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Scintillating polarized targets for spin physics: progress & prospects

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PSI-JINR Dubna collaboration with

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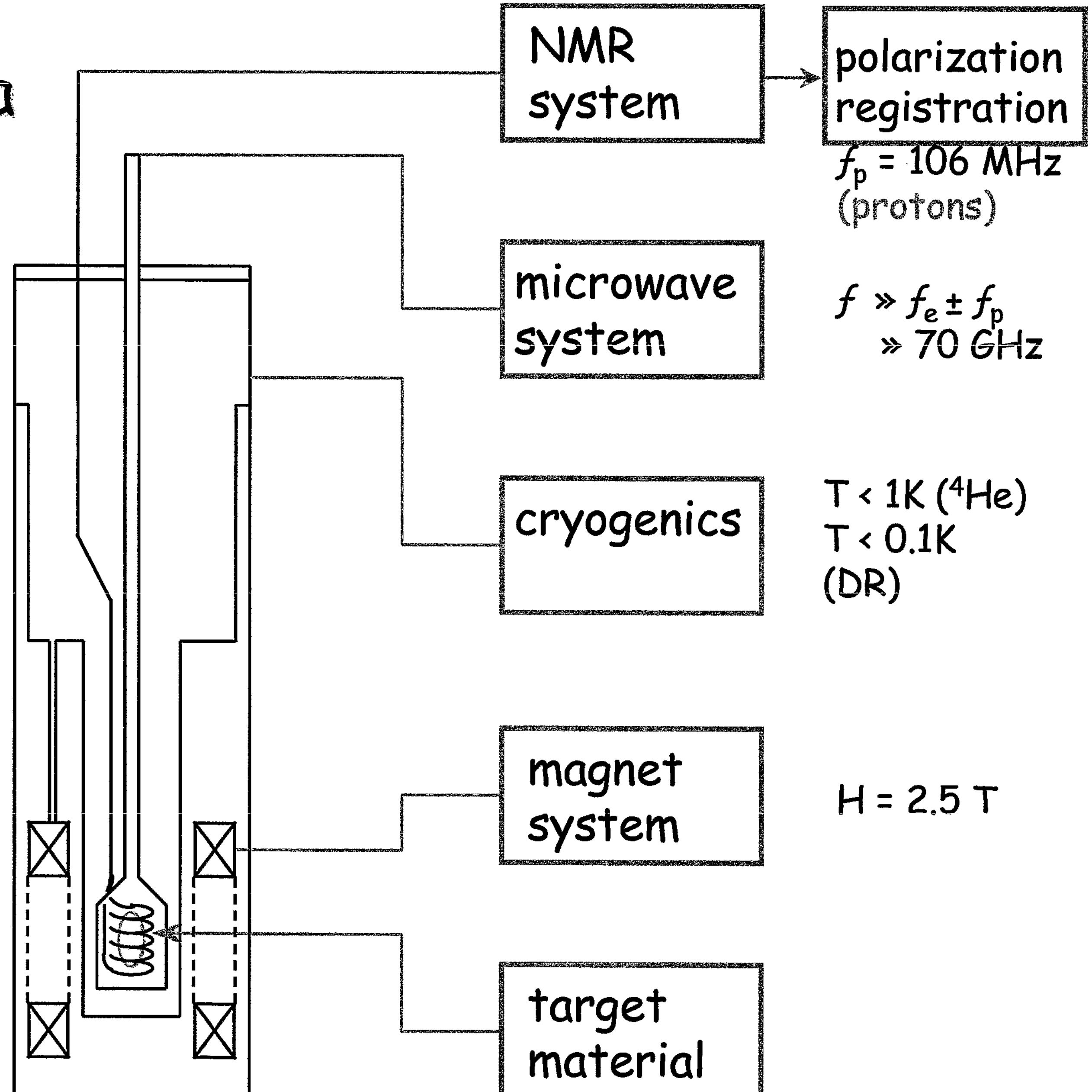
a special polarized target:

polarized nuclei in the scintillating detector itself

- coincident *in situ* detection of low energy recoil protons in the target itself
- suppress background scattering by TOF
- many new possibilities for the measurement of spin-dependent observables in nuclear and particle physics (np, πp, γp, γd,......)

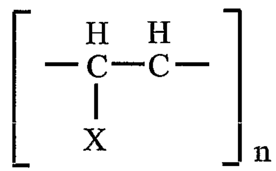
Components of a Polarized Solid Target



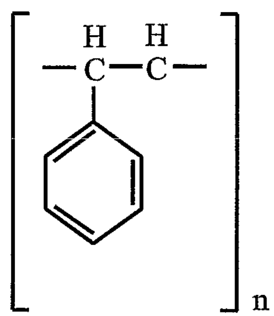
What is a scintillator ?

transparent vinyl-aromatic polymer with
transparent luminescent additives

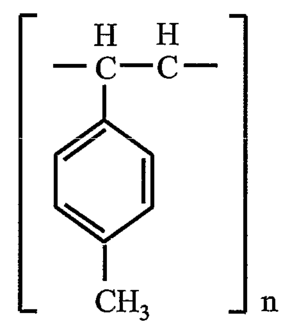
vinyl



vinyl-aromatic

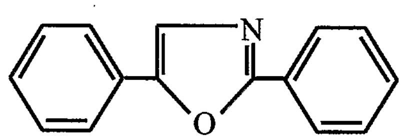


PS

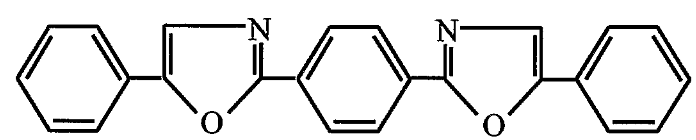


PVT

additives

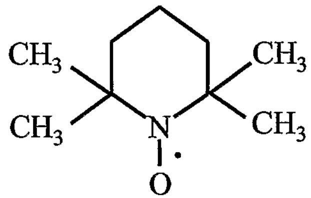


2,5-diphenyloxazole



1,4-di-(2-(5-phenyloxazolil))
benzene (POPOP)

Polarization requires doping



2,2,6,6-methyl-piperidine-1-oxyl
(TEMPO free radical)
conc. ~ 0.5 wt %

introduce TEMPO by solution

- dissolve scintillator in toluene
- add the free radical
- let the toluene evaporate at RT

➔ scintillating 40 μm thick films

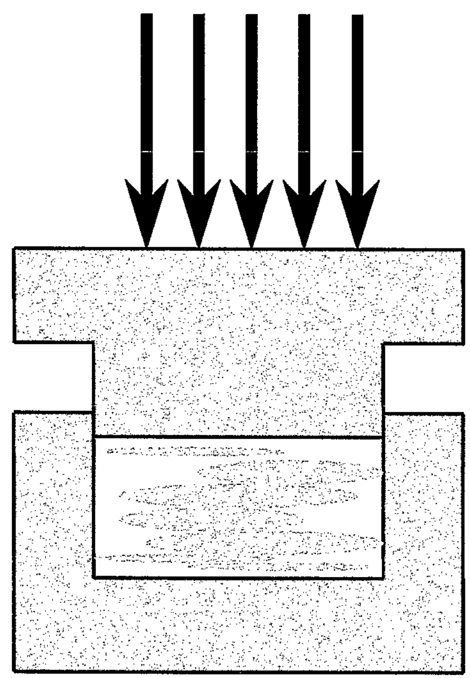
bubble free and transparent
homogeneous TEMPO distribution
high proton polarization P = 80 %

How to produce blocks of polarizable scintillator ?

warm pressing

1 - 4 h at 100 °C - 130 °C

➔ scintillating 5 x 18 x 18 mm blocks



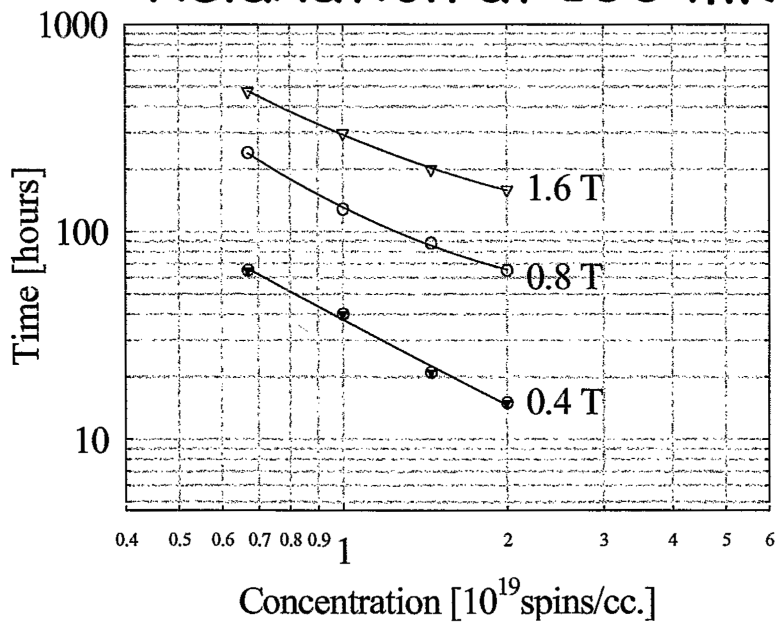
DNP results

PS based scintillator + TEMPO 2.10[19] Spins/cc

P_{max} = +84 / -83 %

polarization from 0 % → 60 % in 85 min
-80 % → 80 % in 7 hours

Relaxation at 100 mK



B. van den Brandt, E.I. Bunyatova, P. Hautle, J.A. Konter. S. Mango, *Polarized scintillator targets*, Nucl. Instr. Meth. **A446** (2000) 592-599

Scintillation characteristics

(compared to untreated material)

light output	: > 30 %
detection limit	: protons > 1.5 MeV
energy resolution	: degraded to ~ 25 %
timing resolution	: unchanged

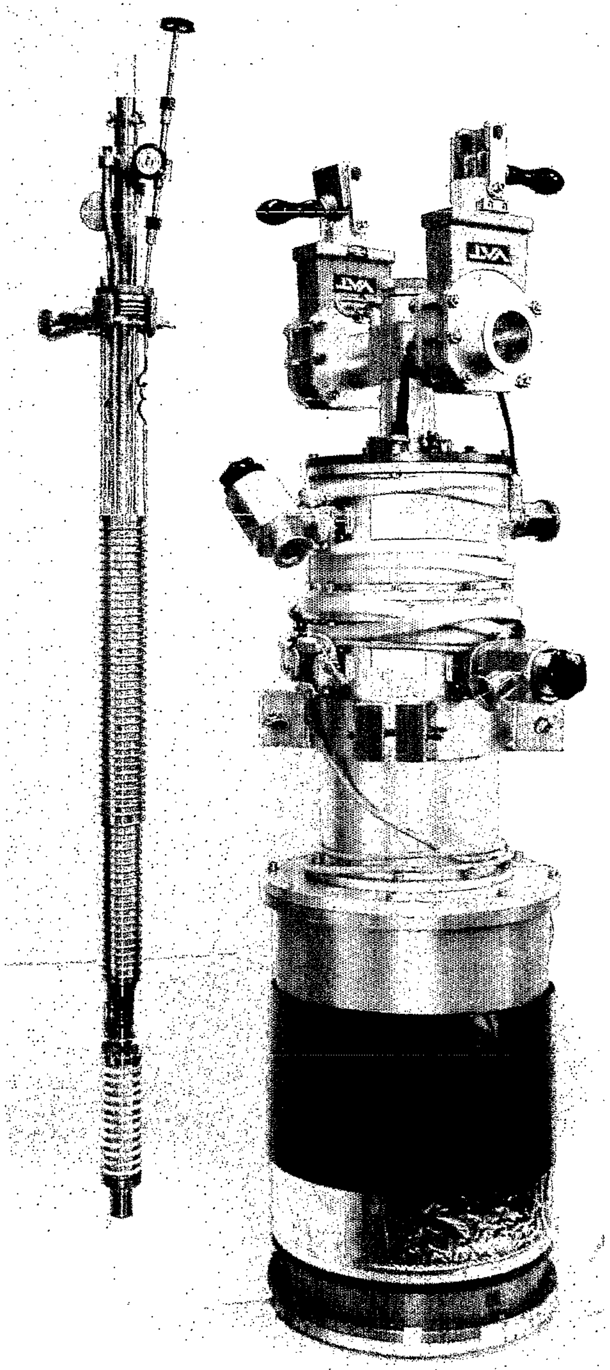
Characterization and verification with

- with ^{90}Sr source
- protons from a tandem accelerator
- actual scattering experiments (neutrons & pions)

light extraction

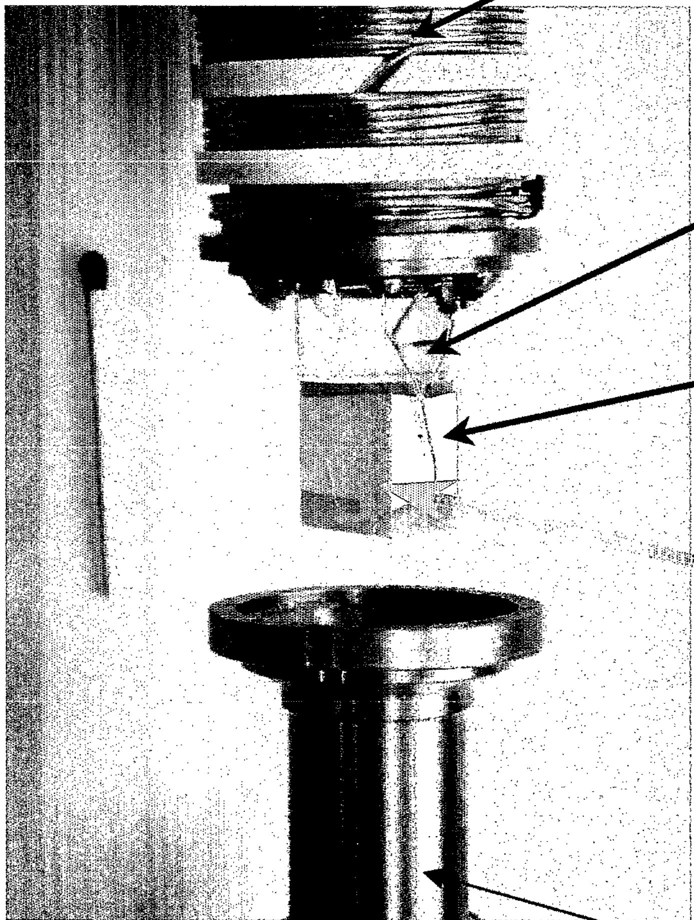
simulation with raytracing (GUIDEIT)

➔ 19 mm lightguide (BC 800) 36.4% (of produced photons)



via lightguide to PM at 300 K

heat exchanger
dilution refrigerator

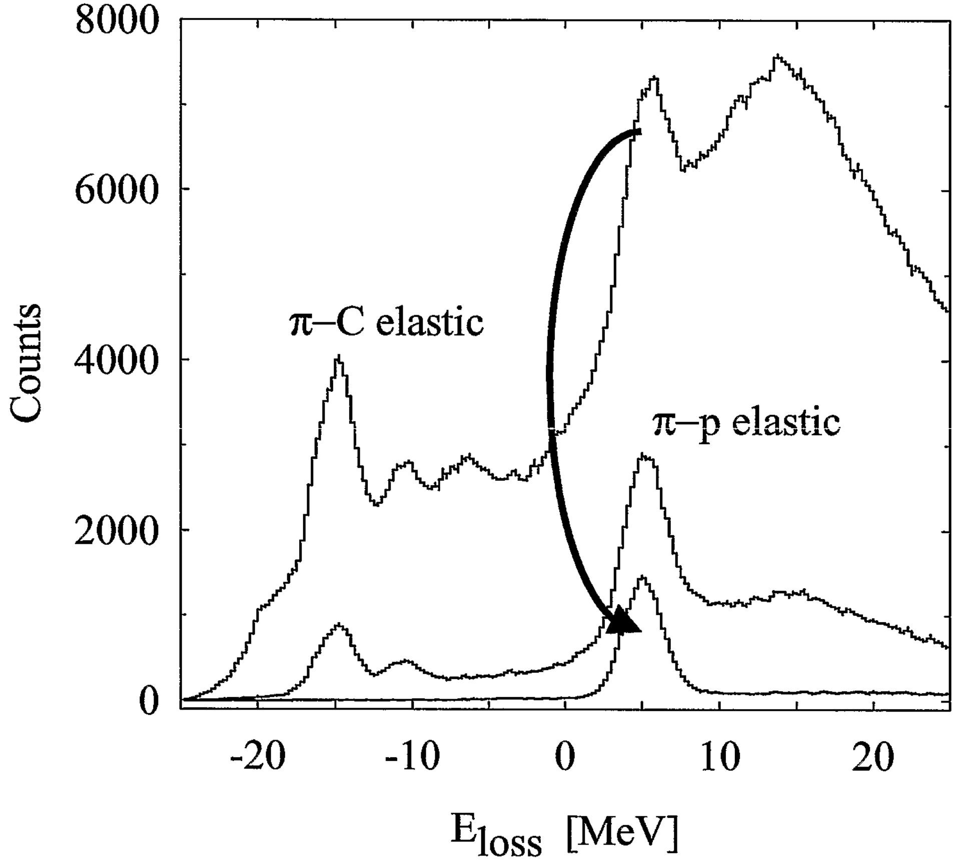


quartz adapter

scintillator block,
polarized nuclei
(at T < 100 mK)

beam
(π, γ, n ...)

microwave cavity



E_{loss} spectra taken with LEPS and active polarized target

upper curve : raw LEPS information
middle curve : coincident signal in target
lower curve : minimum energy deposition in target required

achievements

PS-based scintillator	5 x 18 x 18 mm
Proton polarization	84 %
during experiment on beam	60 %
scintillation efficency	30 %
deuterated scintillator with	P_d = 25 %

dilution refrigerator with built-in lightguide

lowest temperature	63 mK

Experiments realized at PSI

6 month : np - scattering
3 month : πp - scattering

➔ is this the end ?

progress

the specific experimental restrictions and possibilities revisited

the scintillator

- base materials + solvents
- radicals
- production process

→ **scintillation & polarization properties**

other possible experiments

- shapes
- mechanical properties

→ **PT & Cryostat design**

the composition

the solution of the base material in the corresponding solvent

aromatic polymers + p-terphenyl
(PS, PVT)

- high lightoutput
- less favourable mechanical properties, films and sheets are brittle
- very good radiation hardness

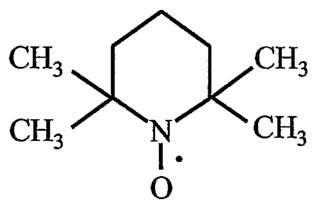
alifatic polymers + naphtalene
(PMMA, plexi glass)

- very good mechanical properties, flexible films and sheets are very tough
- glass clear
- lower lightouput

in solvents:
toluene, benzene,
MEK, tetrahydrofurane

TEMPO

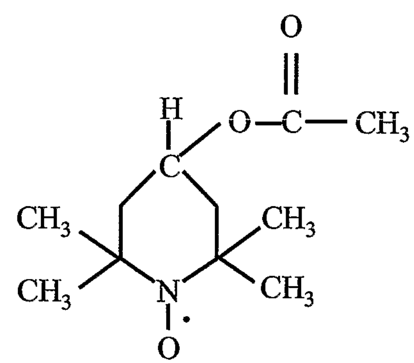
is coloured



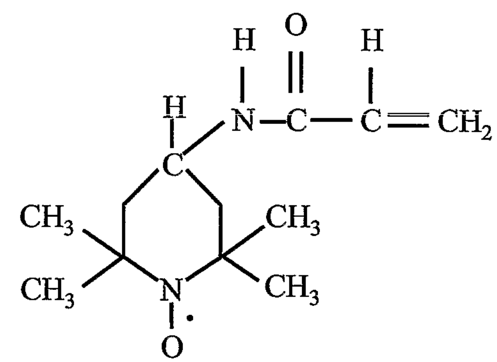
2,2,6,6-tetramethyl-piperidine-1-oxyl (TEMPO)
$C_9H_{18}NO$ M=156

TEMPO derivatives

less coloured



2,2,6,6-tetramethyl-4 acetooxypiperidine-1-oxyl (aceto-TEMPO)
$C_{11}H_{20}NO_3$ M=214



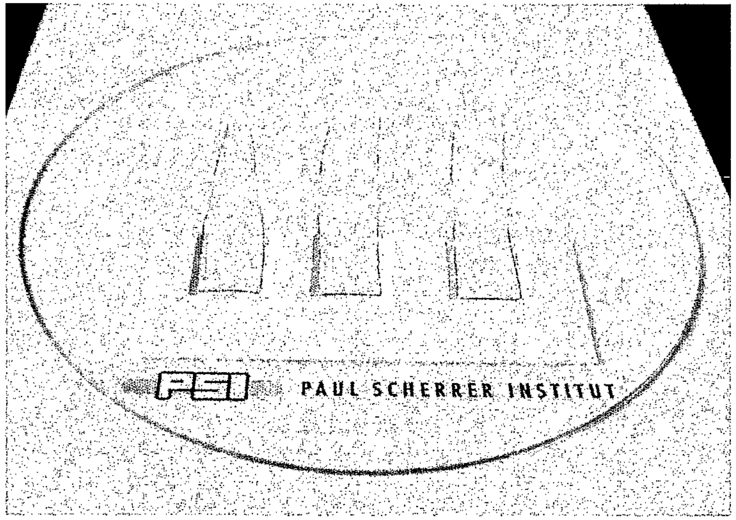
2,2,6,6-tetramethyl-4-acryl-amidopiperidine-1-oxyl (TEMAAPO)
$C_{12}H_{21}N_2O_2$ M=225

absorbs scintillation light

shifts emmission spectrum

425 nm to > 500 nm

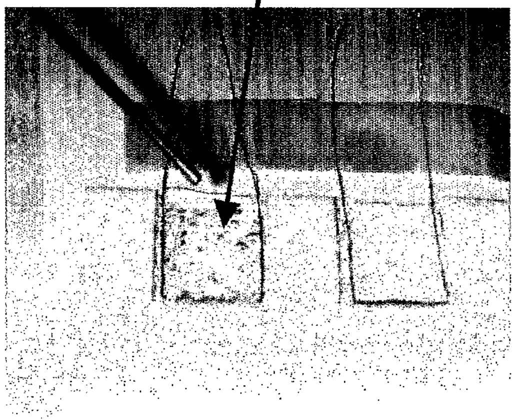
production process

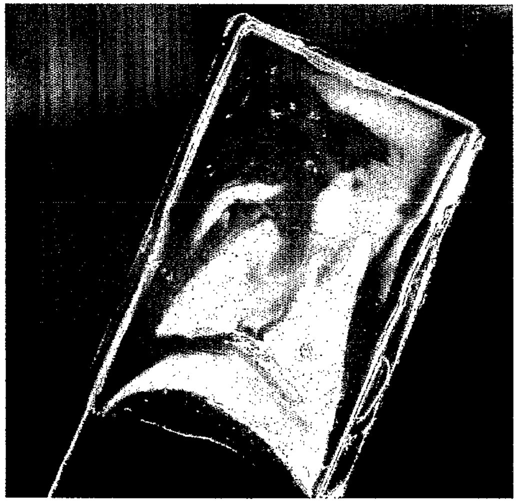


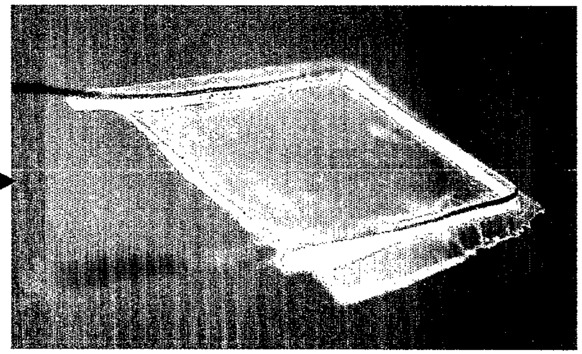
scintillator in solvent + free radical

dried (solvent evaporated)

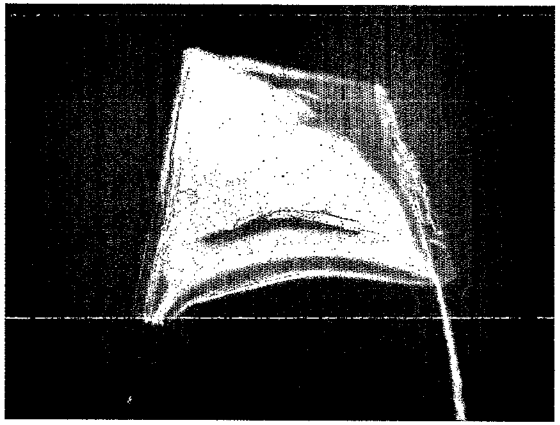
Scintillating (UV light)





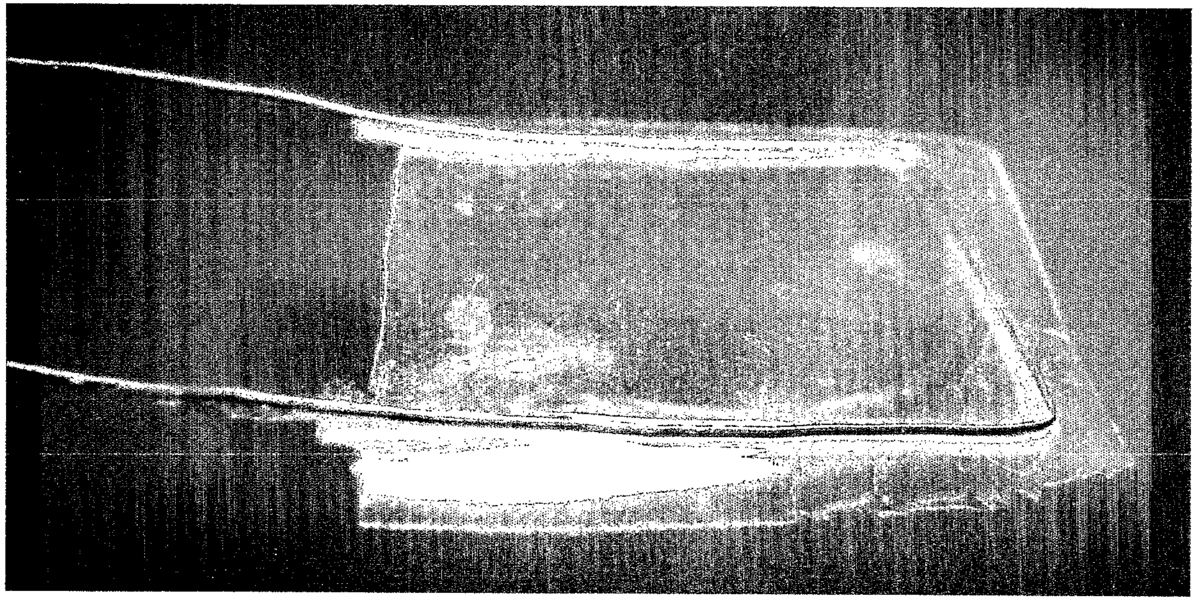


70 μm thick PMMA scintillator + aceto-TEMPO



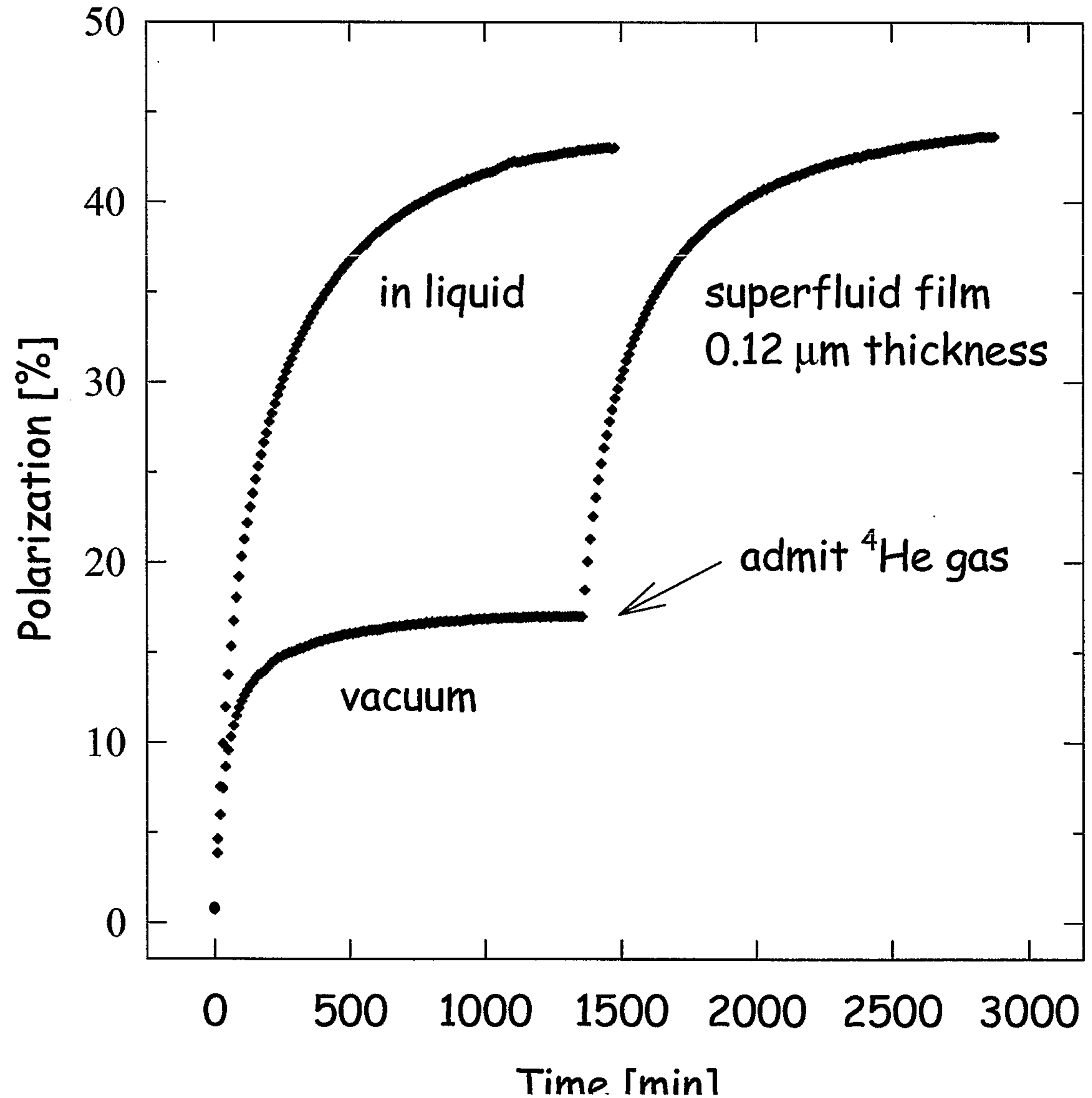
P = +/- 76 %

0 → 70 % in 45 min



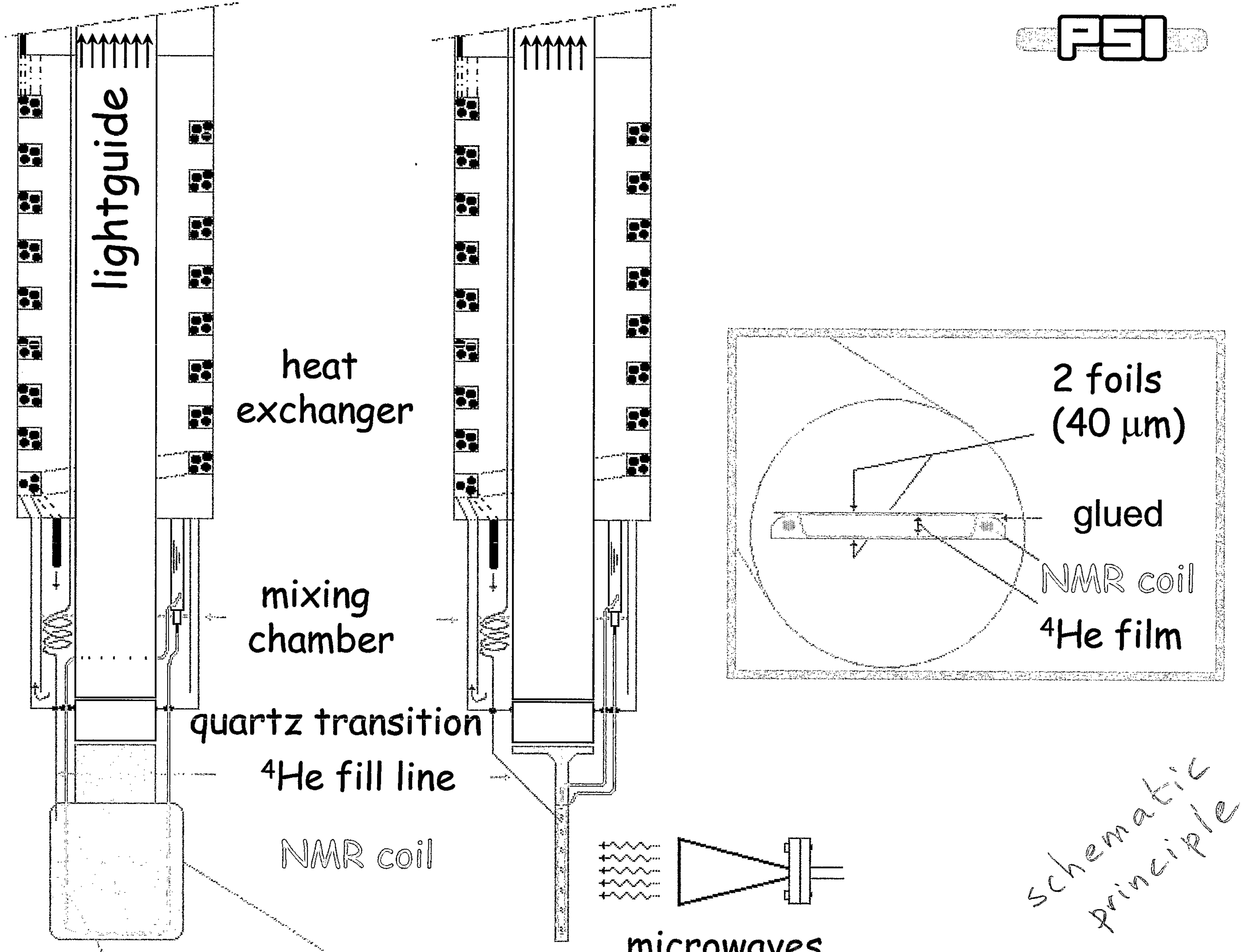
transparent 40 mm thick film
PS scintillator + TEMAAPO

DNP of thin foils in "vacuum" ?



➔ Cooling via a superfluid ^{4}He film !!

Ref: NIM **A381** (1996) 219


lightguide
heat exchanger
mixing chamber
quartz transition
4He fill line
NMR coil
microwaves
2 foils (40 μm)
glued
NMR coil
4He film
schematic principle

prospects

deuterated scintillators

deuterated TEMPO & TEMPO derivatives

"colorless" block scintillators

TEMPO derivatives, alternative production

➔ better scintillation properties

50 μm polarized scintillating target

➔ new class of experiments

heavy ions, radioactive beams, fusion ?

conclusion

the scintillating PT is an experimentally well proven instrument

much more potential

sample production

find the best composition of
radical + base material + solvent
and the optimum preparation method

not a dedicated instrument!

many possible experimental questions and physical conditions can be met :

beams, space available, target shapes, ...

more information:
ltf.web.psi.ch