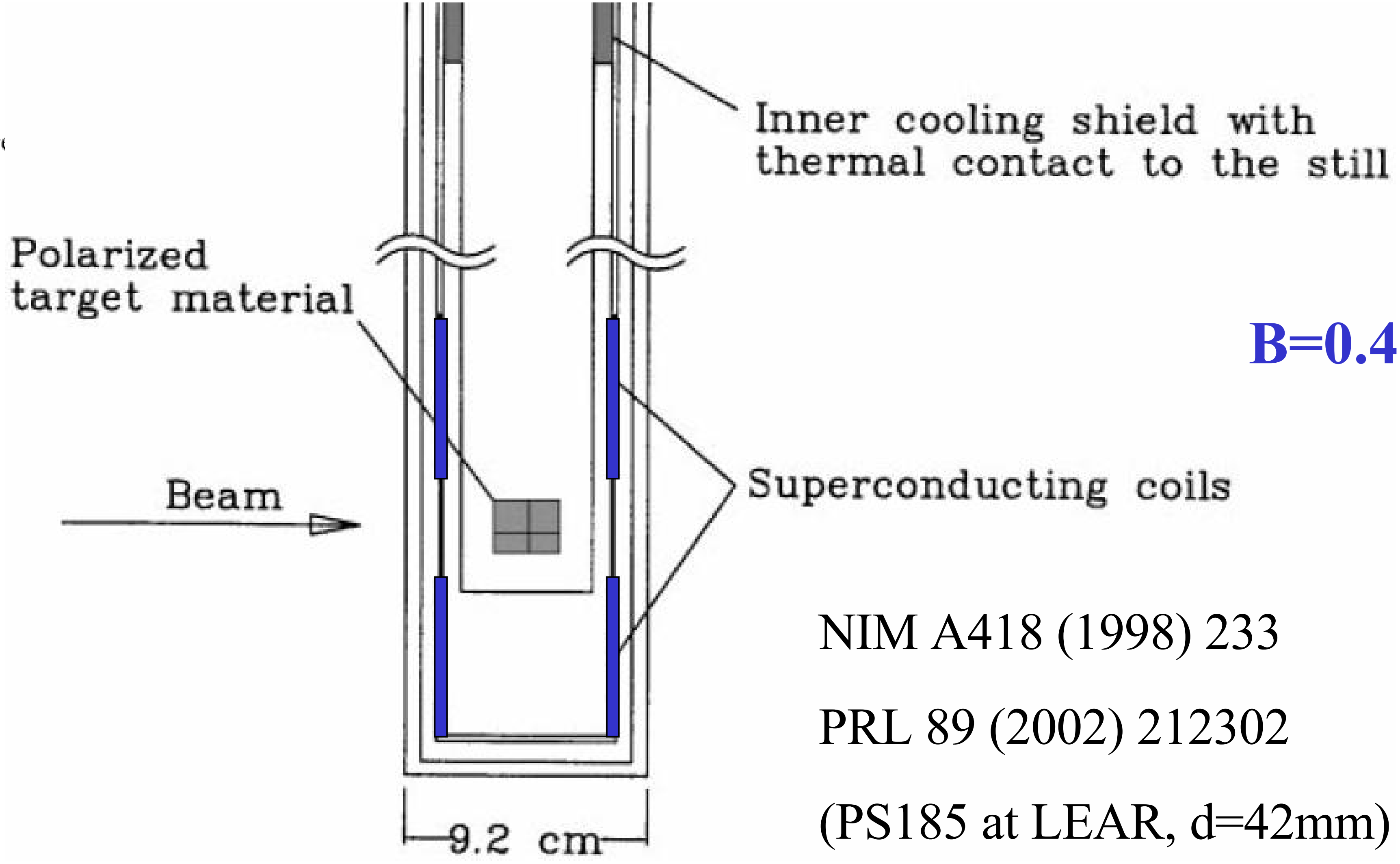
RESEARCH
Section A

R. G

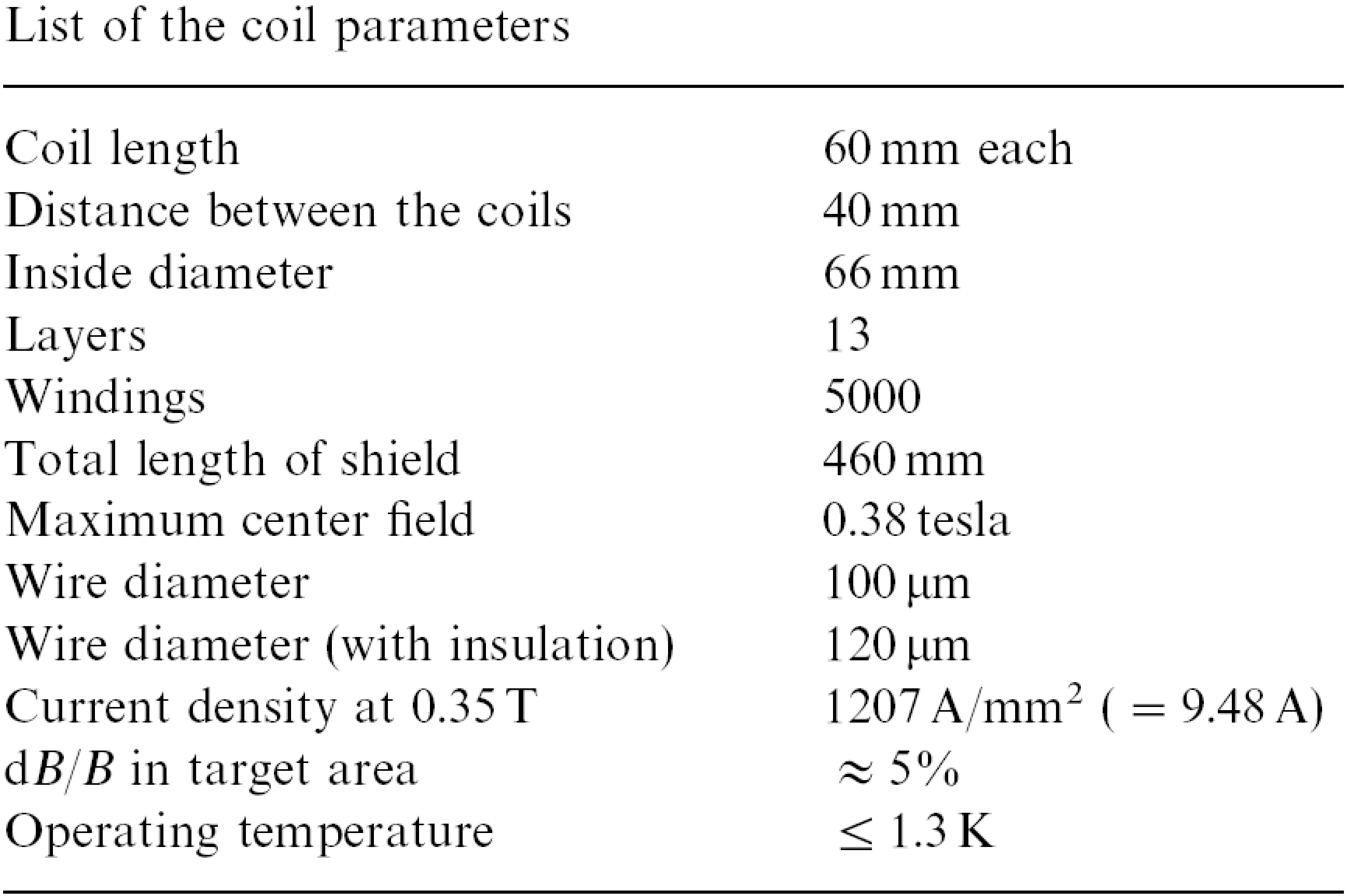


B=0.4T

NIM A418 (1998) 233

PRL 89 (2002) 212302

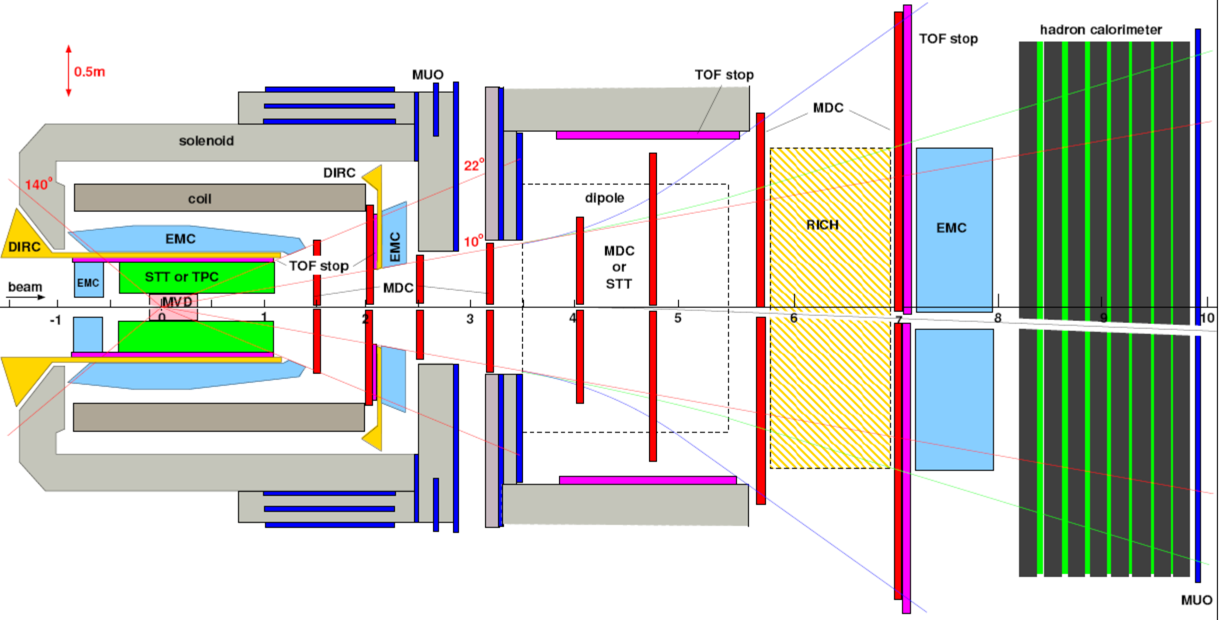
(PS185 at LEAR, d=42mm)



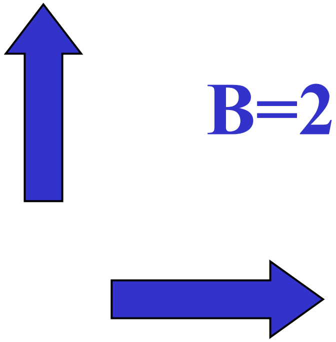
List of the coil parameters

Coil length	60 mm each
Distance between the coils	40 mm
Inside diameter	66 mm
Layers	13
Windings	5000
Total length of shield	460 mm
Maximum center field	0.38 tesla
Wire diameter	100 μm
Wire diameter (with insulation)	120 μm
Current density at 0.35 T	1207 A/mm^2 (= 9.48 A)
dB/B in target area	$\approx$ 5%
Operating temperature	$\leq$ 1.3 K

Copper support wall thickness 1mm, reduced in central region to 300μm. Hole for the primary beam.



e.g. superposition:



B=2T

B=2T

Problem: Mechanics

Dipole Moment

m=nIA=1700Nm/T

Bending Moment

$\vec{M} = \vec{m} \times \vec{B} = 3400$ Nm

d = 66mm

A = 3400mm^2

I = 50A

n = 10000

Add reverse Coils???

B=2T

Estimate: Mechanics

Dipole Moment m=nIA=1700Nm/T

Bending Moment

$$\vec{M} = \vec{m} \times \vec{B} = 3400 \text{ Nm}$$

Widerstandsmoment

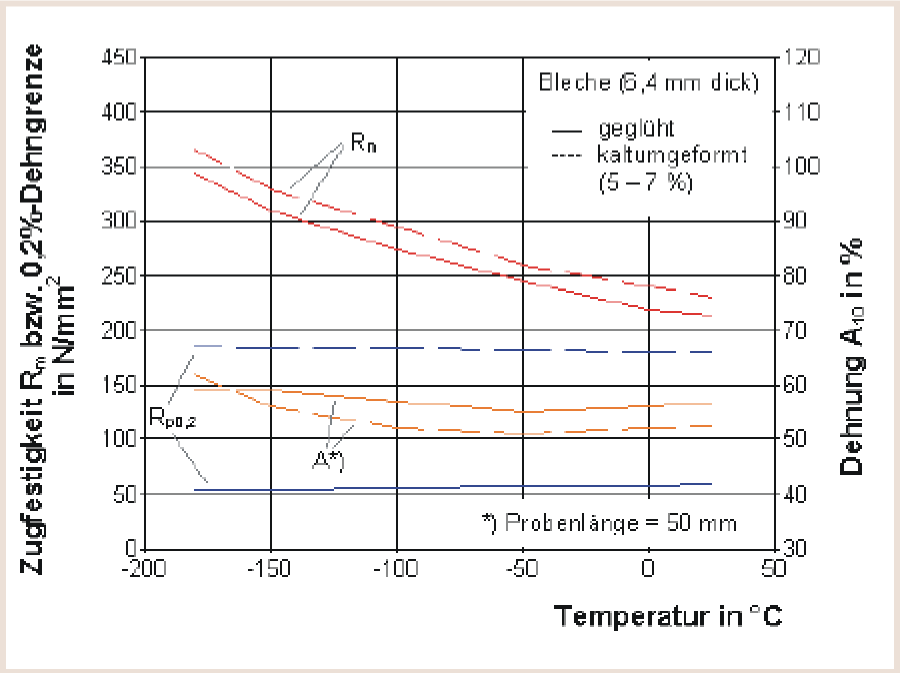
$$W = \pi d^2 s / 4 \quad \text{(thin wall s)}$$

Bending Stress

$$\sigma_{max} = M / W = n I B / s = 10^3 / s[mm]$$

s ~ 5mm

4.2.1 Festigkeitswerte



FEM design of mechanical, thermal and magnetic properties
+ GEANT necessary

Thin Scintillating Polarized Targets for Spin Physics

B. van den Brandt [1], E.I. Bunyatova‡, P. Hautle and J.A. Konter

Paul Scherrer Institute, CH-5232 Villigen PSI, Switzerland
‡Joint Institute for Nuclear Research, Dubna, Head P.O. Box 79, 10100 Moscow, Russia

Abstract. At PSI polarized scintillating targets are available since 1996. Proton polarizations of more than 80%, and deuteron polarizations of 25% in polystyrene-based scintillators can be reached under optimum conditions in a vertical dilution refrigerator with optical access, suited for nuclear and particle physics experiments. New preparation procedures allow to provide very thin polarizable scintillating targets and widen the spectrum of conceivable experiments.

PMMA $(C_5O_2H_8)_n$

Plexi glass

$\rho=1.19 g/cm^3$

D=20-100µm ($\sim 10^{19} cm^{-2}$)

f=8%

Cooled by 12µm He-film

NIM A381 (1996) 219

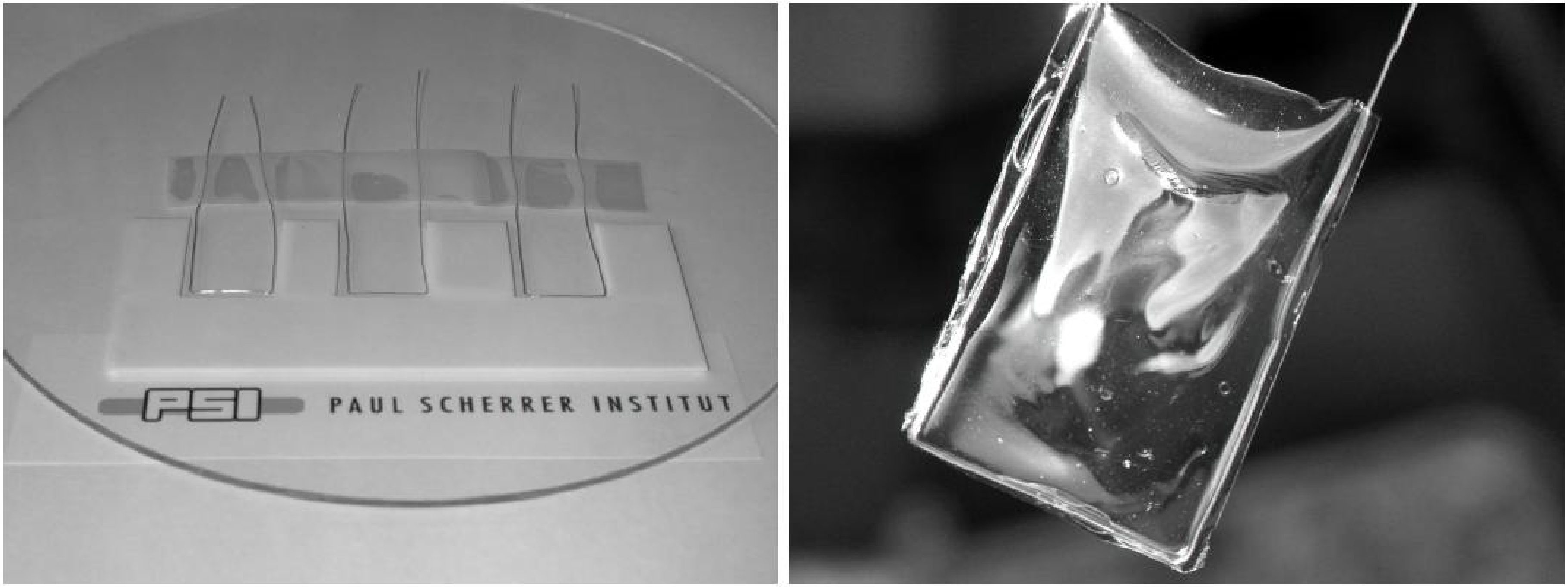
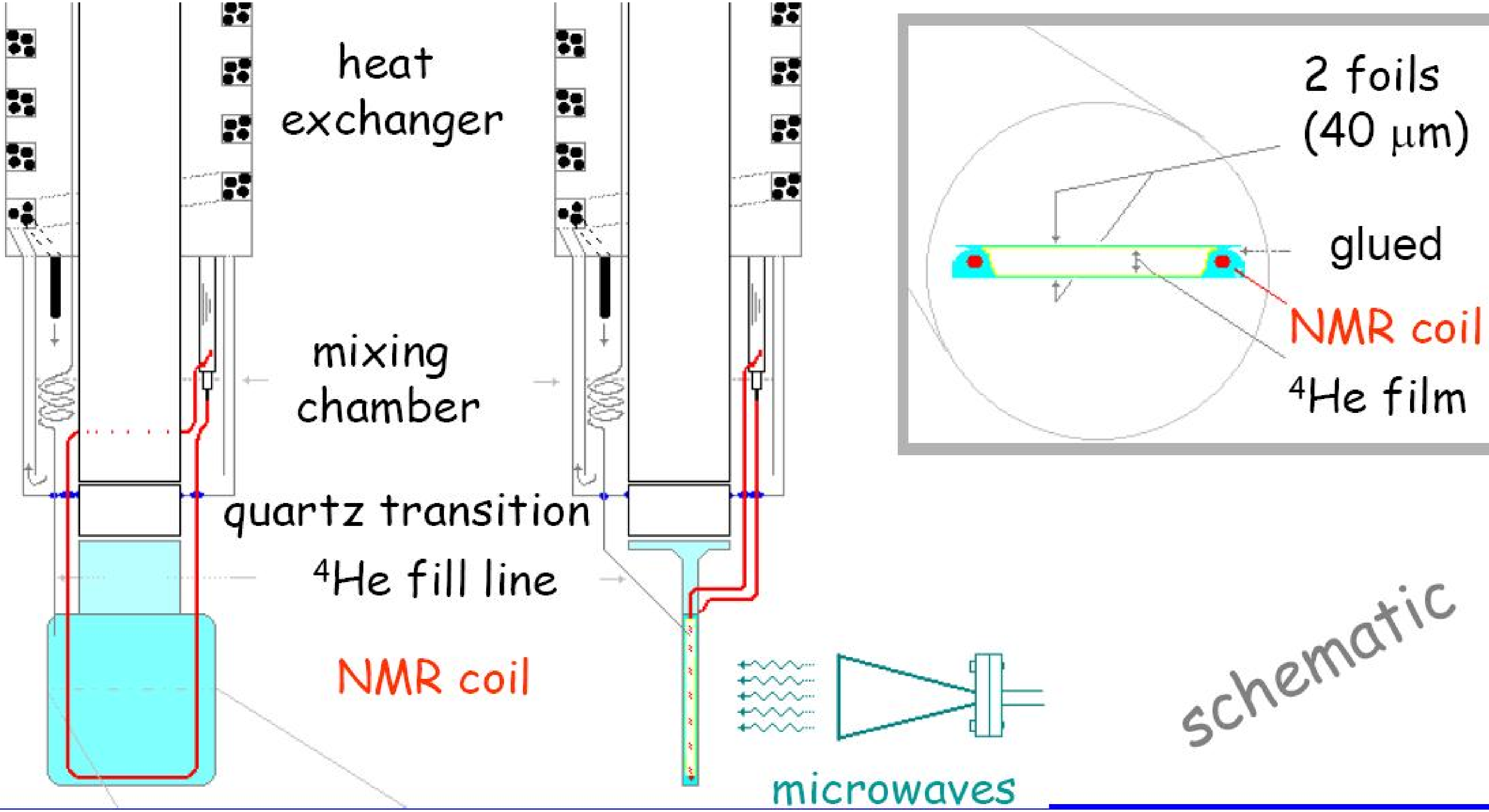


FIGURE 1. The mould (left) to produce scintillating foils. On the right a 70 micrometer foil of PMMA, doped with aceto-TEMPO.


heat
exchanger
mixing
chamber
quartz transition
^{4}He fill line
NMR coil
microwaves
2 foils
(40 μm)
glued
NMR coil
^{4}He film

schematic

Problems:

3. Radiation damage of material and ‚free radicals‘
4. Beam heating

   (max. electron beam int.~ 100nA with beam scanning):

Hadron Physics 2 – Joint Research Project
SPIN ORIENTED NUCLEI
for
STRUCTURE MAPPING (SPINMAP)

Acting spokesperson : W. Meyer
Leading institution : Ruhr-Universität Bochum
Germany

Frascati, Sept 28-30, 2007

Particle physics

Proton (Deuteron) rich material
(see before)

polarized

at T < 0.2 K (^{3}He/^{4}He)
and B = 2.5 T (70 GHz)

⇓

High polarization (80–100%)
with good polarization resistance
against radiation damage

⇓

Experiments

Medical applications

^{13}C-enriched material
(e.g. urea; pyruvic acid)

polarized

at T = 1.2–1.3 K (pure ^{4}He)
and B = 3.5 T (98 GHz)

⇓

Reasonable polarization (40%)

⇓

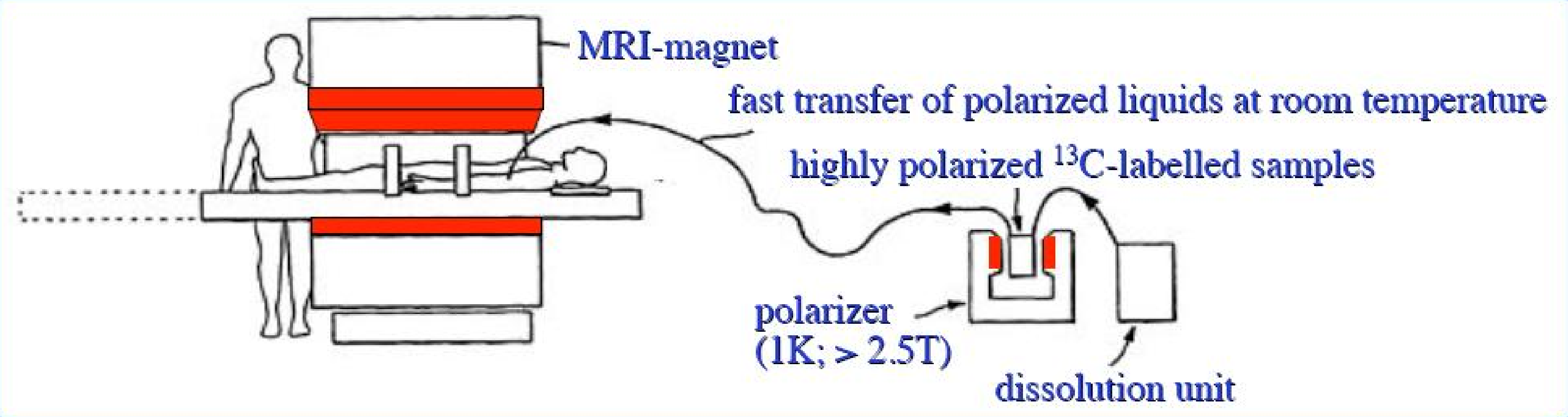
⟹ Fast dissolution of frozen material

⇓

Hyperpolarization in liquid state
transfered for in vivo studies

Spin oriented ^{13}C-nuclei for medical diagnostics

- Optimized production path for hyperpolarized ^{13}C-labelled contrast agents
  Improvement twofold:
  → high degree of polarization gives sufficient time at room temperature for in vivo studies (exponentiell decay of nuclei spin polarization)
  → transportable polarizers for use in medical environment



Conclusions and outlook