Johannes Gutenberg-Universität Mainz

Institut für Kernphysik

Status of the Crystal Ball Frozen Spin Target at the Mainz Real Photon Facility

1.- Overview Physics: Real Photon Experiments at MAMI

2.- Overview Apparatus: MAMI C, Crystal Ball, Tagger, Targets

3.- The new Frozen Spin Target

4.- Conclusion and Outlook

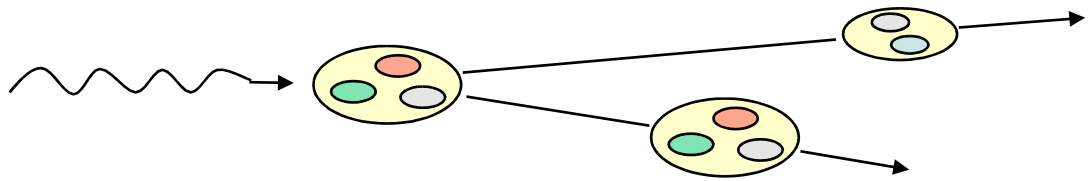
1st Meeting ‚Polarized Nucleon Targets for Europe

Bochum, November 29th –30th 2004

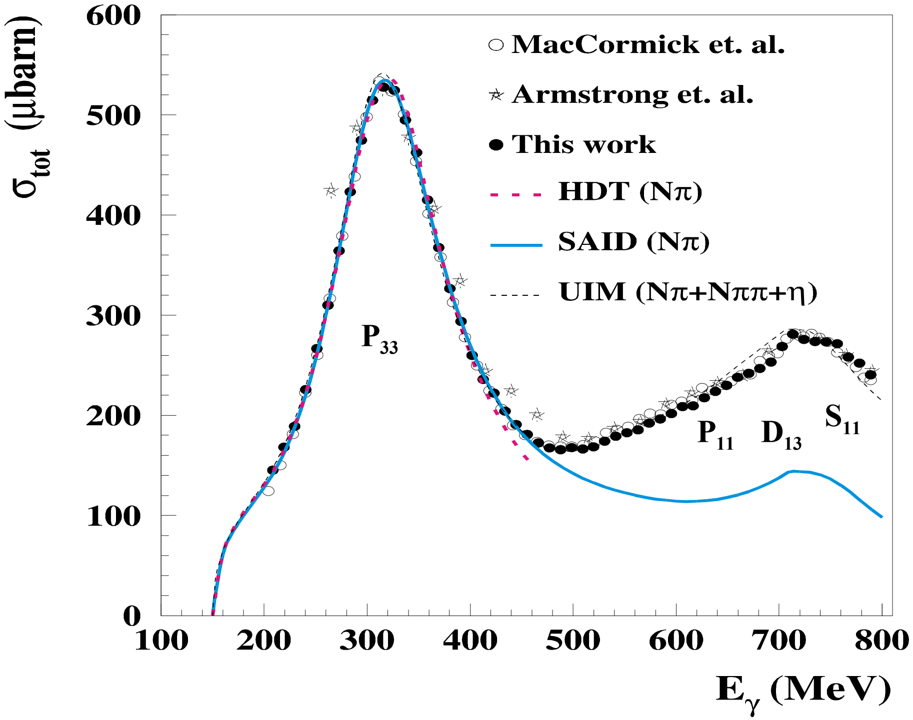
Andreas Thomas

Overview Physics

Investigation of the nucleons resonance spectrum with real photons



In the MAMI B energy range ($E_{electron}$ < 882MeV) we can produce photons by Bremsstrahlung and look for π- and η-meson production

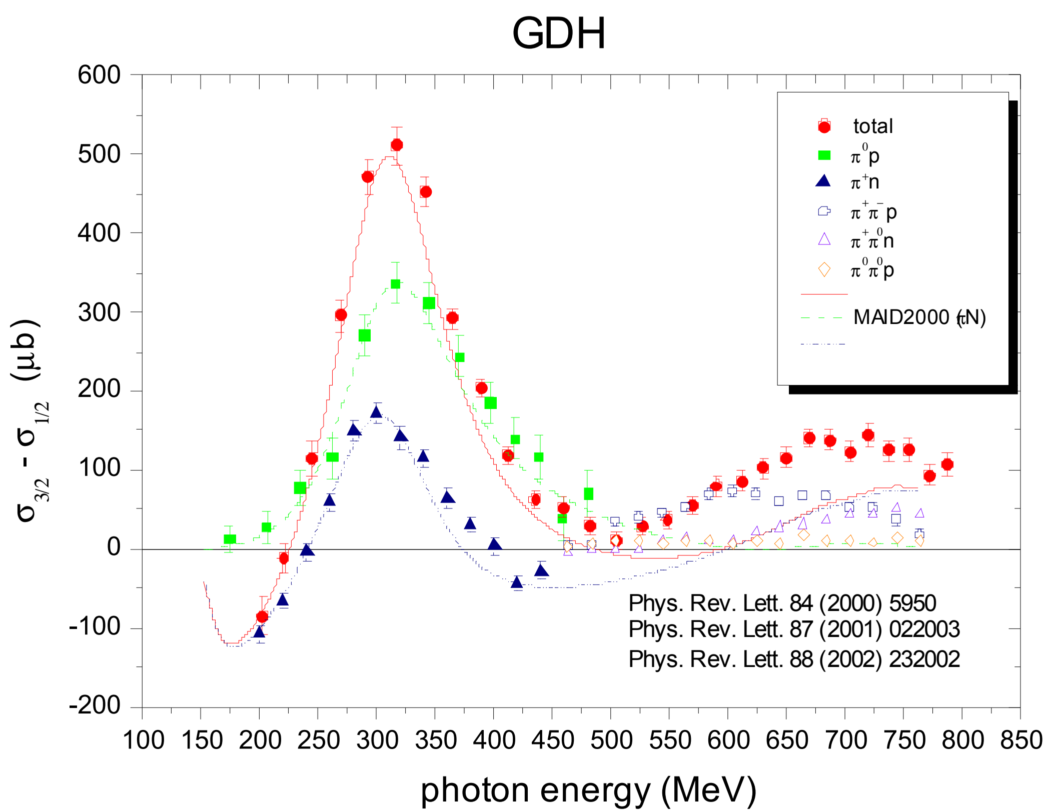


We can learn more if we fix the spin degree of freedom in the initial state

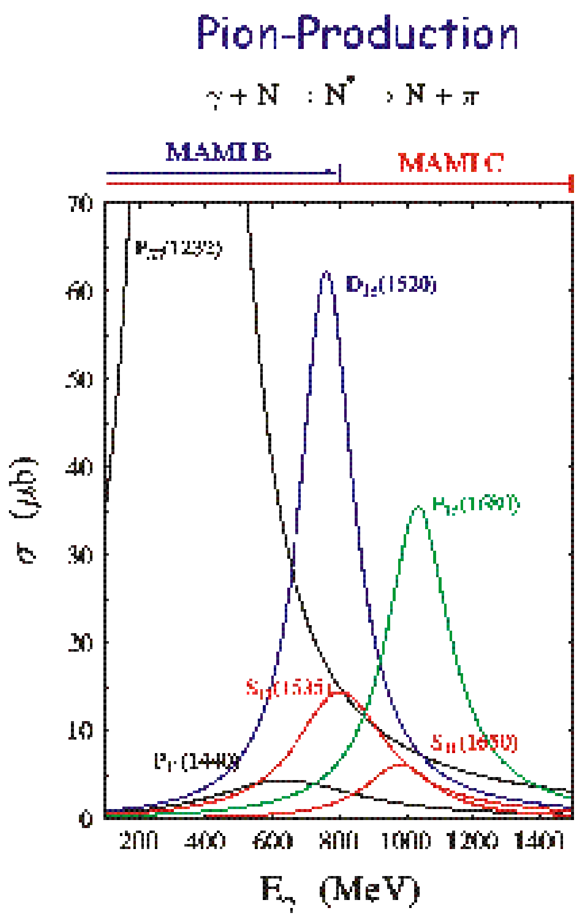
Constituent quark picture:

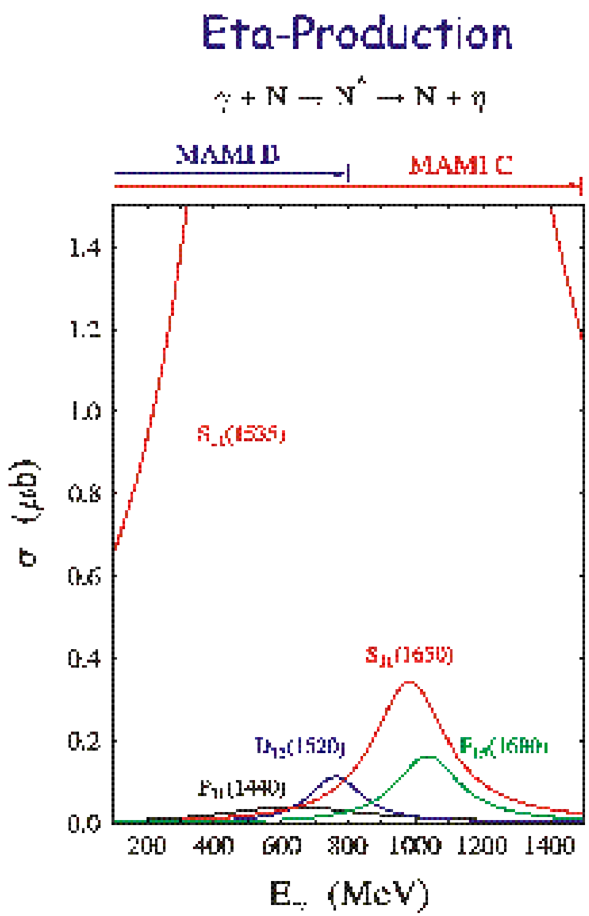
Proton p(932): |uud> ~ |↑↑↓> Spin 1/2

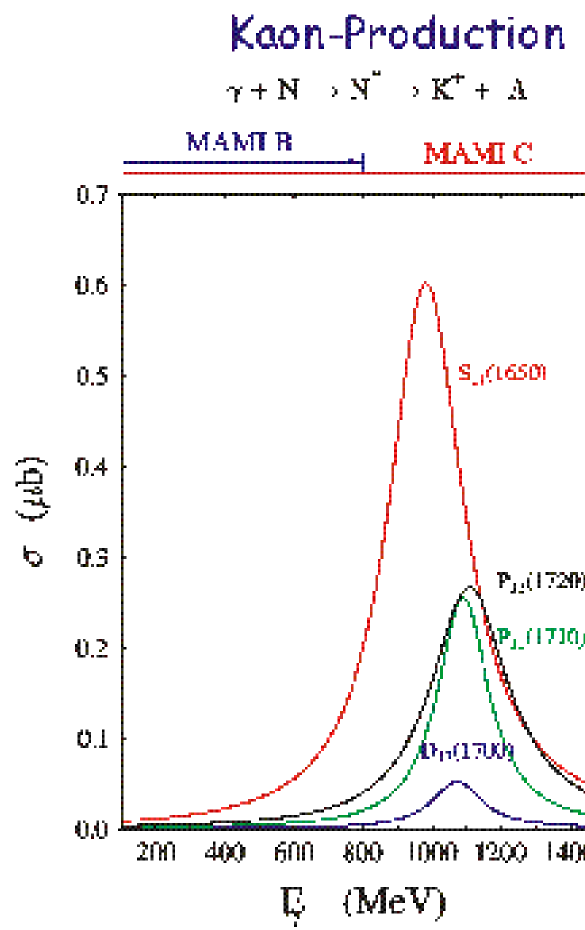
Delta Δ(1232): |uud> ~ |↑↑↑> Spin 3/2



Nucleon Resonances







problem : overlapping resonances
polarization observable

MAMI C : polarized photons, polarized targets
and recoil-proton polarimeter

Pion photo production with polarized beam and polarized target

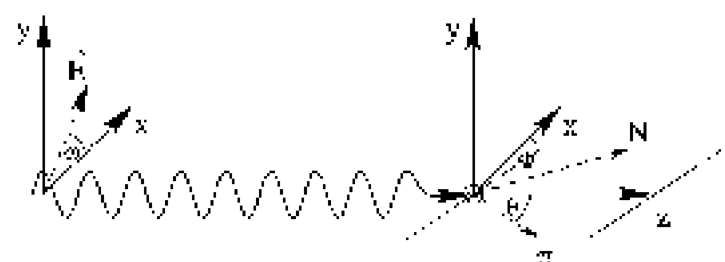
$$
\frac{d\sigma}{d\Omega} = \left(\frac{d\sigma}{d\Omega}\right)_{unpol} \Big[1 - P_\gamma^{lin}\Sigma(\theta)\cos(2\phi)
$$

$$
+ P_x \left[- P_\gamma^{lin} H(\theta)\sin(2\phi) + P_\gamma^{circ} F(\theta) \right]
$$

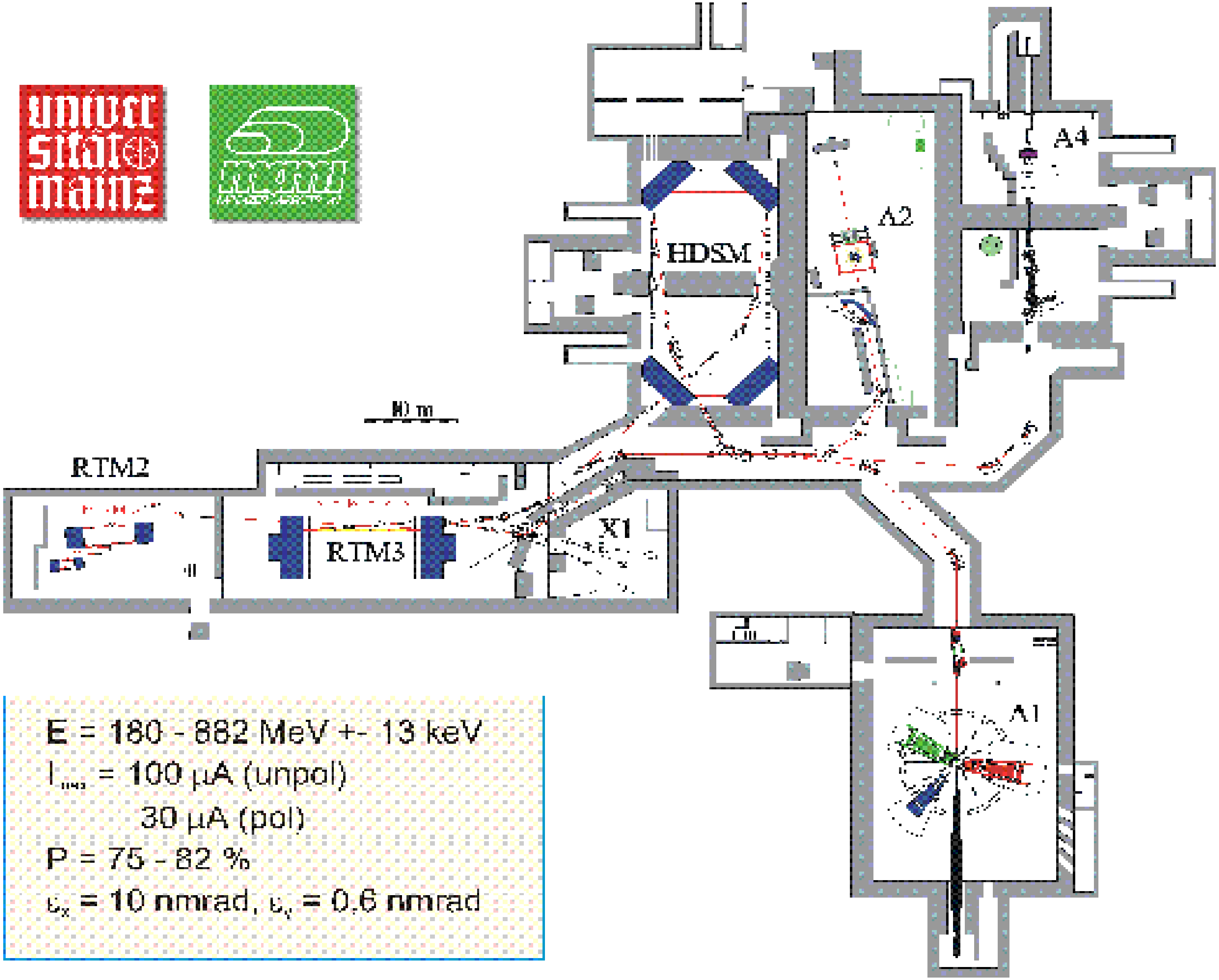
$$
+ P_y \left[- T(\theta) + P_\gamma^{lin} P(\theta)\cos(2\phi) \right]
$$

$$
+ P_z \left[- P_\gamma^{lin} \underline{G(\theta)}\sin(2\phi) + P_\gamma^{circ} \underline{E(\theta)} \right] \Big]
$$

Beam / Target	γ_{unpol}	P_γ^{lin} $\left(0, \frac{\pi}{2}\right)$	P_γ^{lin} $\left(+\frac{\pi}{4}, -\frac{\pi}{4}\right)$	P_γ^{circ}
P_{unpol}	$\left(\frac{d\sigma}{d\Omega}\right)$	$\Sigma(\theta)$	-	-
P_x	-	-	$H(\theta)$	$F(\theta)$
P_y	$T(\theta)$	$P(\theta)$	-	-
P_z	-	-	$G(\theta)$	$E(\theta)$



Overview Apparatus



E = 180 - 882 MeV +- 13 keV

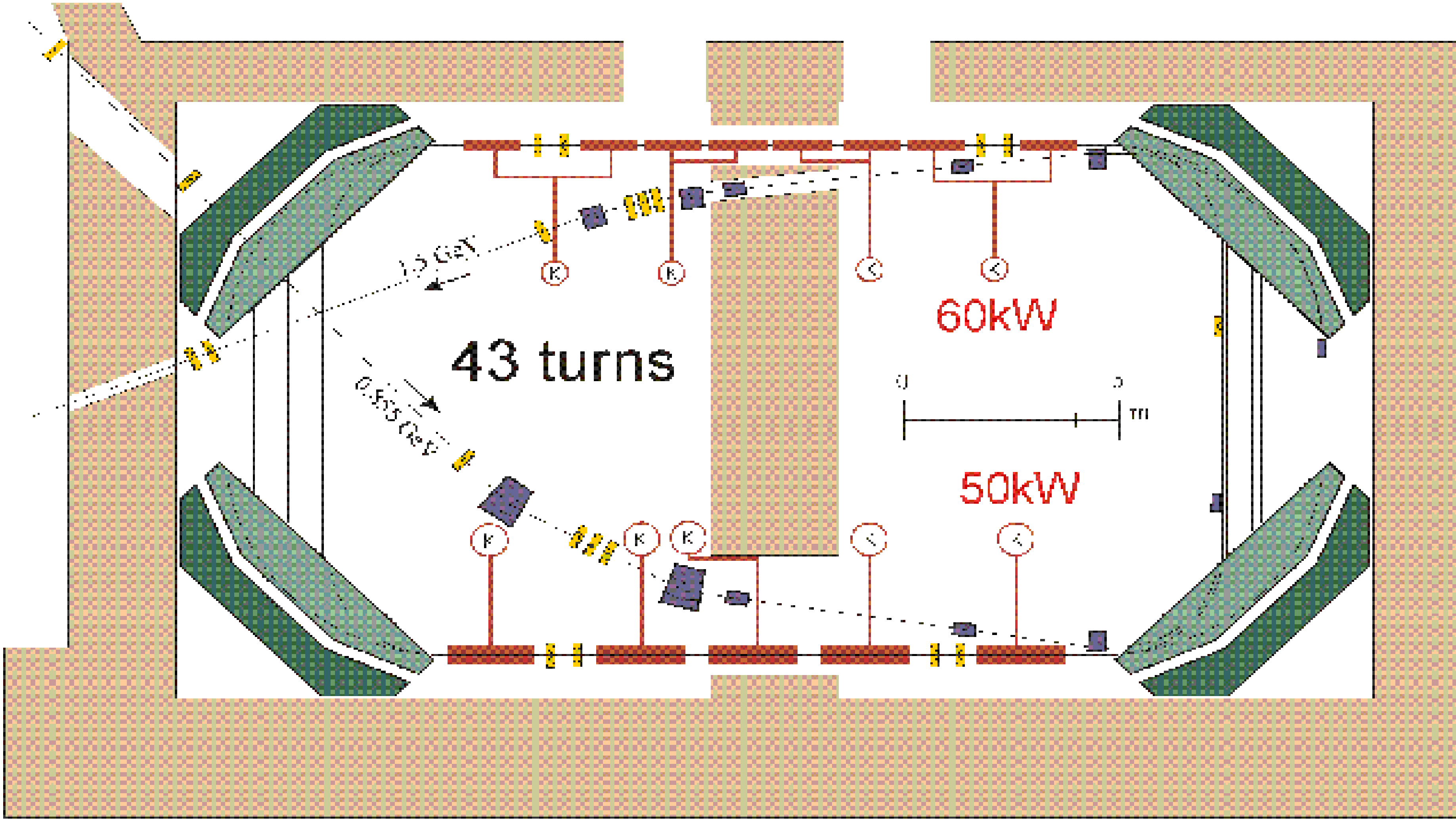
I_{max} = 100 μA (unpol)

30 μA (pol)

P = 75 - 82 %

ε_x = 10 nmrad, ε_y = 0.6 nmrad

MAMI C



Status of MAMI C

- HDSM dipole magnets
  - all four magnets assembled
  - field mapping finished
- Beamline upgrade to experimental areas
  - done !
- RF structures
  - 2.45 GHz (MAMI B design) ACCEL
  - five structures in house
  - 4.9 GHz
    prototype build in our institute
    two more are coming next month ACCEL
- Klystrons
  - 2.45 GHz (MAMI B design)
    five in house and tested THALES
  - 4.9 GHz
    three in house and tested

First beam planned for end of 2005

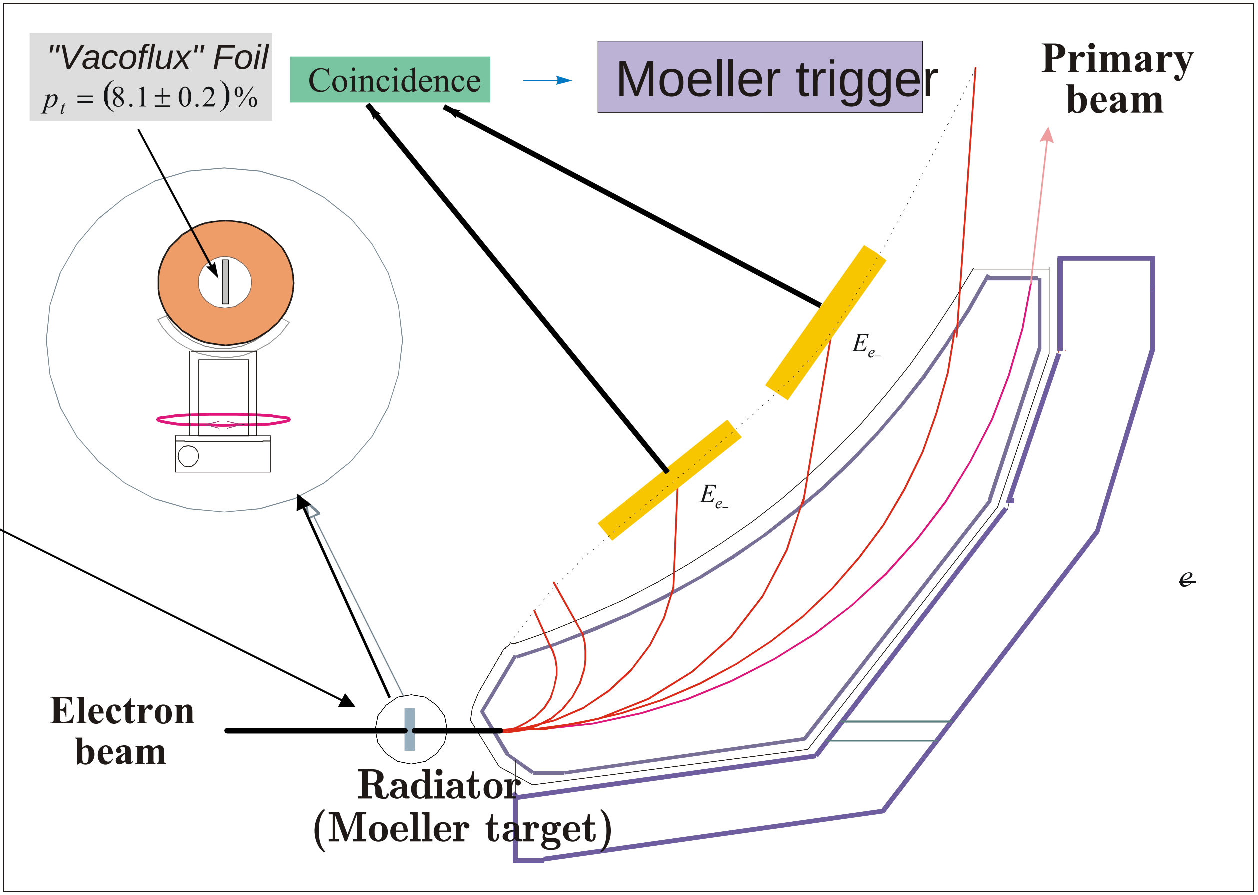
A2 Tagging system

1. Production und energy measurement of the Bremsstrahlungs photons

2. Determination of the degree of polarization of the electron beam (Moeller Polarimeter); Circularly pol. phorons

$$A = \frac{N^+ - N^-}{N^+ + N^-} = a\vec{p}_t\vec{p}_b\cos(z)$$

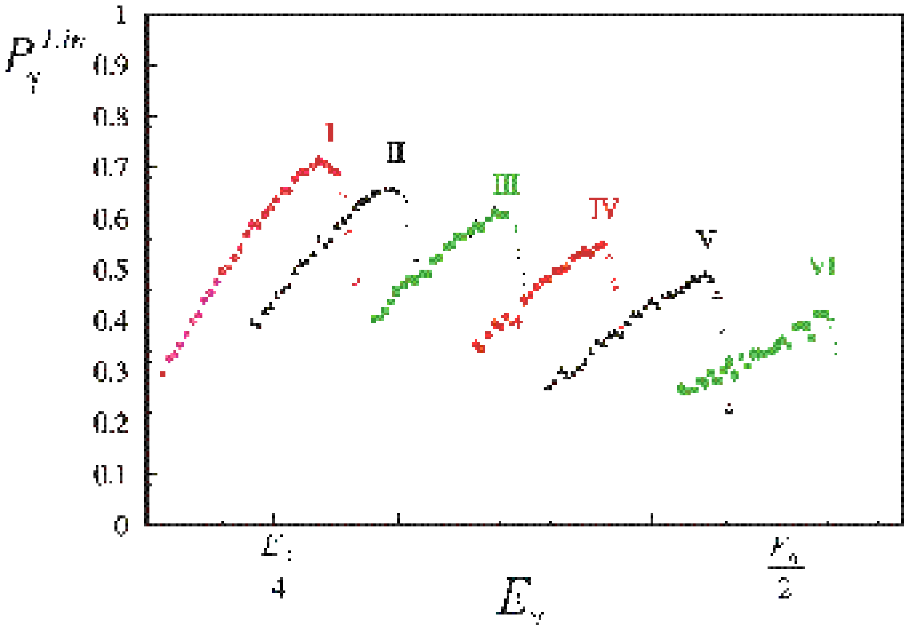
3. Coherent production of linearly polarized photons on a diamond radiator



Polarized Photons @ MAMI C

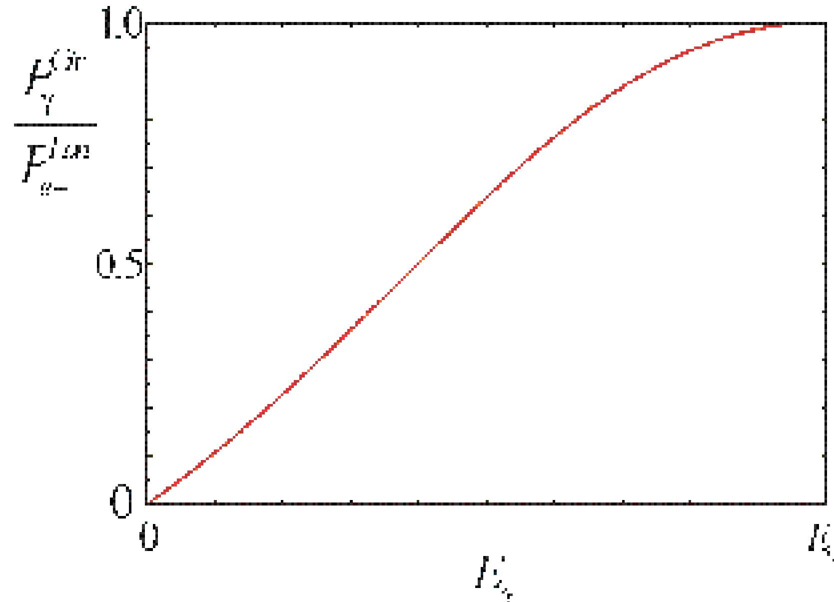
MAMI C : E_γ 75 – 1425 MeV ΔE_γ 4 MeV $N_\gamma = 2 \cdot 10^5 s^{-1} MeV^{-1}$

linearly polarized photons



$P_\gamma^{Lin} \sim 70\%$

circularly polarized photons



$P_{e-}^{Lon} = 80\%$ → $P_\gamma^{Cir} = 80\%$

- high photon flux !
- high polarization !

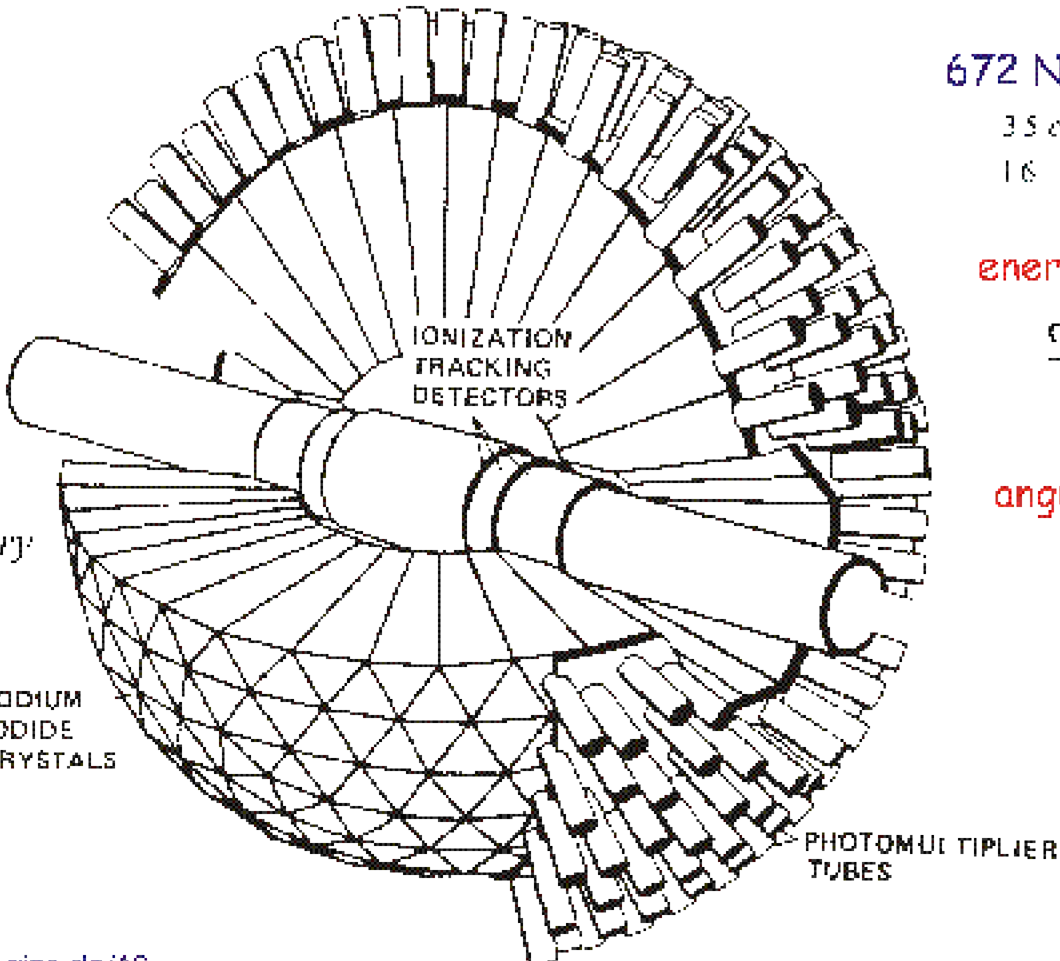
Crystal Ball Detector

acceptance :

$20^\circ \leq \theta \leq 160^\circ$

$0^\circ < \Phi < 360^\circ$

$\theta - and\ \Phi - symmetry$



672 NaJ detectors

35 cm long crystals

16 radiation lenghts

energy resolution :

$$\frac{\sigma_E}{E} = \frac{2.0\%}{\sqrt[4]{E(GeV)}}$$

angular resolution :

$\sigma_\theta = 2^\circ - 3^\circ$

$\sigma_\phi = 2^\circ / \sin\theta$

http://www.kph.uni-mainz.de/A2

4π Photon Spectrometer @ MAMI

TAPS:

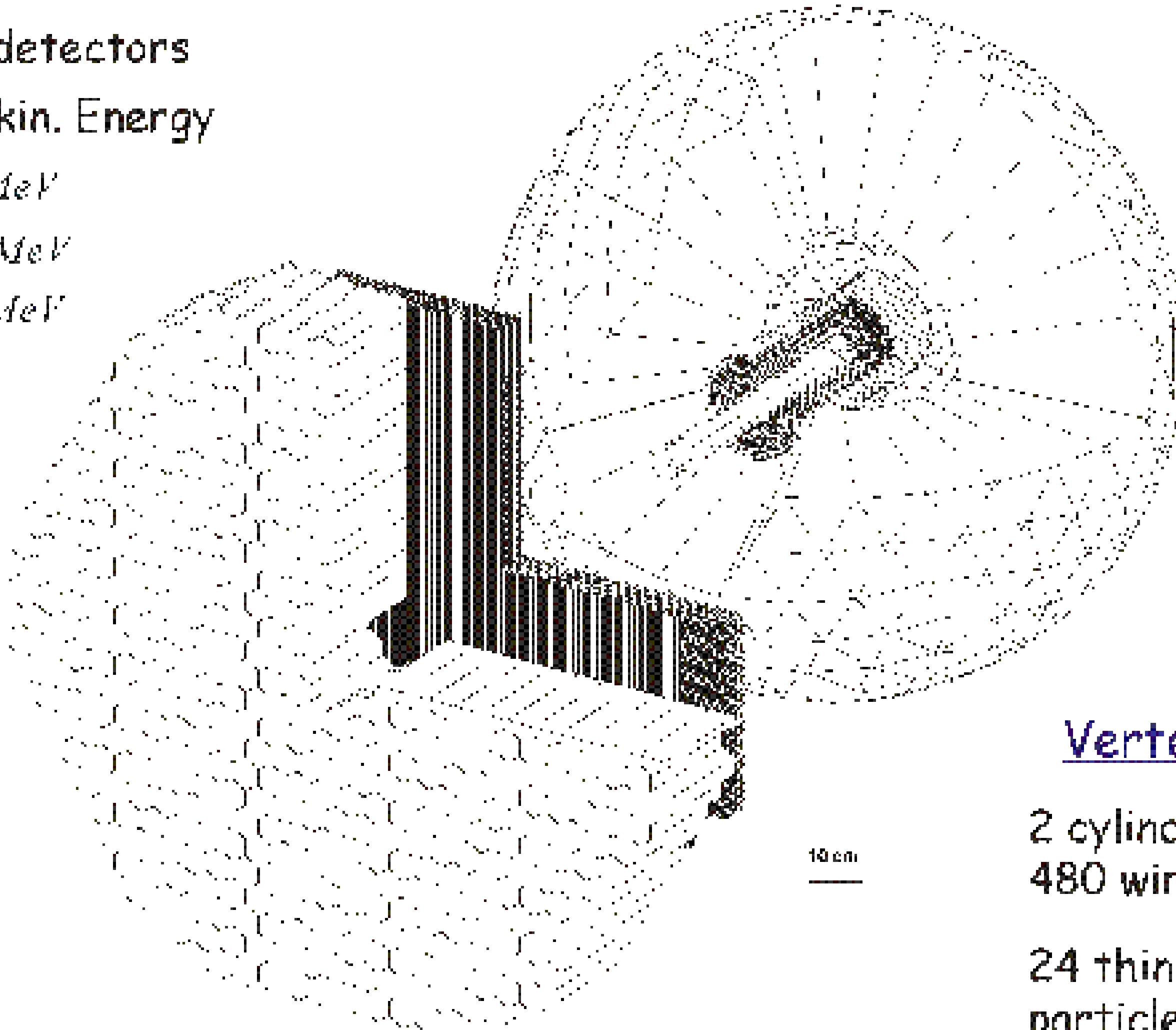
510 BaF_2-detectors

maximum kin. Energy

π : 180 MeV

K : 280 MeV

p : 360 MeV



Crystal Ball:

672 NaI-detectors

maximum kin. energy

μ^- : 233 MeV

$\pi^\pm$: 240 MeV

K^- : 341 MeV

p : 425 MeV

Vertex Detectors:

2 cylindrical wire chambers
480 wires, 320 strips

24 thin plastic counters
particle separation

Crystal Ball / TAPS

A2 Targets for MAMI C experiments

Liquid Hydrogen/Deuterium Target

Liquid ^{3}Helium Target

Polarized ^{3}Helium Gas Target

The new Frozen Spin Target for Crystal Ball

The new Frozen Spin Target for Crystal Ball

Tagged CW photon beam $10^7 \frac{\gamma}{\sec}$ ➡ **4π- detector**

➡ **Frozen spin target (50mKelvin, 0.4Tesla)**

$?*10^8 \frac{\gamma}{\sec}$ Kapitza Resistance Beam Hardening

Technical concept:

➡ Horizontal Dilution refrigerator

➡ Beam along cryostat axis

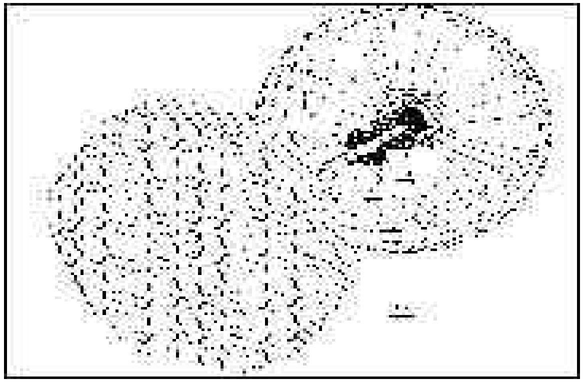
➡ φ symetric, $\theta > 160^0$

➡ Thin internal holding (saddle) coil and shielding

➡ Loading along cryostat axis

Collaboration with the Dubna/Moskau Polarized Target Group [Y.Usov, N. Borisov, G. Gurevic et al.]

Goal: Design, construction and complete test of the new ^{3}He/^{4}He-Dilution cryostat



Horizontal cryostat in Crystal Ball

Holding Coil [Bonn concept]

NMR + Material [Bochum concept]

Magnet , μwave, , Vacuum [Mainz]

Dubna: Temp < 50mK

→ transversal polarization

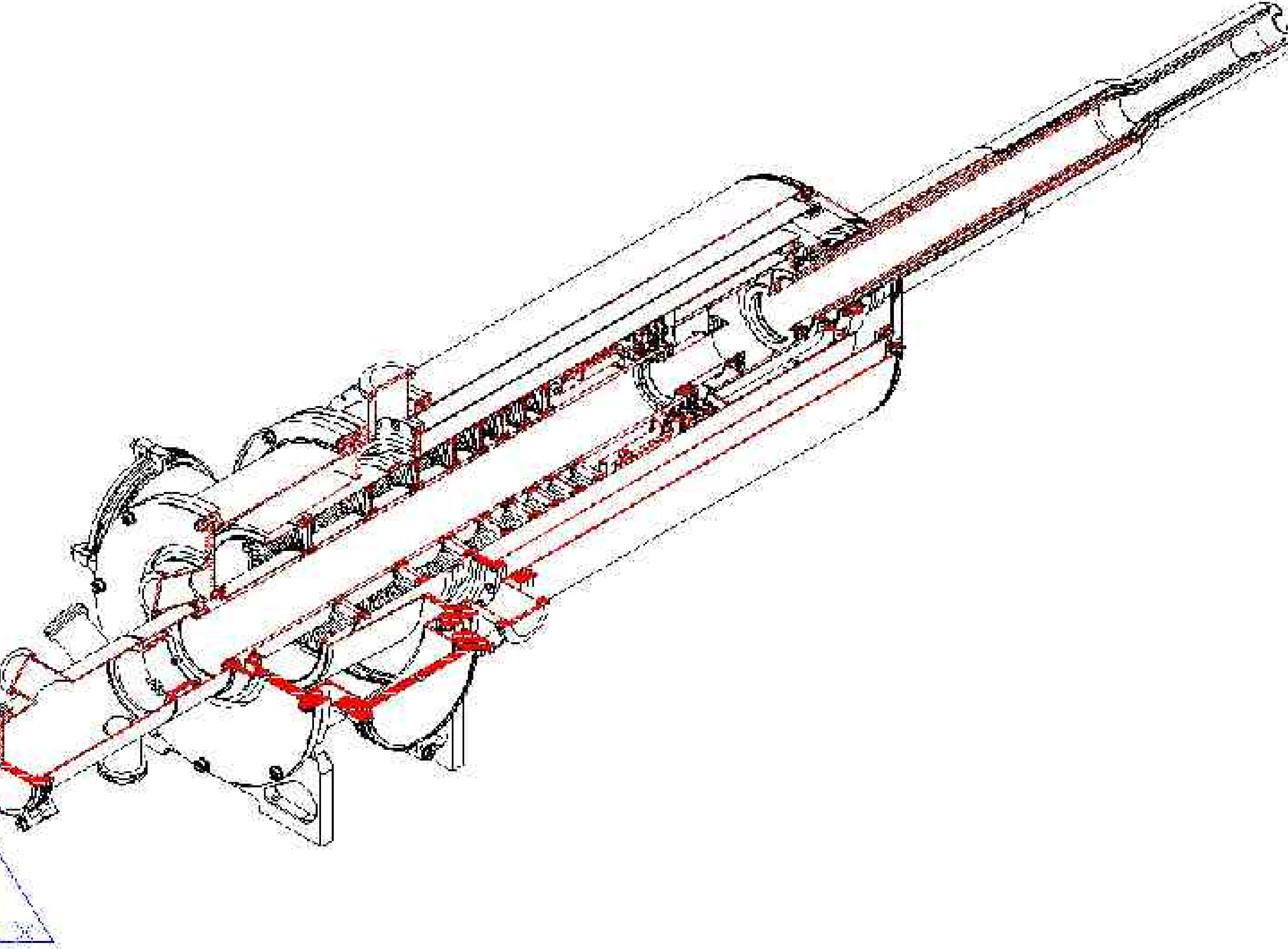
Long **cryogenic experience** in Russian polarized target group with horizontal cryostats:

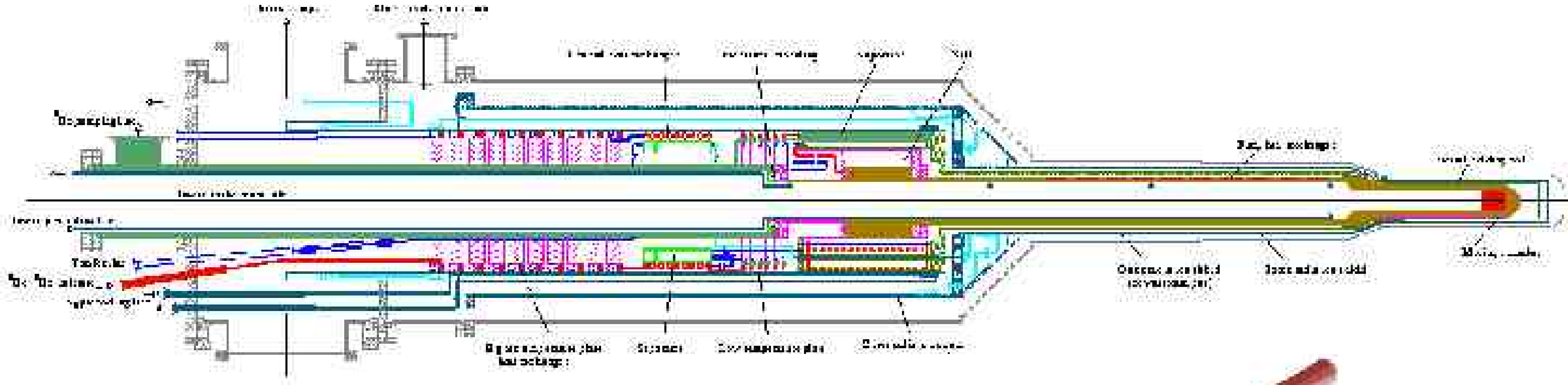
Dubna/Gatchina:	1976-2003		P_p=98%
Protvino:	1980-2003	P_p=87%	P_D=37%
Prag:	1994-2003	P_p=98%	20mK
Dubna/Fermilab/Saclay:	1995-2003	P_p=91%	

Workshop power, engineers, technicians and target experts available immediately.

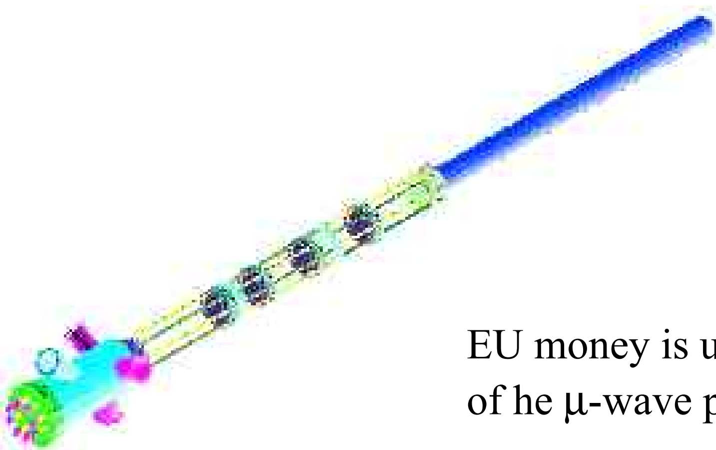
Contract signed in 12/2003 -> total costs 260k€

→ **Cryostat ready in 2.5years**.



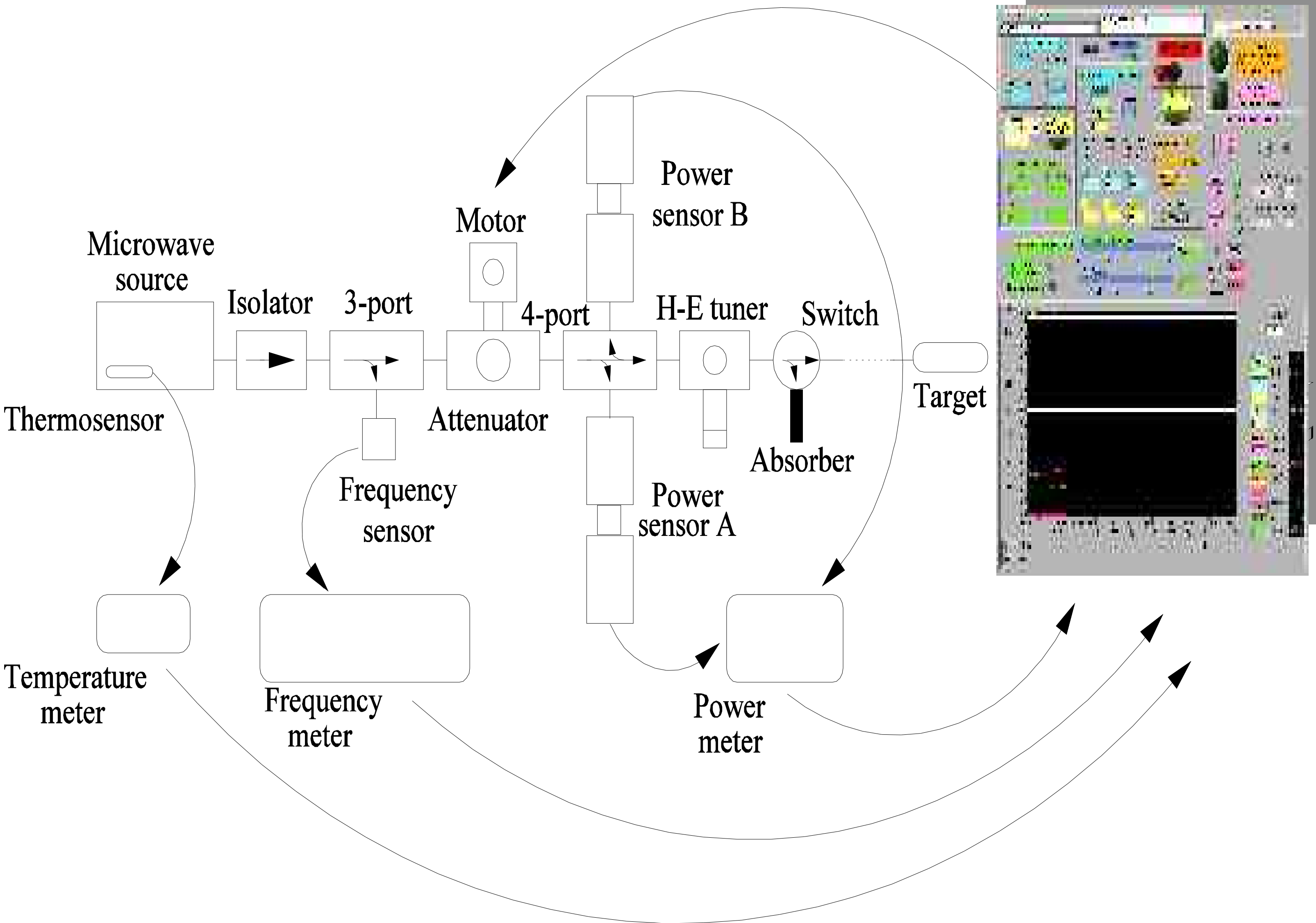


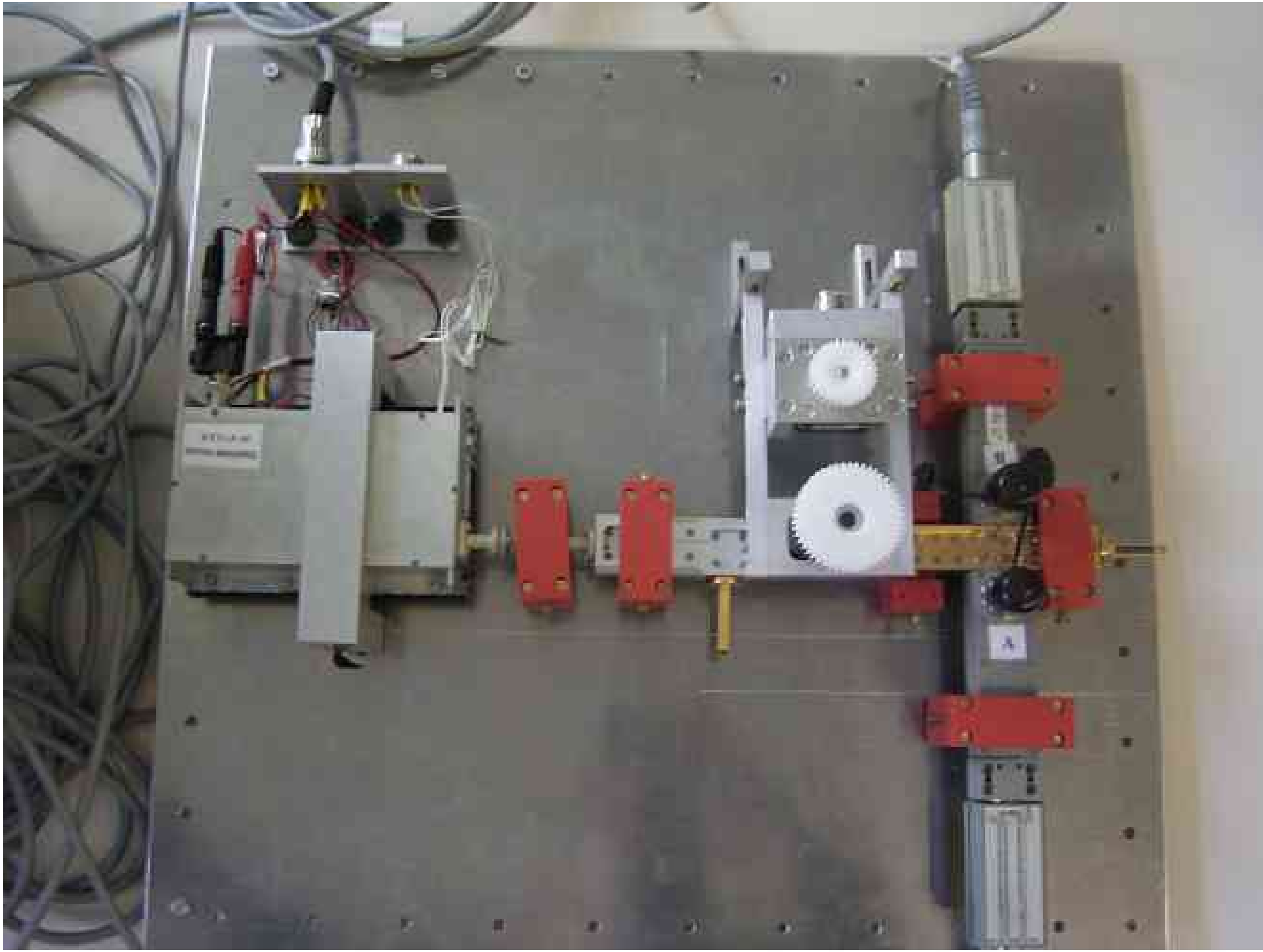
^{3}He/^{4}Helium Dilution refrigerator with ^{4}helium-evaporation precooling stages for the incoming ^{3}He, the radiation shields and internal coil.



EU money is used for the construction of he μ-wave parts of the cryostat

Microwave setup for a frozen spin target

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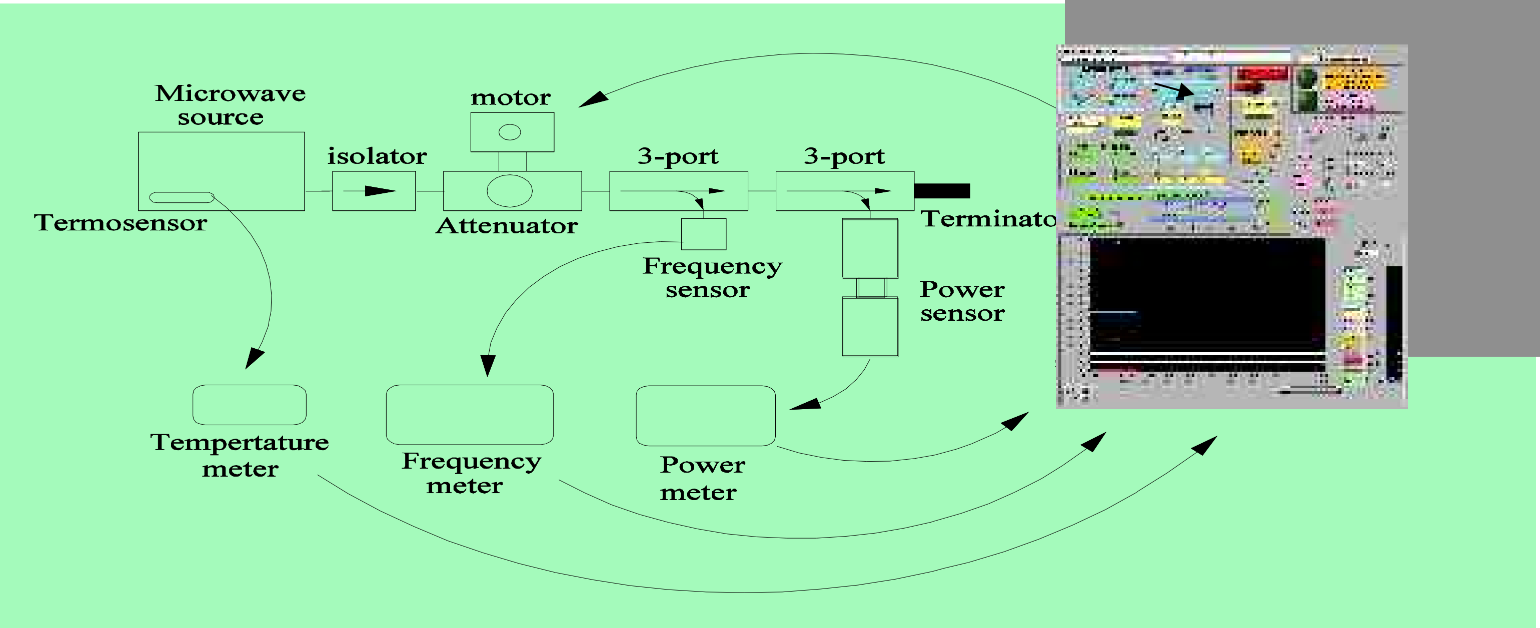
Stability te



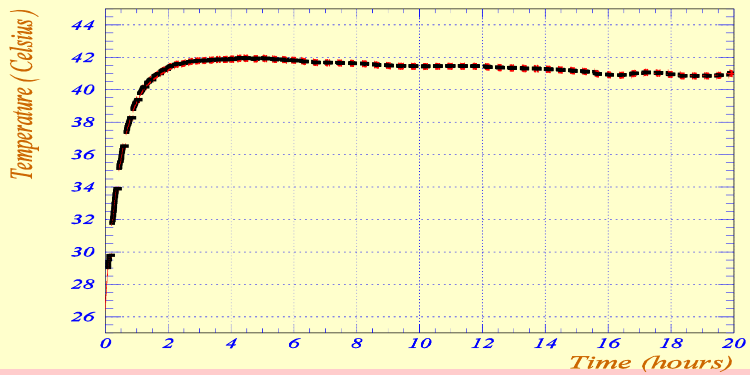
5 Days general test
Check stability of the source

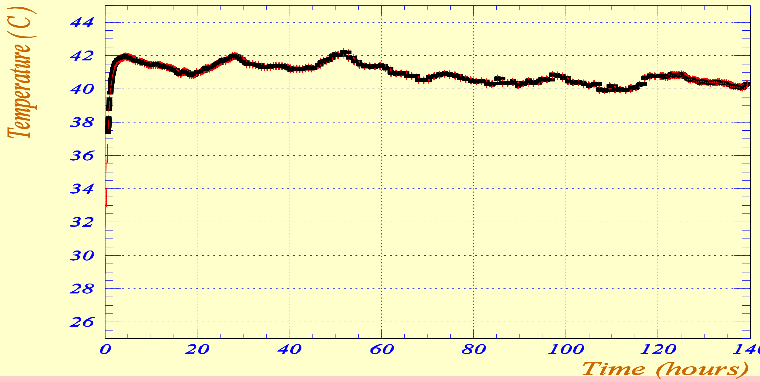
Temperature stability 0.6%
Frequency stability: 0.008%
Power stability: 2%

Stability test

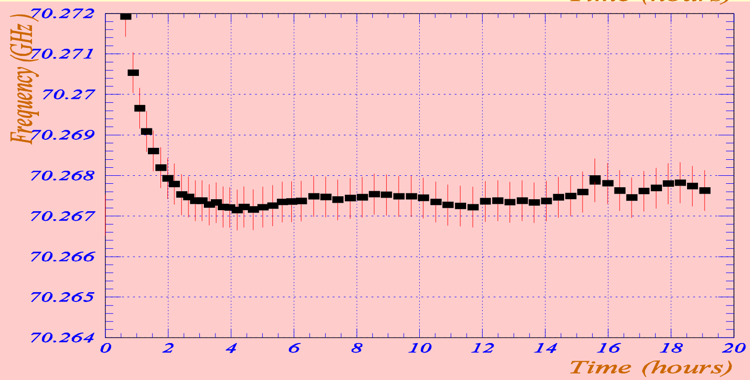
Hours | **Days**

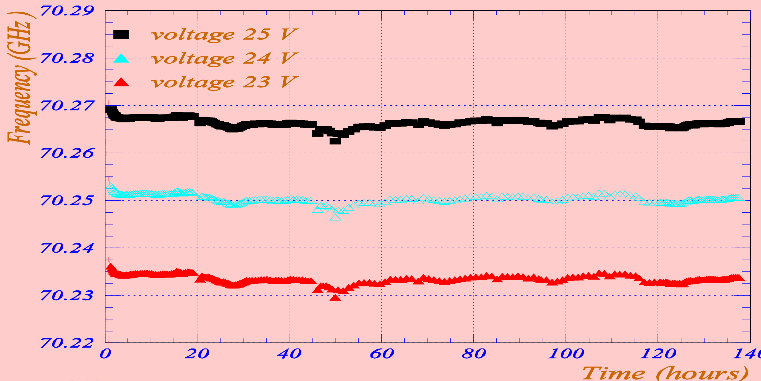
TEMP



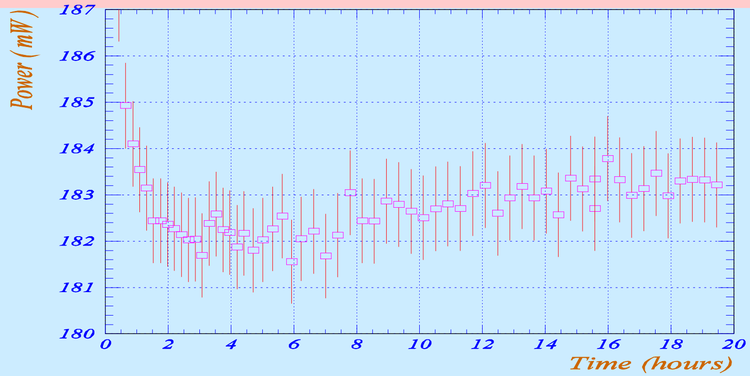


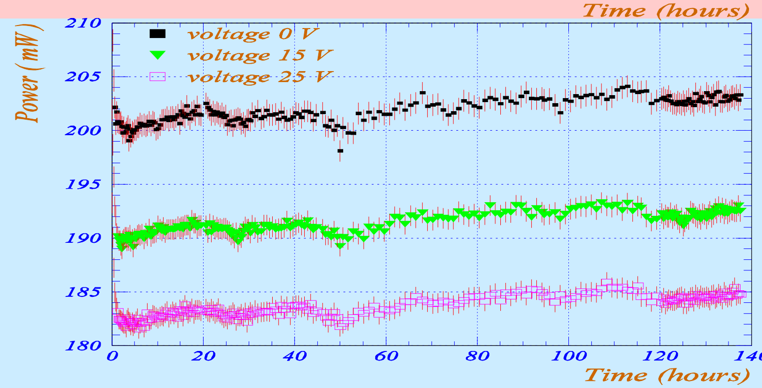
Freq



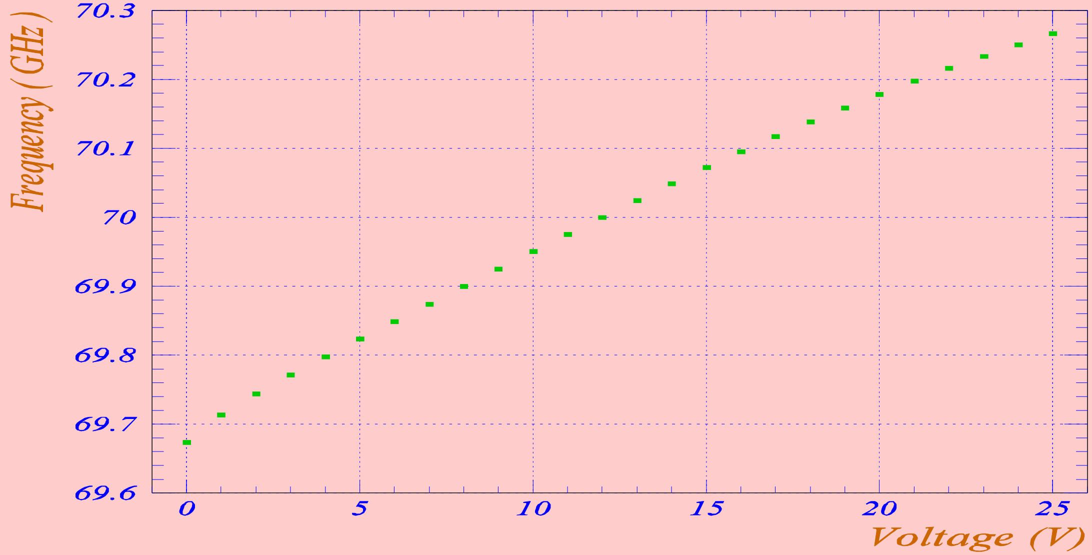


Power

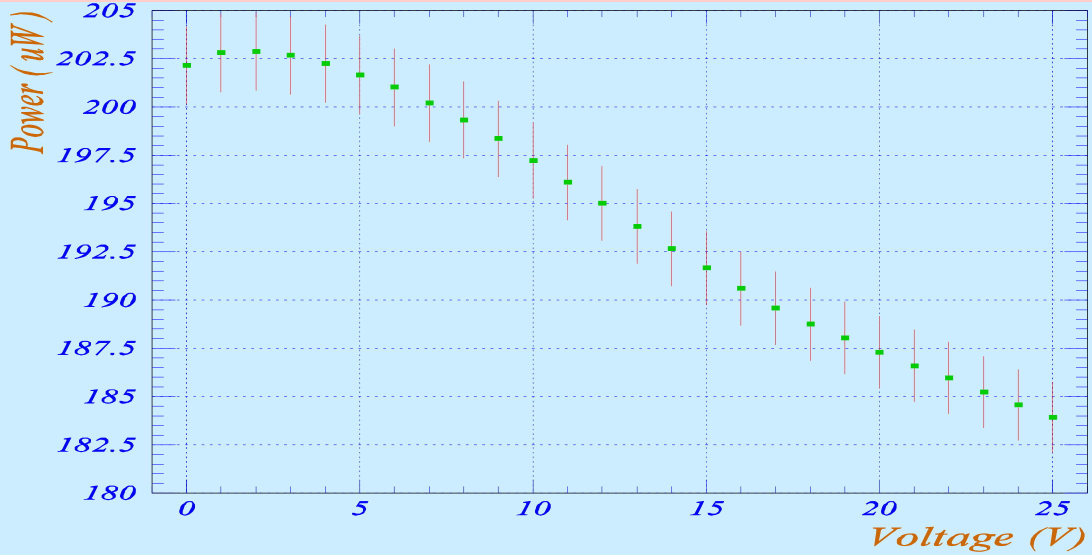




Calibration

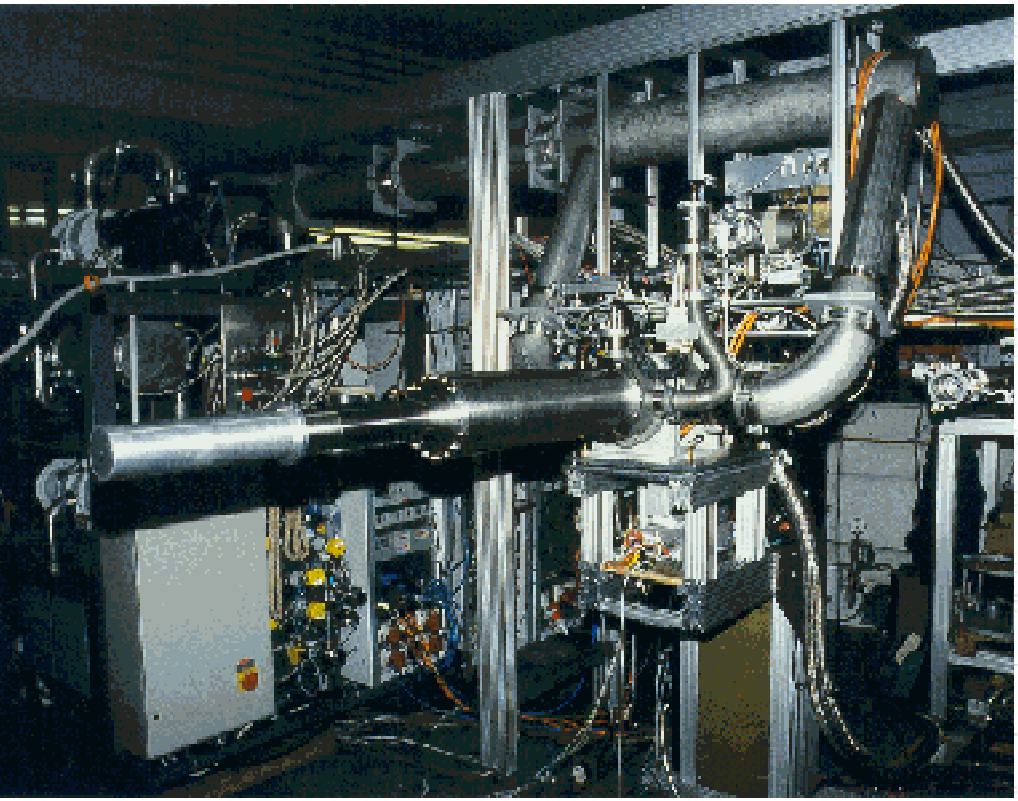


Frequency :
from 69.673 GHz
up to 70.266 GHz

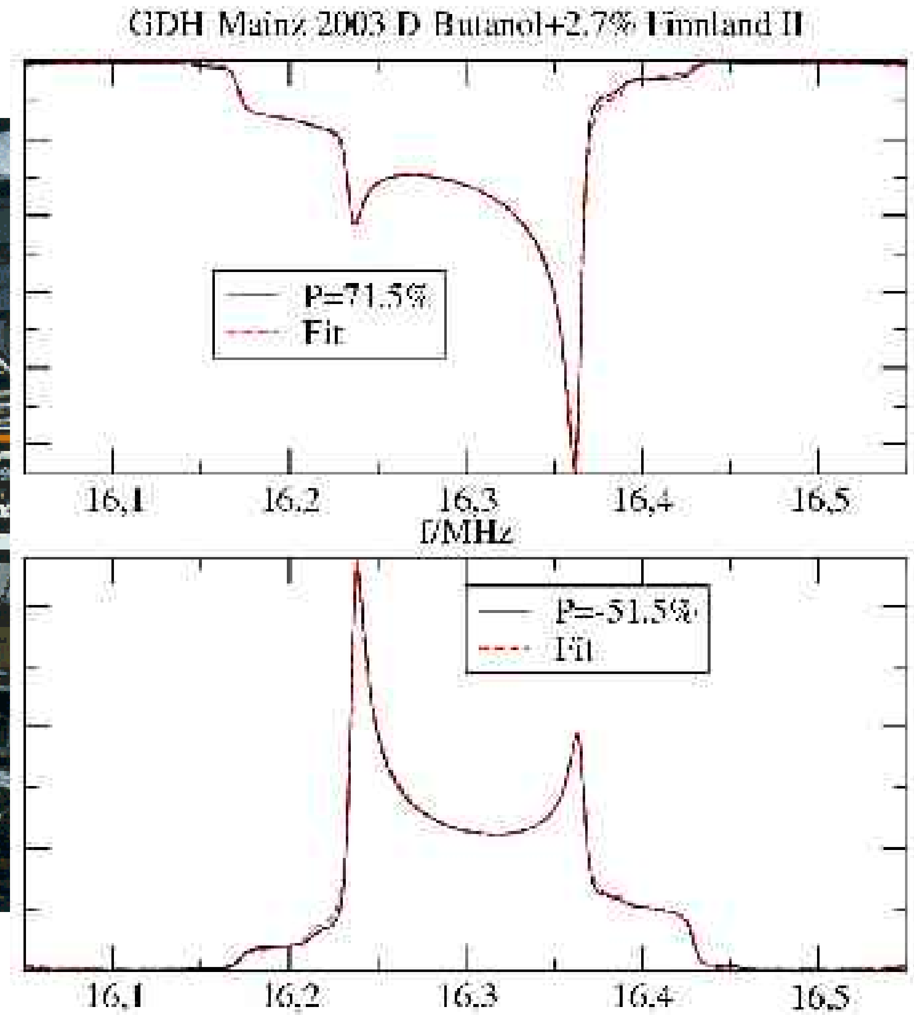


Power:
About 200 mW.

The GDH Experiment on the Deuteron



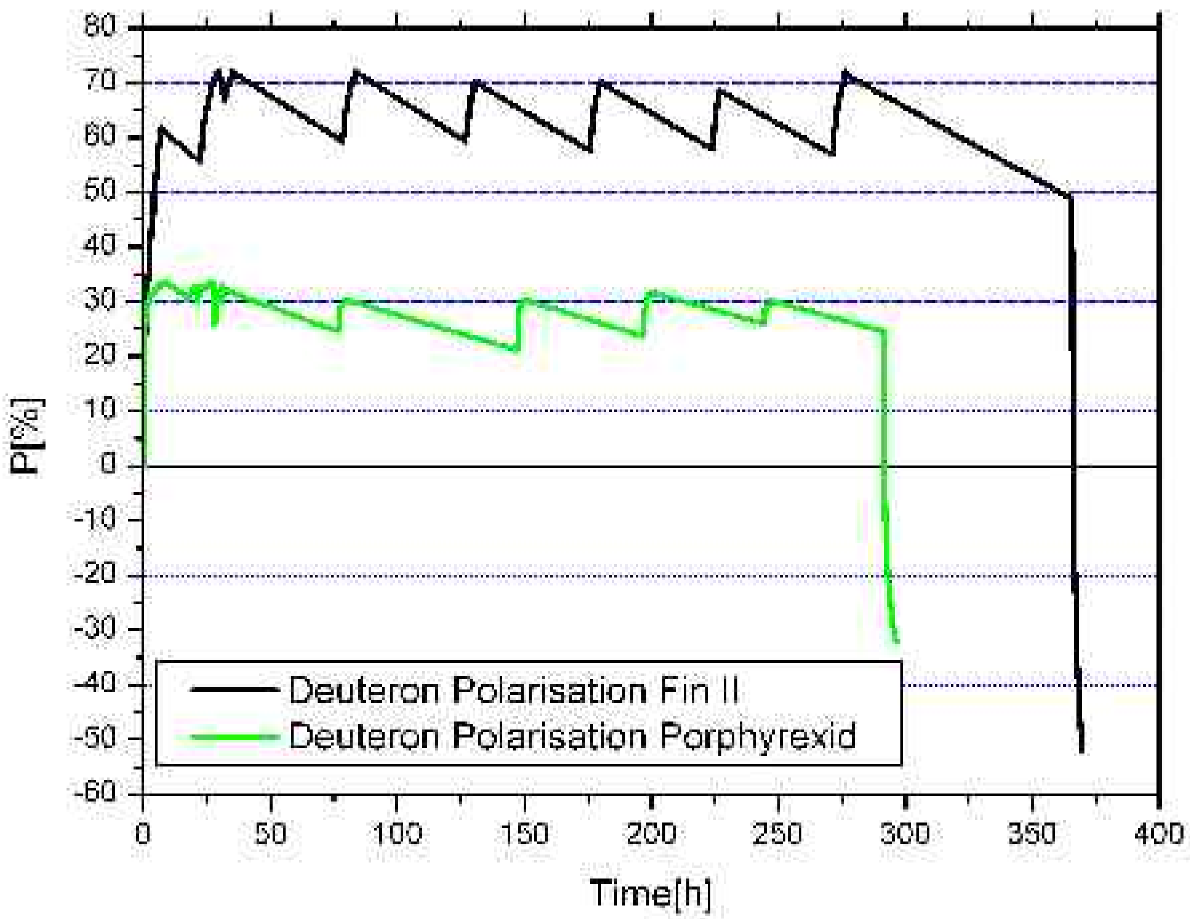
Bonn Polarized Target



Bochum NMR-Sig. Trityl doped But.

Deuteron measurement

Pilot Experiment in 1998
Data taking period in 2003:
Very high degree of deuteron polarisation and high relaxation time (t ~ 230h @ 0.6T, 75mK) during the experiment.



Repolarize every 2nd day for approx. 5 hours with the Mainz μ-wave apparatus.
Average polarization > 60%.

Conclusion and Outlook

•The microwave set up was used in the GDH Experiment sucessfully.

•There is needed an additional thermal isolation for improved stability.
•More microwave parts needed in order to change the magnetic field (sensors, waveguides ...) .
•A PID regulation using the relevant input parameters has to be realized.
•The possibility to do computer controlled frequency modulation will be applied.
•The dilution cryostat is under construction (insert design, reflexion-transmission, bolometer required ...).

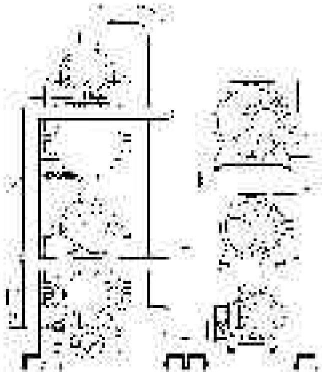
Investment money from the EU is used to realize a part of the above mentioned tasks.

Manpower: Needed at least: 1 Permanent Position,
1 Postdoc,
2 PhD,
2 Diploma students

EU money will be used for a part of the postdoc position

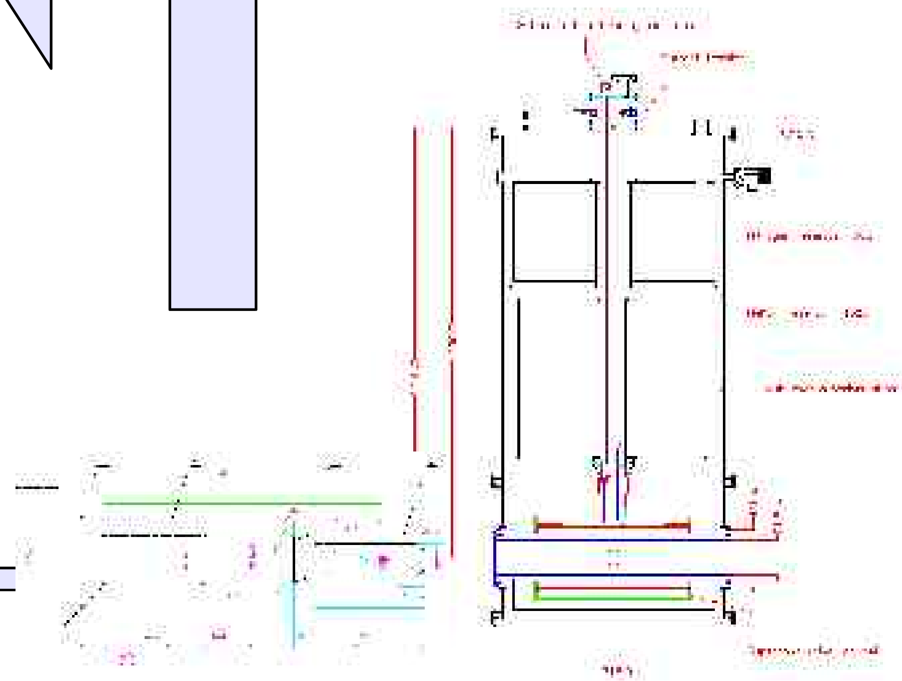
Components of the polarized target for the Crystal Ball detector

He^3/He^4 Roots 4000m^3/h Vacuum system



Mikrowaves 70GHz

Dynamic
Nuclear
Polarization



Superconducting Polarization magnet 5Tesla

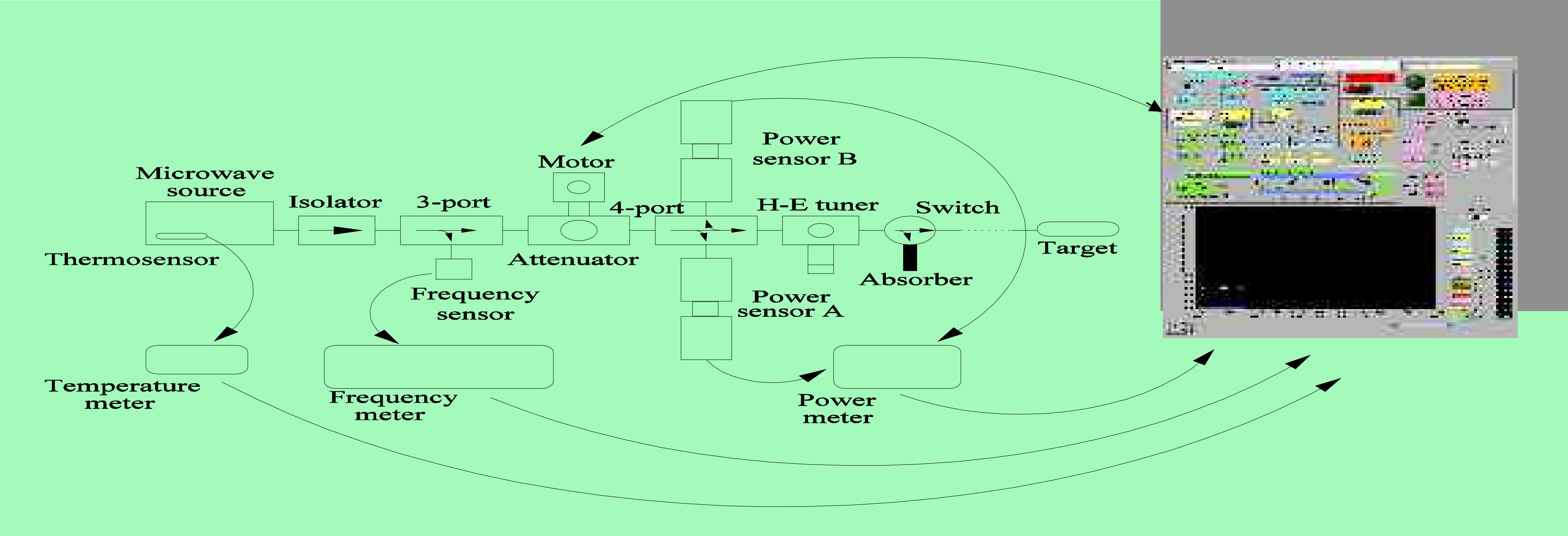
NMR-Apparatus

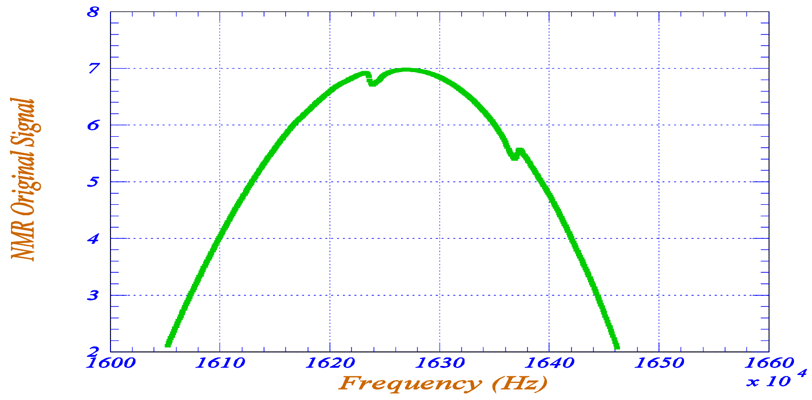
106MHz

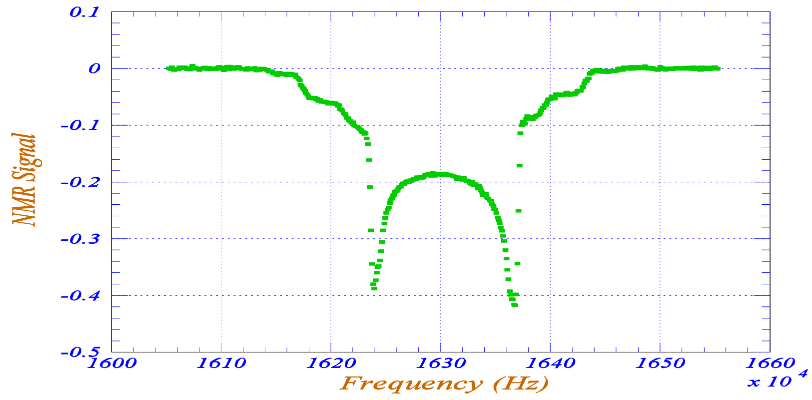
Polarisation meas.

Horizontal He^3/He^4 Dilutionrefrigerator (50mKelvin) with internal Holding coil

D-propandiol test







Vacuum apparatus

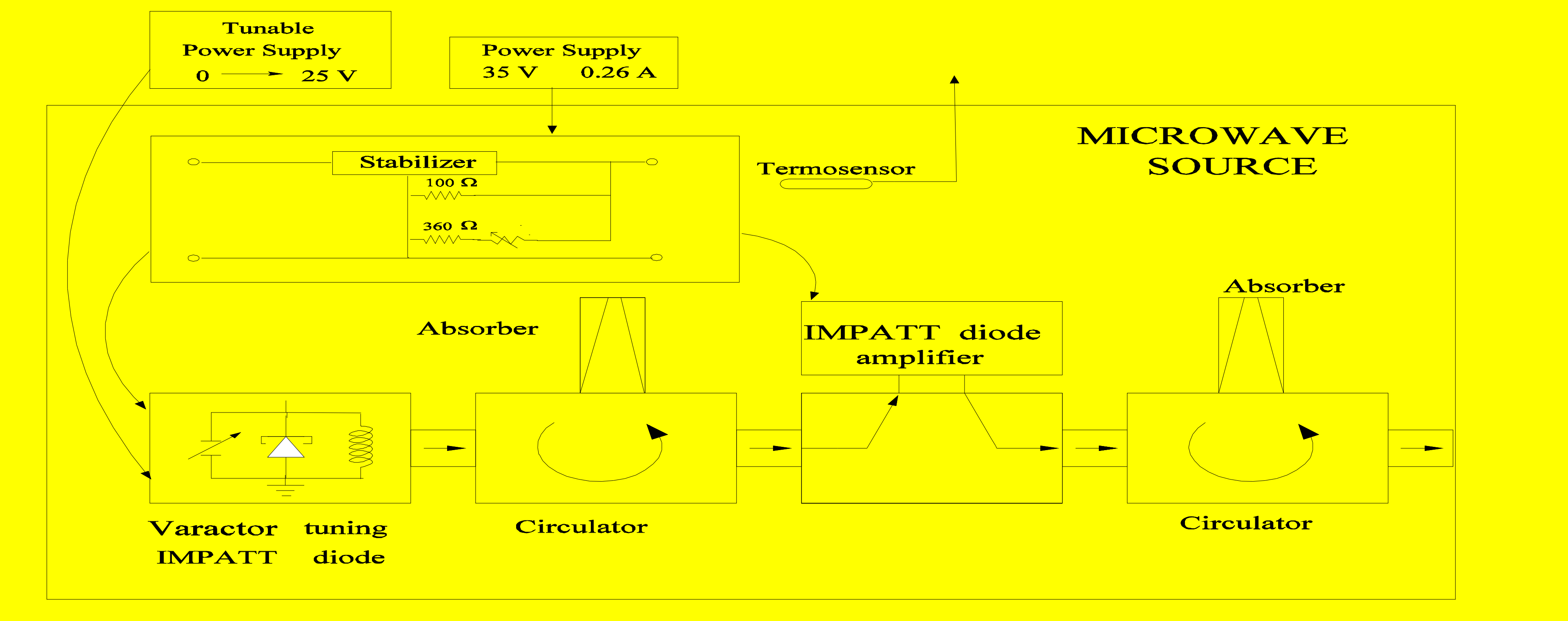
Roots [Pfeiffer Vacuum]

Separator circuit

Precooling [Diploma M.Mouahid]

Evaporator circuit

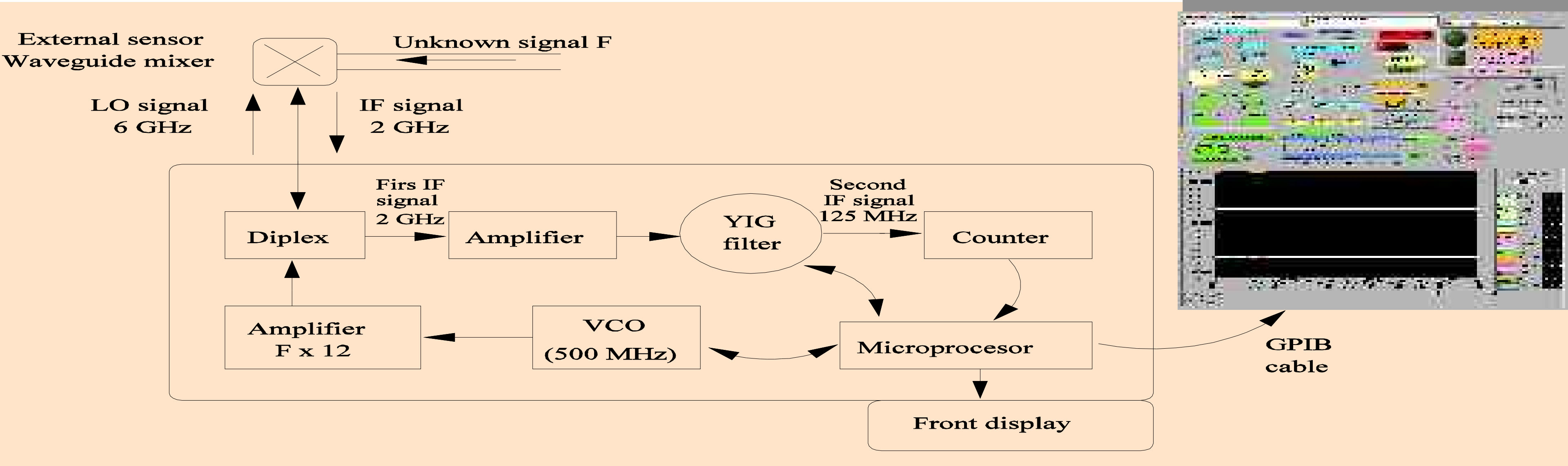
Microwave source



- Varactor tuning IMPATT (IMPact Avalanche Time Transition) diode
- Frequency from 69.673 up to 70.266 GHz
- Power 200 mW
- Temperature stability of 0.7%, Power stability of 2% and Frequency stability of 0.008%

Frequency Counter

Heterodyne technique



• 598A Phase Matrix, Inc. Measure 100 Hz to 170 GHz.

•Mix unknown signal with an harmonic of the local oscilator (LO), produce a signal (IF), measure this signal.

$$F = H * LO \pm IF$$

• Know the harmonic: change 1MHz in LO will move IF a integer number, it is the harmonic.

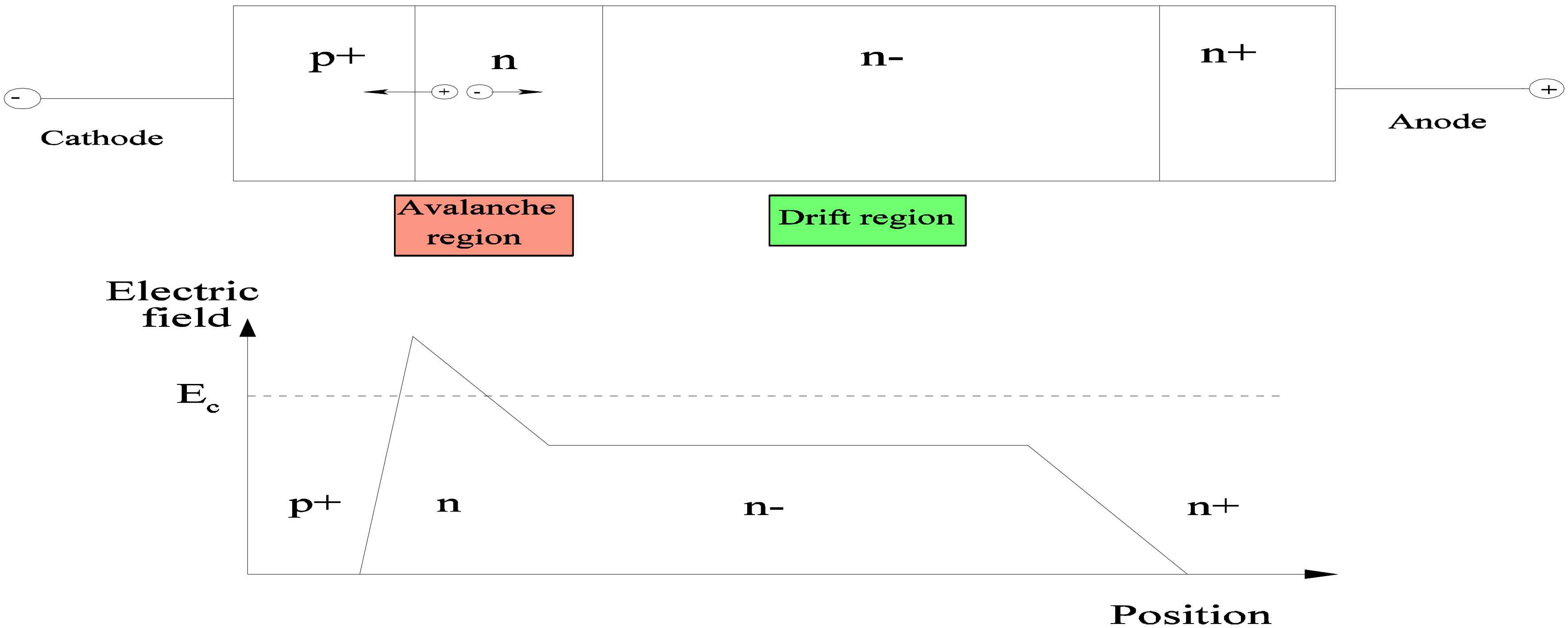
• If the IF increase the F signal is lower, should be subtracted.

Power Meter

E4419B EPM Series Power Meter from Agilent Technologies
Two sensors V8486A

IMPATT diode

Converts DC power to RF power by introducing a 180 Degree phase delay between the voltage and the current



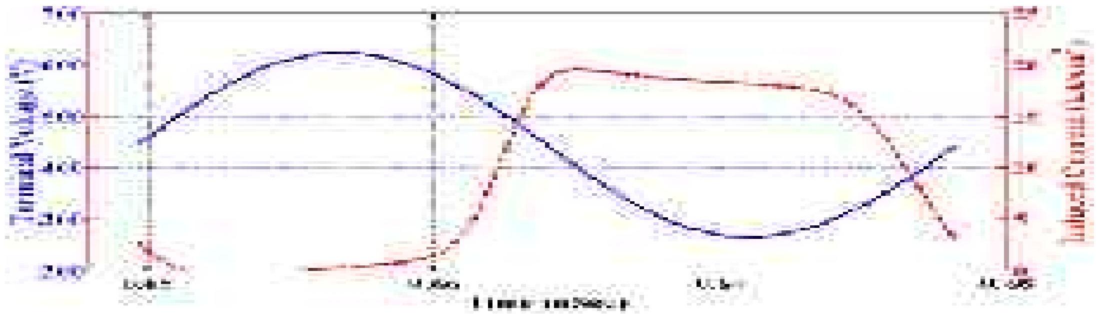
•External potential creates a peak and produces electron-holes pair. Avalanche region

• Electrons move to Anode with constant velocity. Drift region

• Induce mirror charges in anode.

IMPATT diode

- Current Increases as voltage decreases ⇨ opposit phase.



- Diode embedded in resonant cavity produce microwave.
- Frequency depending on drift velocity and lengh of the drift: $\upsilon = \frac{V_d}{2L}$

$$P_n = \frac{E_c^2 V_d^2}{4\pi X_c \upsilon^2}$$

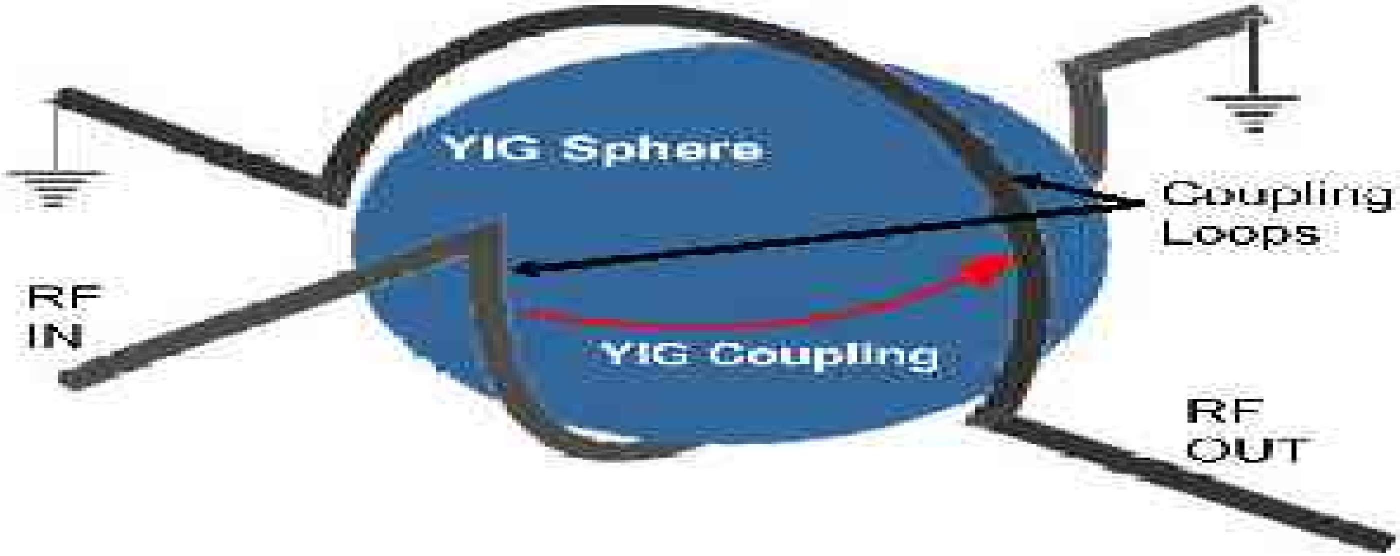
- Power: X_c

E_c

Frequency Counter

YIG

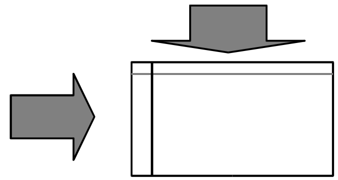
- YIG (Yttrium Iron Garnet) ferrite cristal, high Q material.
- Natural frequency can be modulated by an external magnetic field.
- Used as band filter.
- RF IN induces magnetic field in the YIG sphere.
- YIG sphere induces a magnetic field in the RF OUT.
- Frequency bandwidth depends on distance sphere-Coupling loop.

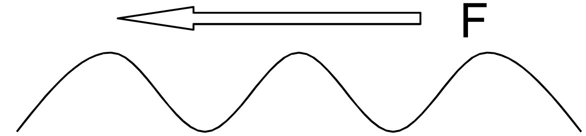


Frequency Counter

Traditional wavemeter

Resonance cavity





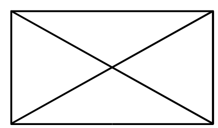
F

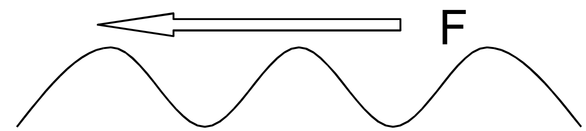
$$Frequency = 70GHz \pm 0.1MHz \Longrightarrow \lambda = 4mm \pm 2nm$$

Read-out error of 0.1%

Heterodyne technique

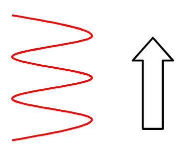
Waveguide mixer



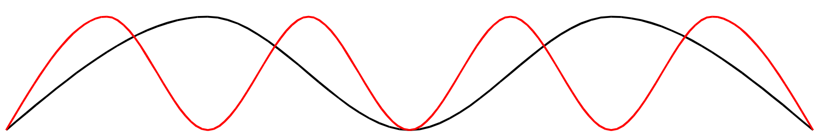


F

Variable reference signal (Local Oscilator)



LO



Measure the difference in phase

Attenuator tes