RUHR-UNIVERSITÄT BOCHUM

FAKULTÄT FÜR PHYSIK UND ASTRONOMIE

RUB

SPIN 2018

23RD INTERNATIONAL SPIN SYMPOSIUM

September 10-14, 2018 at Ferrara, Italy

COMPASS polarized target in 2018 and 2021
on behalf of the COMPASS Collaboration

G. Reicherz

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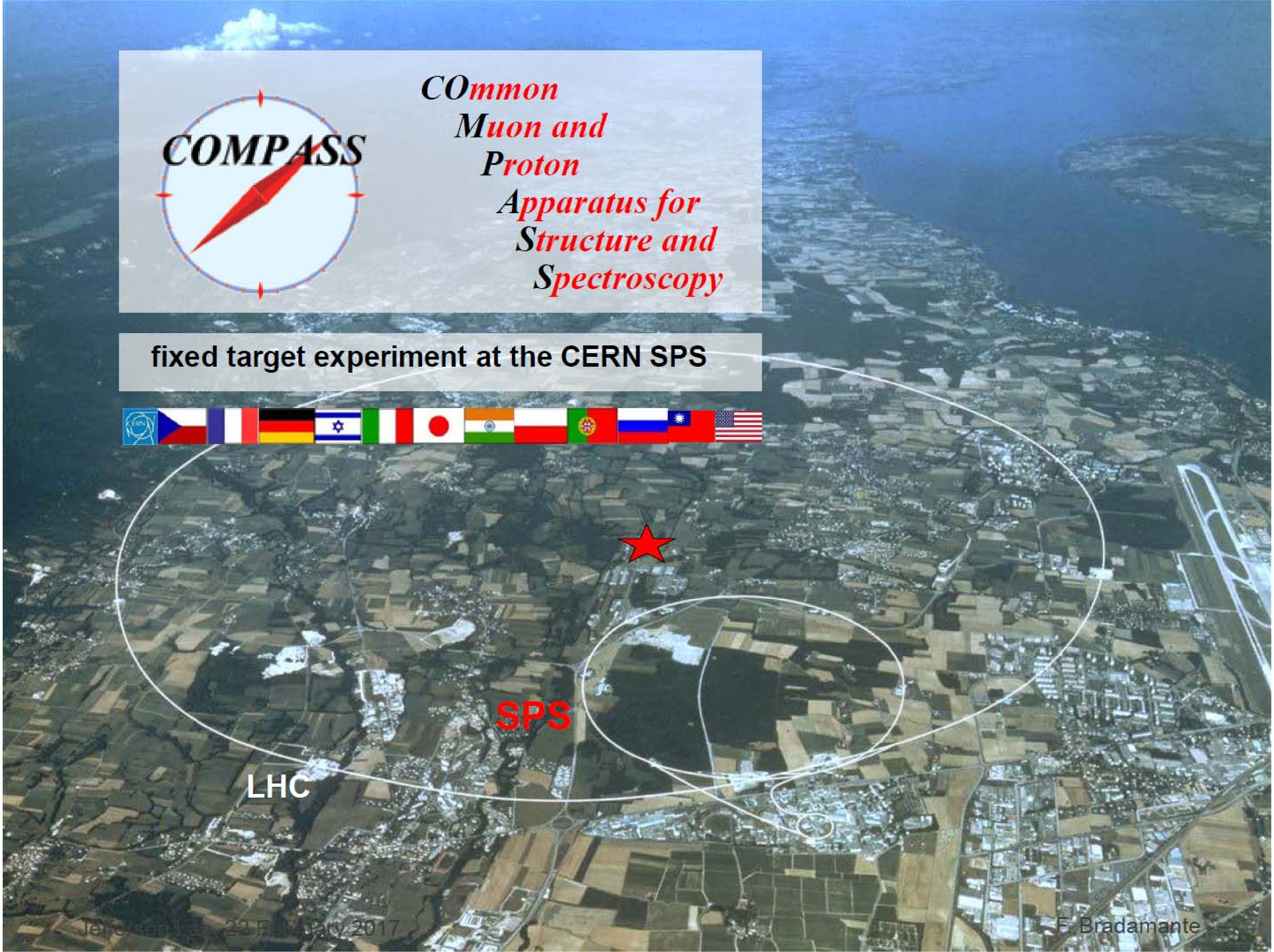

COMPASS
COmmon
Muon and
Proton
Apparatus for
Structure and
Spectroscopy
fixed target experiment at the CERN SPS
SPS
LHC

COMPASS II

approved by CERN Research Board in 2010

- Polarized Drell-Yan measurement
  TMD PDFs — *π^{-} beam with polarized proton target*
- GPD measurement
  Transverse imaging — *μ^{+} μ^{-} beam with liquid hydrogen target*
- Pion and Kaon polarizability
  Chiral perturbation theory — *π^{-}, K^{-} (μ^{-}) beam with nucleus target*

With a upgraded COMPASS spectrometer

2014	Test beam Drell-Yan process with π beam and T polarized proton target
2015	**Drell-Yan process with π beam and T polarized proton target**
2016	**DVCS / SIDIS with μ beam and unpolarized proton target**
2017	**DVCS / SIDIS with μ beam and unpolarized proton target**
2018	**Drell-Yan process with π beam and T polarized proton target**

Introduction

Structure of the nucleon

- 8 intrinsic transverse momentum dependent PDFs
- Asymmetries with different angular dependences on hadron and spin azimuthal angles, *Φh* and *Φs*

nucleon polarization (columns); **quark** polarization (rows)

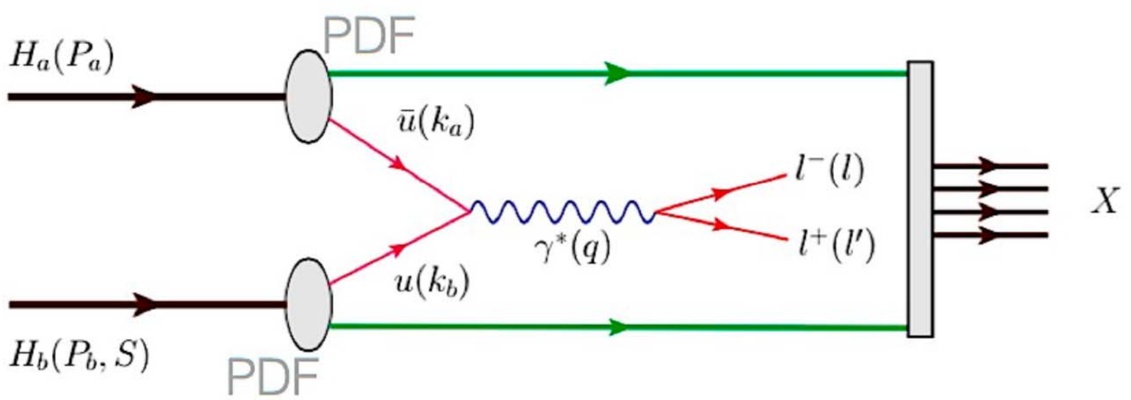
	U	L	T	
U	f_1 number density q		$f_{1T}^{\perp}$ - Sivers	$\Delta_0^T q$
L		g_1 - helicity Δq	g_{1T} -	
T	$h_1^{\perp}$ - Boer Mulders	$h_{1L}^{\perp}$ -	h_1 - transversity; $h_{1T}^{\perp}$ -	$\Delta_T q$

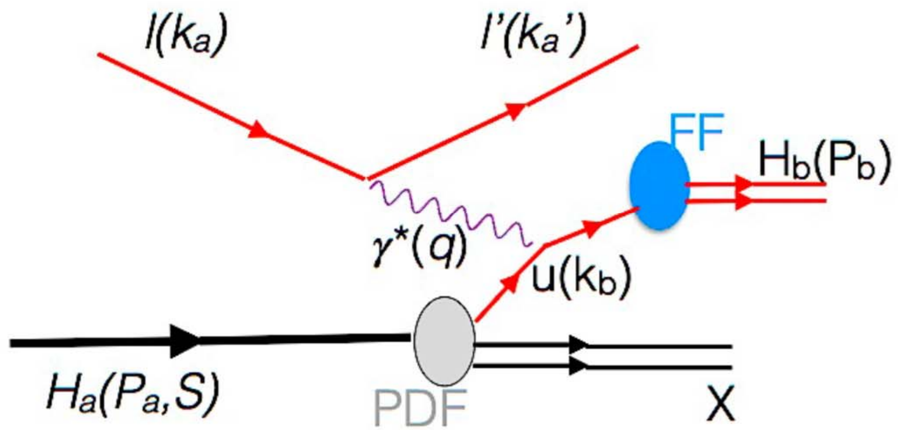
SIDIS gives access to all of them

Drell-Yan and SIDIS

Drell-Yan Process

Semi-Inclusive DIS process





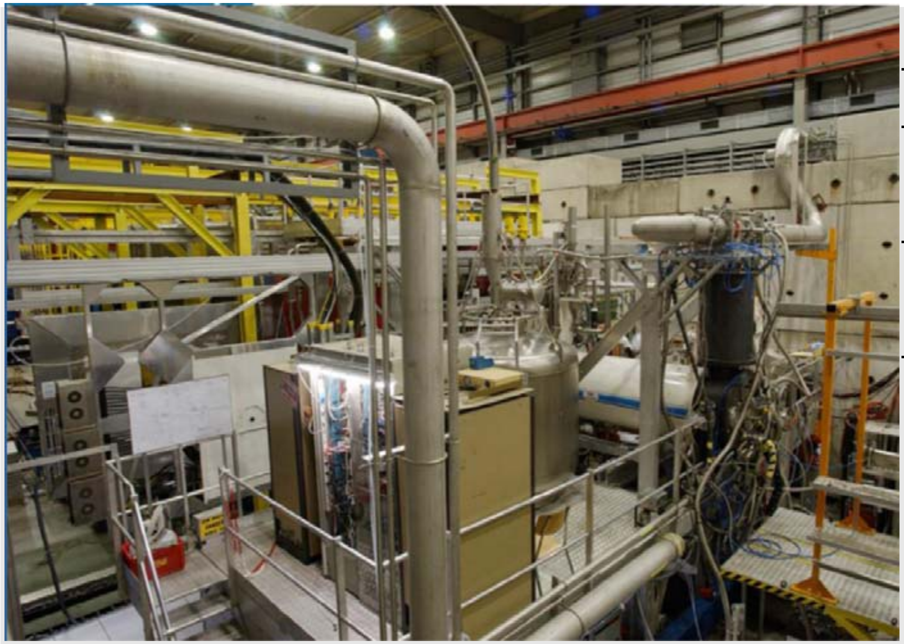
- Quark-Antiquark annihilation with two leptons in the final state
- Small cross section
- Describe the cross section with convolution of two PDFs only

$$(PDF)\otimes(PDF)$$

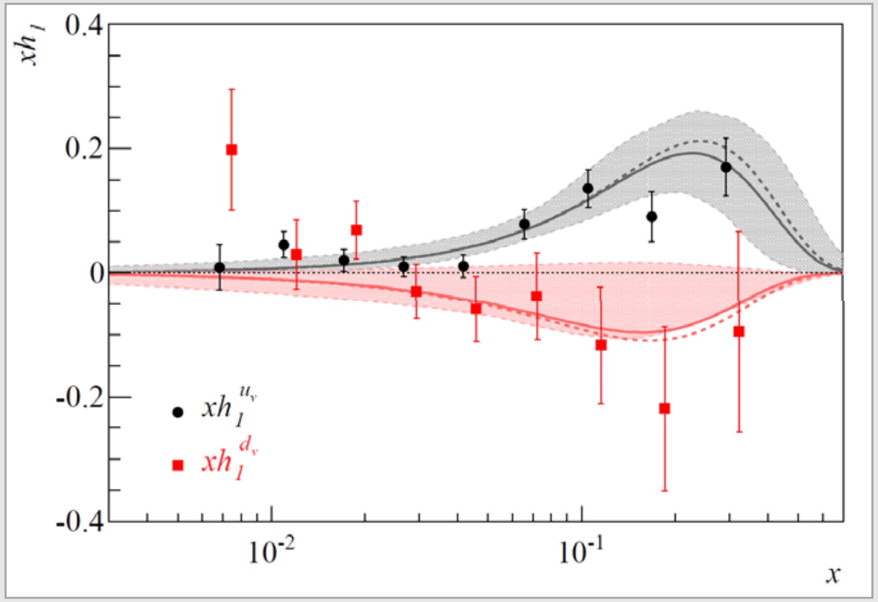
- Describe the cross section with convolution between PDF and FF
- Higher cross section
- Uncertainty of FF

$$(PDF)\otimes(FF)$$

SIDIS – transversely polarized Deuteron Target Transversity/Sivers PDF extraction



- TMD PDFs and Transversity $h_1(x)$ are flavor dependent
- Flavour separation -> data on both proton and deuteron transversely polarized targets
- Proton data set is factor 4 compared to deuteron (see error bars for transversity $h_1(x)$ in the plot below)
- It's logical to increase the deuteron data set (so far the only data sets available are COMPASS (^{6}LiD) and CLAS (^{3}He) target



A. Martin, F.B., V. Barone PRD91 (2015) 014034

A new measurement of SIDIS on transversely polarized deuteron is proposed

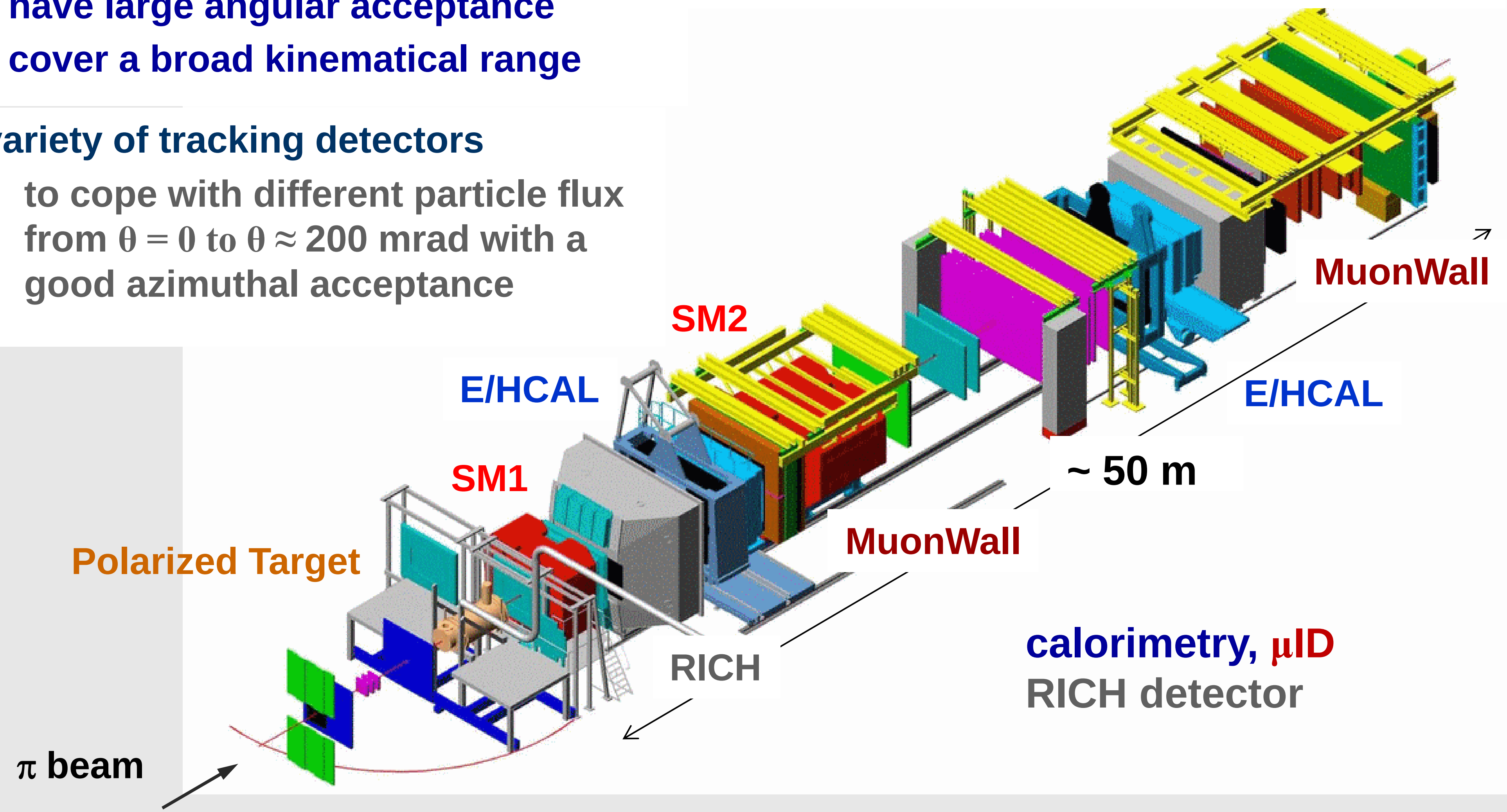
COMPASS setup in 2018

designed to
- **use high energy beams**
- **have large angular acceptance**
- **cover a broad kinematical range**

variety of tracking detectors

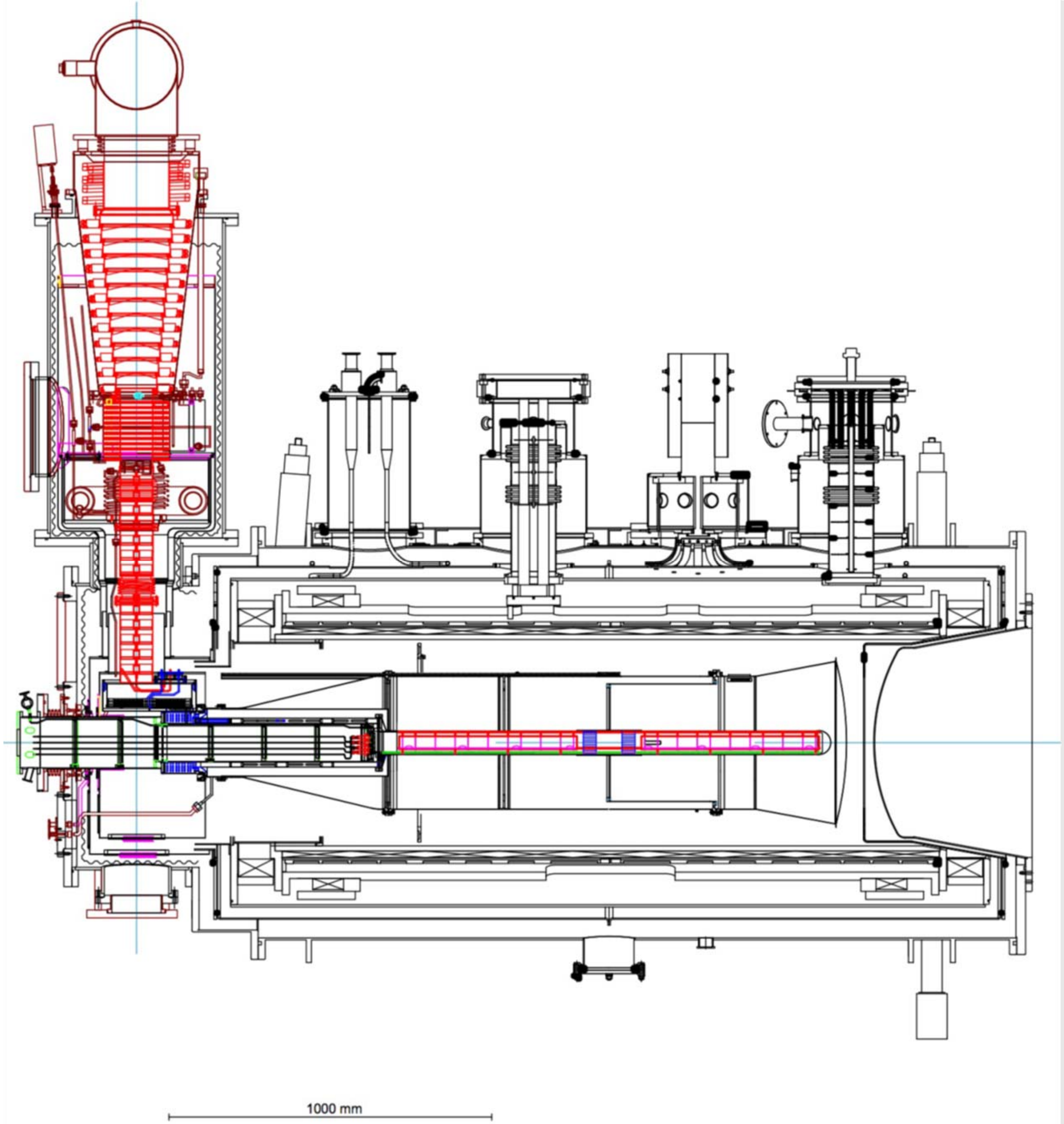
to cope with different particle flux from $\theta = 0$ to $\theta \approx 200$ mrad with a good azimuthal acceptance

Two stages spectrometer
- **Large Angle Spectrometer (SM1)**
- **Small Angle Spectrometer (SM2)**



calorimetry, μID
RICH detector

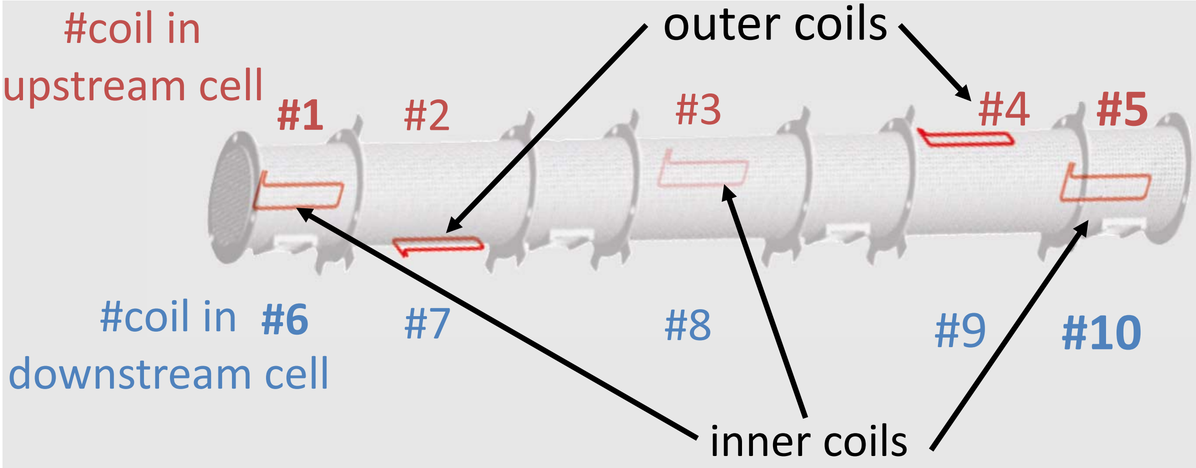
COMPASS Polarized Target



First time hadron beam was used with the COMPASS PT system

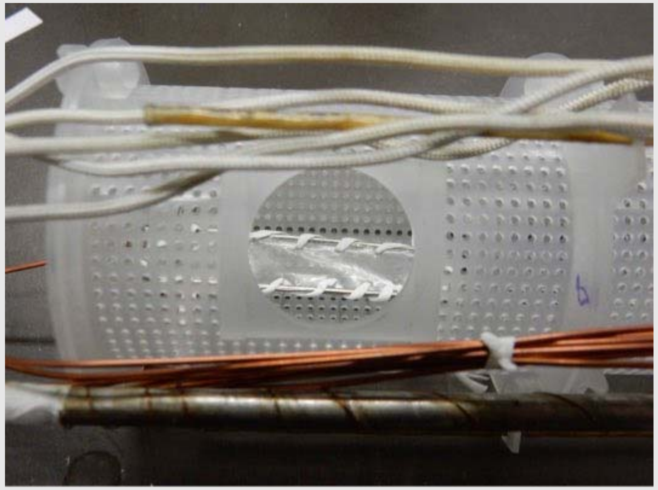
- 2.5 T solenoid + 0.6 T dipole
- 50 mK dilution refrigerator
- 2 x 55 cm long target cells
- NH_3 as proton target (17% df)
- DNP by microwave of 70 GHz
- 10 NMR coils
- Frozen spin mode at 50mK

Target cells and NMR coils

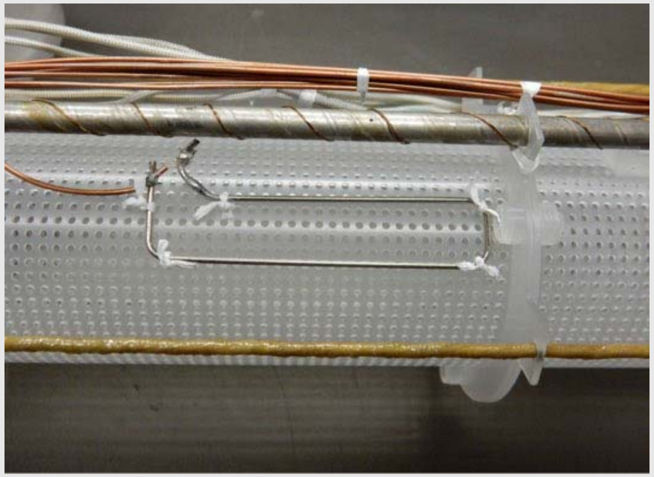


Target cell

- 55 cm × ∅ 4 cm
- made with $(C_2F_3Cl)_n$ to reduce the effect on polarization measurement
- 2(3) outer coils and 3(2) inner coils for each cell
- Since high intensity hadron beam on PT is the first attempt in COMPASS, we installed inner coils which are more sensitive to the effect of the beam
- 2 cells were placed 20 cm apart
- in 2018 old SMC NH_3 material is added to fill up the cells

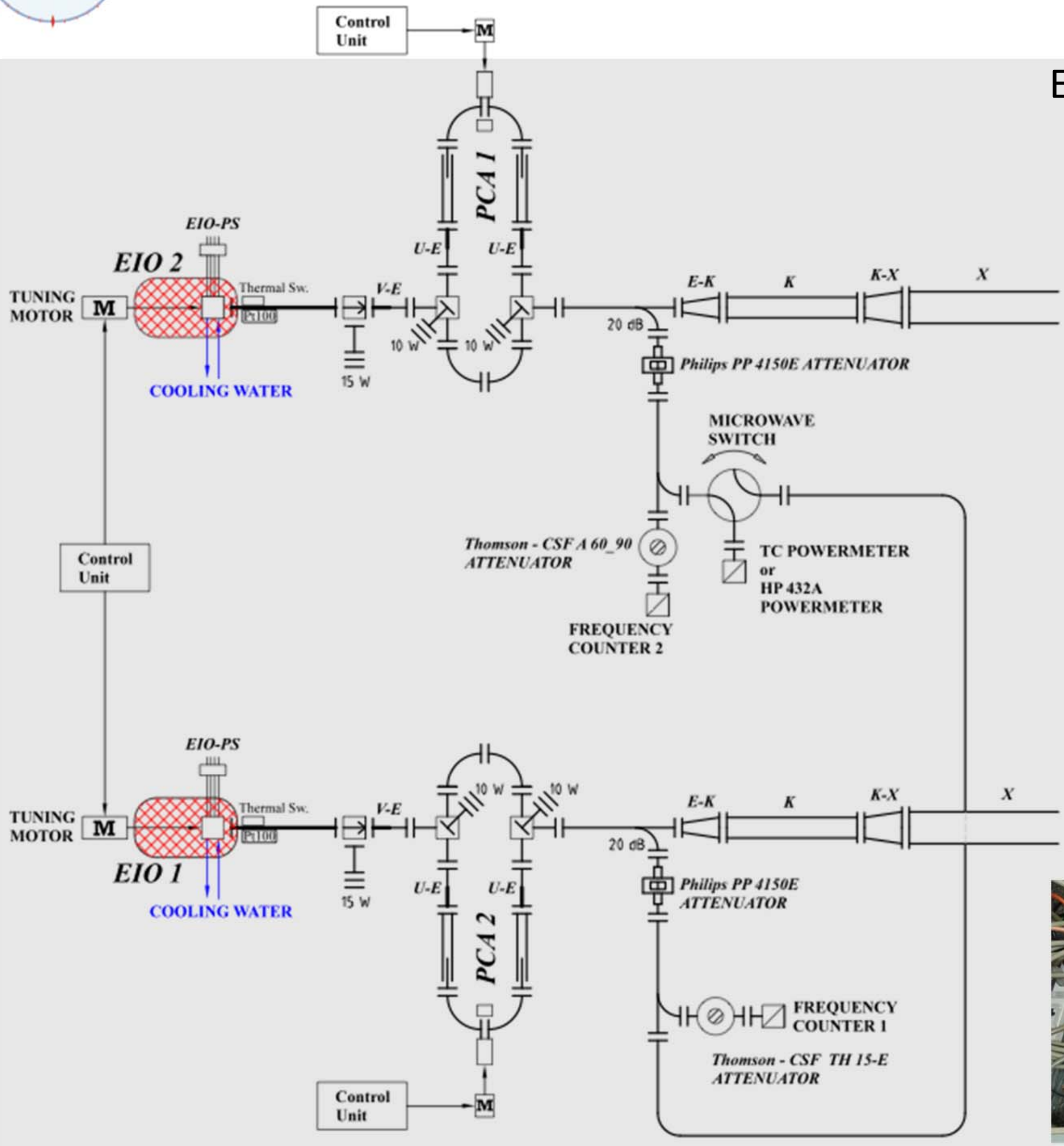


Picture of coil1 (inner)



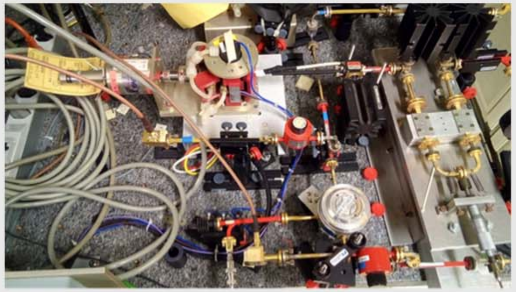
Picture of coil2 (outer)

Microwave system



Equipment

- M.W. generator
  extended interaction oscillator , 20 W
- Power supplies
  - Varian VPW2838 and
    CPI VPW2827
- Power control
- Frequency counters
  - Phase Matrix EIP-548-B
- Power meter
  - Millitech DET-12-RPFW0

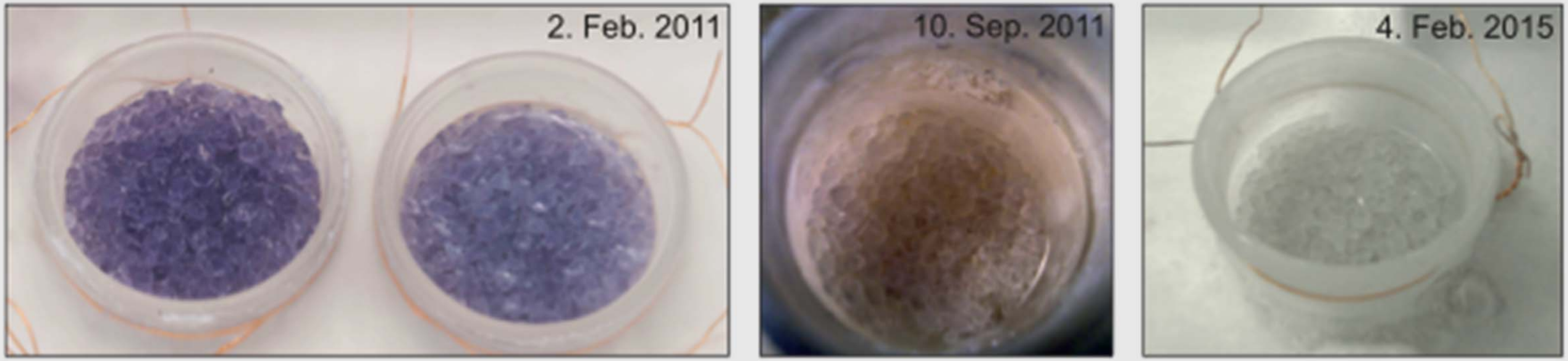


Target material Ammonia

Protons in a solid ammonia (NH_3) are used as a polarized target.

Paramagnetic centers were created by irradiating with electron beam

The NH_3 has typically 10^{-4} - 10^{-3} free radicals/nucleus.



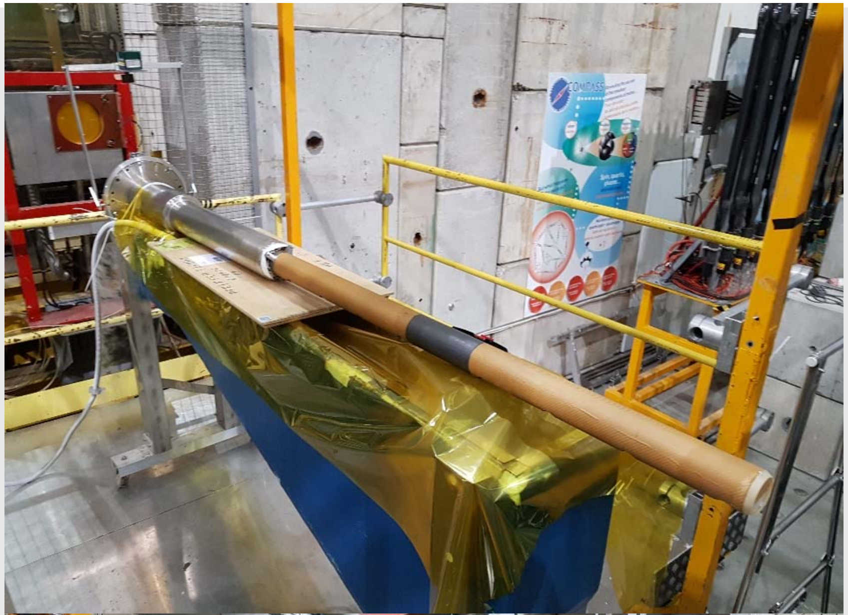
: 1 week 2 weeks 7 months 4 years

Time after radiation

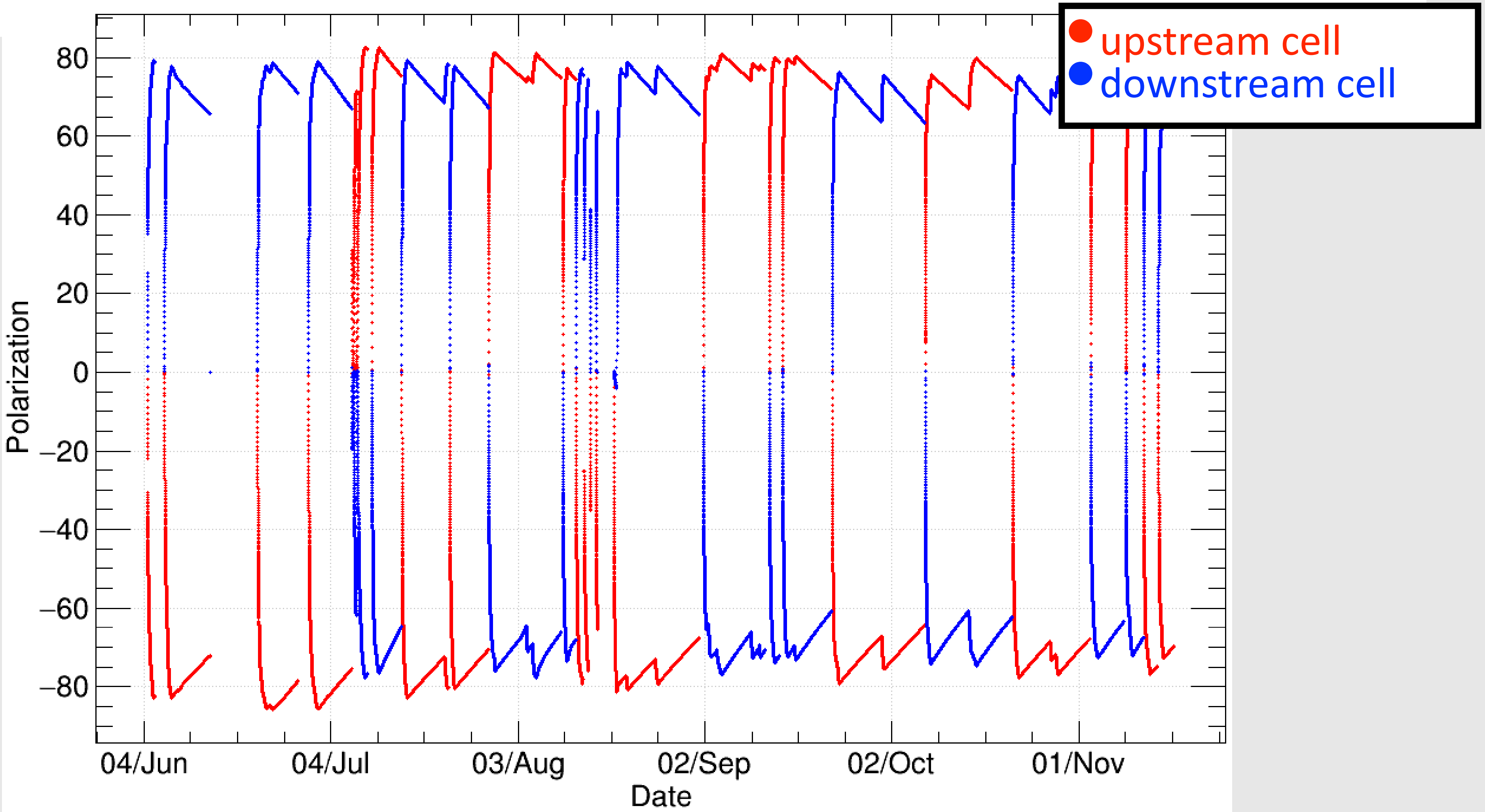
2018 we will add a few grams from the old smc materials (1996)

its still polarizable very high but slower build up and relaxation times

Target loading April 17th



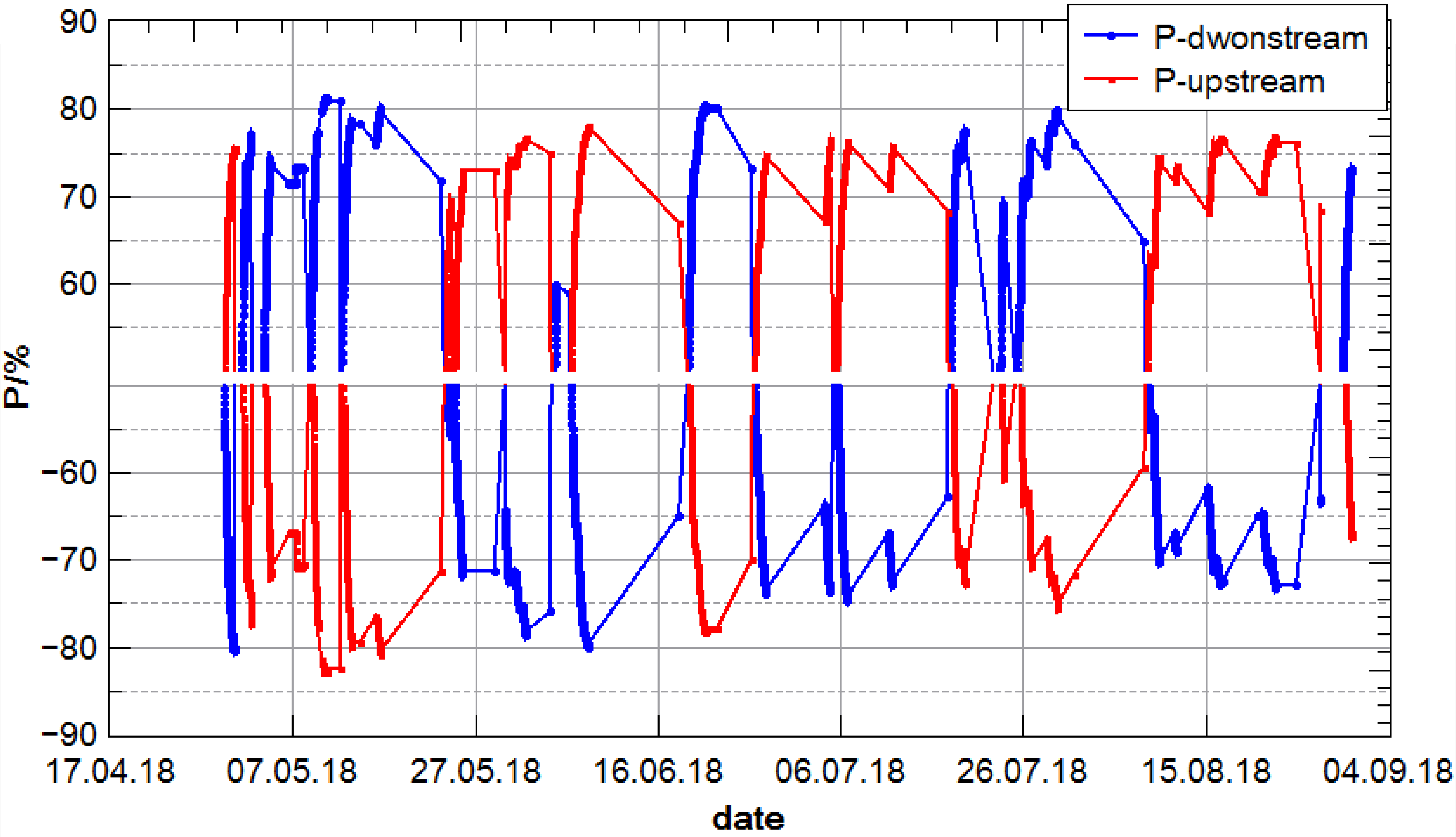
Polarization in 2015



Maximum Polarization
- upstream : 82.7% , -86.0%
- downstream : 79.3% , -77.8%

Typical polarization during phys. data taking
- upstream : 74.2% , -71.4%
- downstream : 69.2% , -67.0%

Polarization in 2018



Maximum Polarization

upstream : 78.1% , -82.8%

downstream : 81.3% , -80.5%

preliminary

Deuteron Targets for SIDIS

A new measurement of SIDIS on transversely polarized deuteron is proposed (2021)

Possible materials are

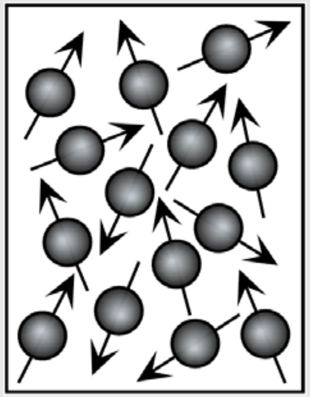
- **^{6}LiD**
- **D-Butanol**
- **ND_3**

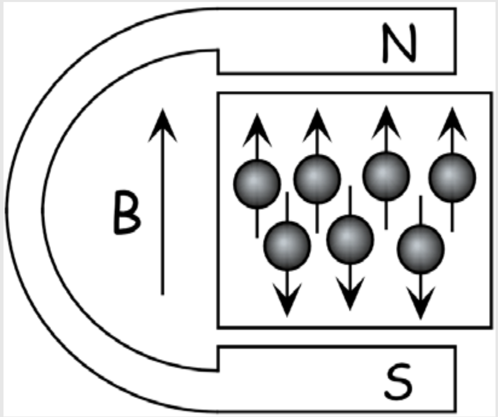
About 900ccm are needed

Nucleon Polarization

Polarization = Orientation of Spins in a magnetic field

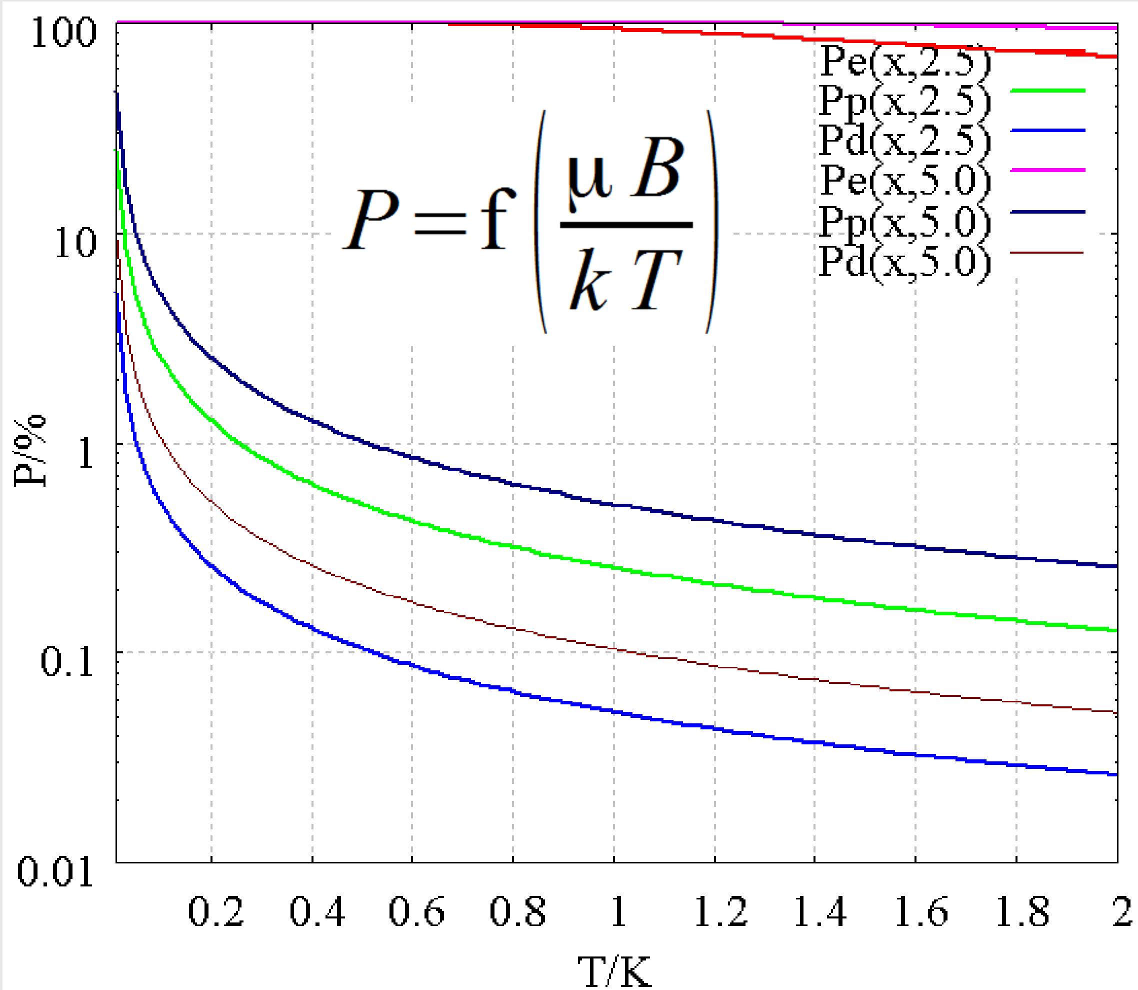
e⁻-, p- and d-polarization vs temperature





$$P = \frac{N\uparrow - N\downarrow}{N\uparrow + N\downarrow}$$

T=1K	B=2.5 T	B=5T
electron	93.3 %	99.8 %
proton	0.255 %	0.512 %
deuteron	0.052 %	0.105 %

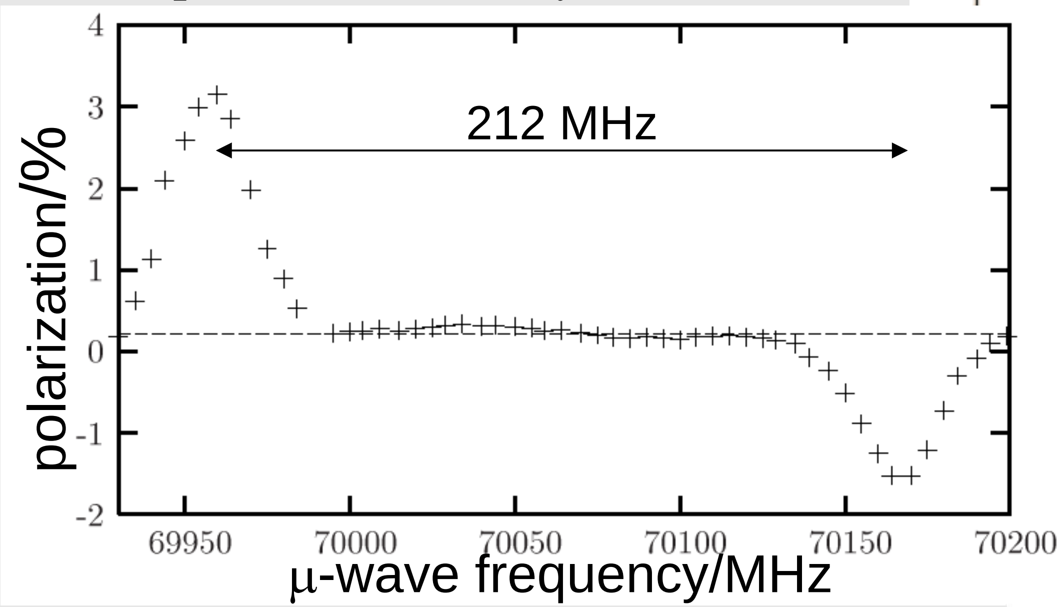


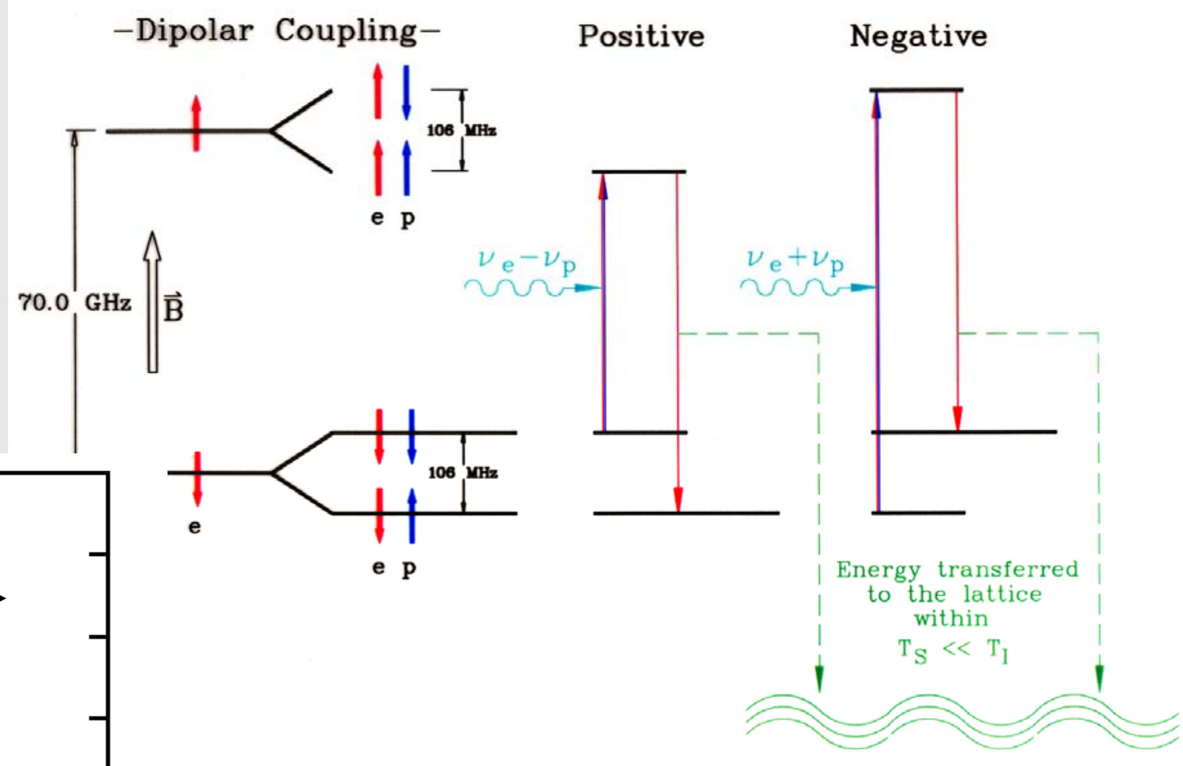
DNP: Solid State Effect(simple)

Idea: Transfer the high $P(e^-)$ to nucleon

B = 2.5T

H-Propanediol with Trityl-Radical





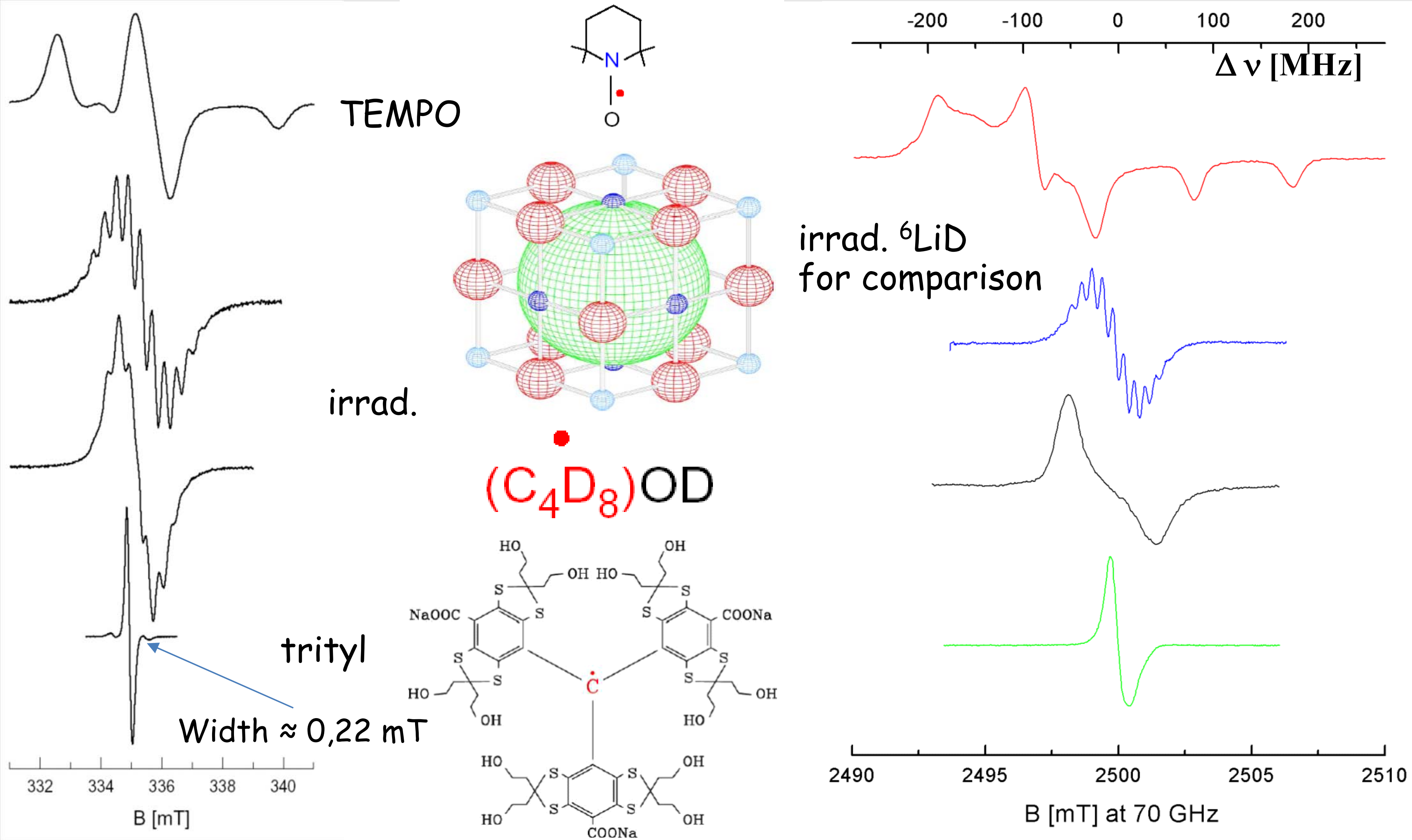
B = 2.5T and T=1K

T_1^{e-} = ms to sec

T_1^{p} = min to hours

$$|P_{max}| < \frac{|P_{TE,e}|}{1+f} \quad \text{mit} \quad f = \frac{N_I}{N_e}\frac{t_{1e}}{t_{1n}}$$

EPR spectra of dif. radicals in D-materials



Deuterated Target materials

Material	Radical	$\Delta g/g$ [10^{-3}]	FWHM [mT]	$P_{D,max}$(2T5) [%]
D-Butanol	EDBA	5.98 ± 0.03	12.30 ± 0.20	26
D-Butanol	TEMPO	3.61 ± 0.13	5.25 ± 0.15	34
D-Butanol	Porphyrexide	4.01 ± 0.15	5.20 ± 0.23	32
$^{14}ND_3$	$^{14}\dot{N}D_2$	$\approx 2 \ldots 3$	4.80 ± 0.20	44
$^{15}ND_3$	$^{15}\dot{N}D_2$	$\approx 2 \ldots 3$	3.95 ± 0.15	-
D-Butanol	Hydroxyalkyl	1.25 ± 0.04	3.10 ± 0.20	55
^{6}LiD	F-center	0.0	1.80 ± 0.01	57
D-Butanol	Finland D36	0.50 ± 0.01	1.28 ± 0.03	79
D-Propandiol	Finland H36	0.47 ± 0.01	0.97 ± 0.04	-
D-Propandiol	OX063	0.28 ± 0.01	0.86 ± 0.03	81

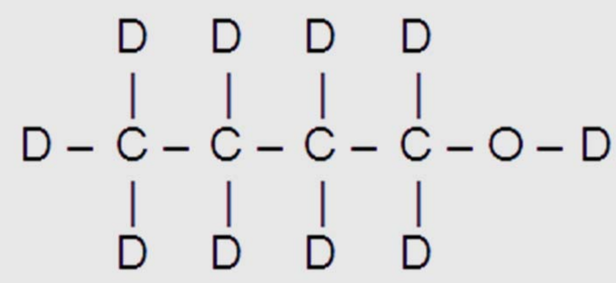
J. Heckmann, et al., Phys. Rev. B 74 (2006) 134418.

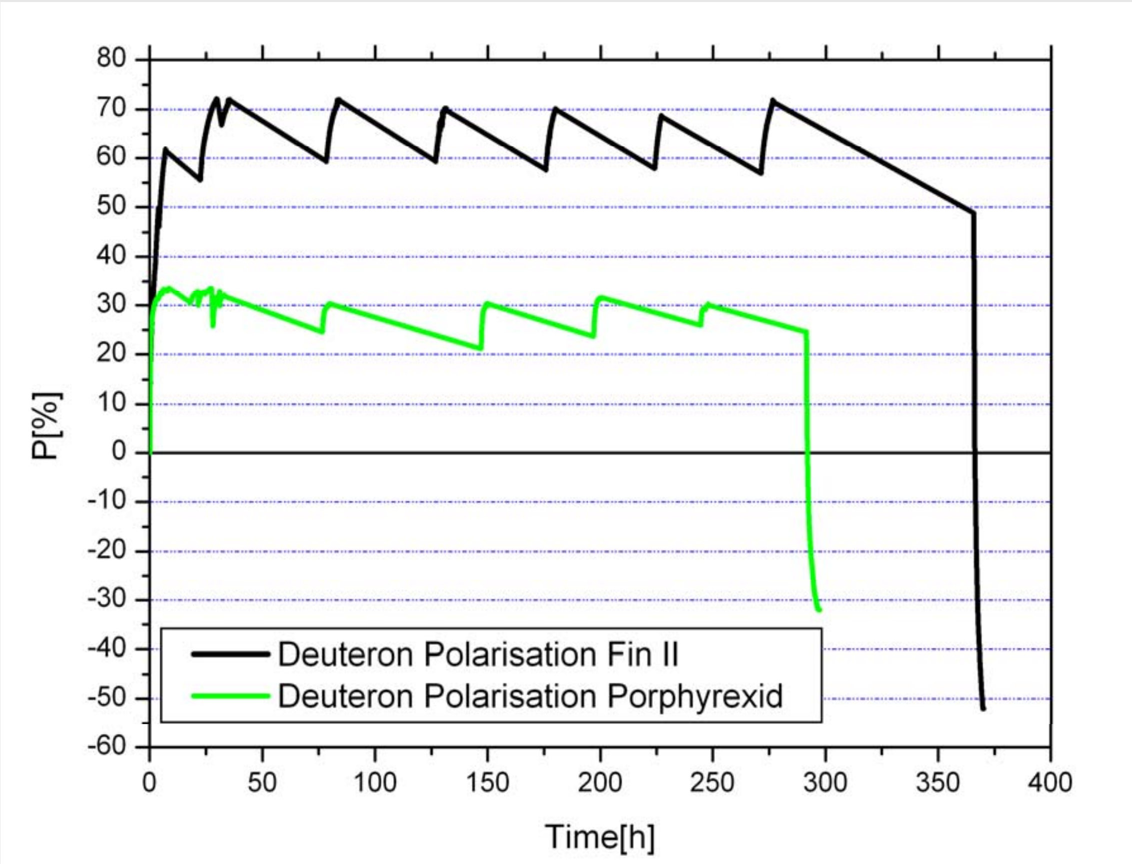
Result: The smaller the EPR line width, the higher the deuteron polarization value

Target material D-Butanol

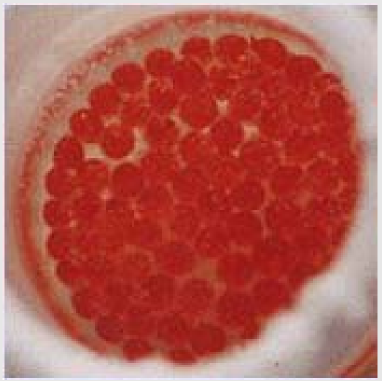
Paramagnetic center induced chemically
- Porphyrexid nitroxyl
- FINLAND trityl

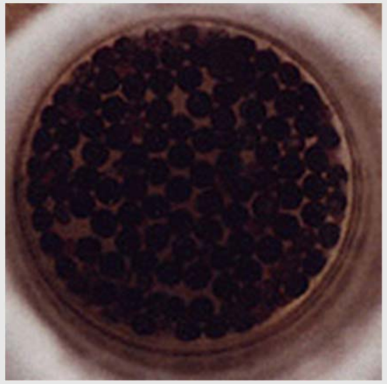
$f = 20/84 = 0.238$





D-Butanol doped with
Porphyrexid and Tritayl radical



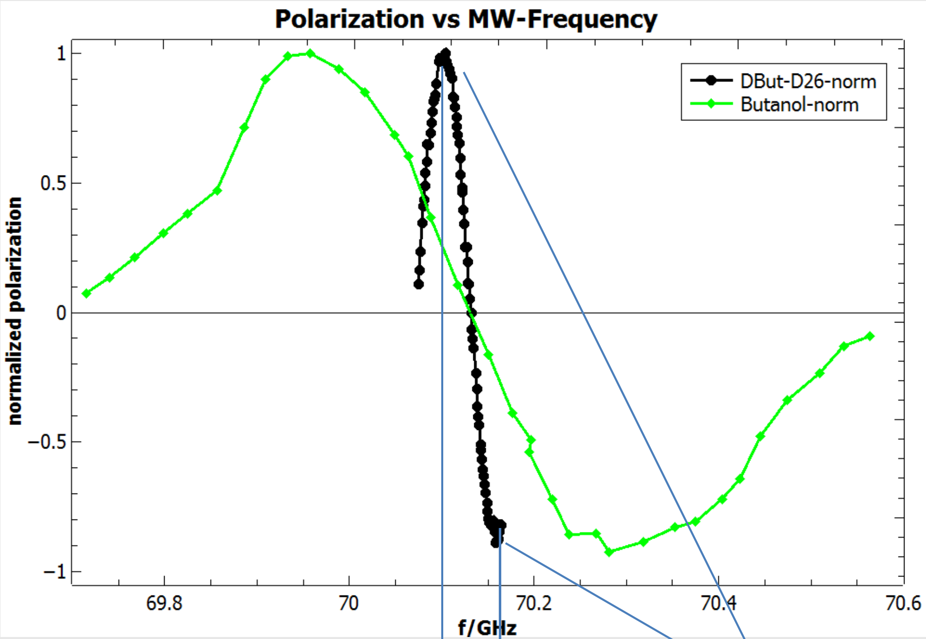


GDH 2003

$\overline{P} \approx 65\ \%$

$\overline{P} \approx 29\ \%$

Target material D-Butanol



- Trityl radical density 2 to 2.5 weight%
- $\varnothing$ 4cm · 55cm · 2 cells · 0.6 $\cong$ 830ccm
  $\Rightarrow$ 16 to 21g of radical trityl

- the magnetic field homogeniety must be about $3{\cdot}10^{-5}$

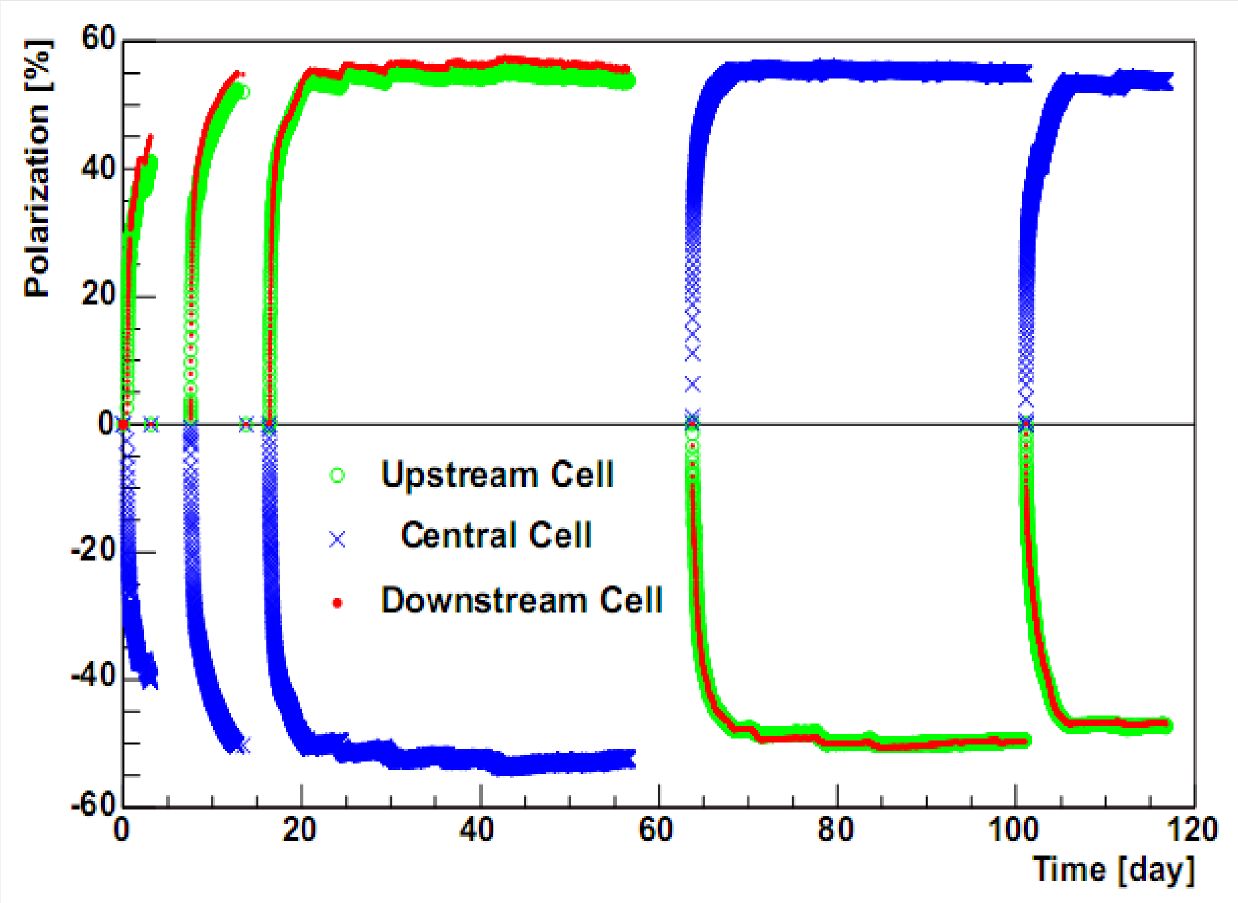
$\Delta f \approx \pm 2$MHz

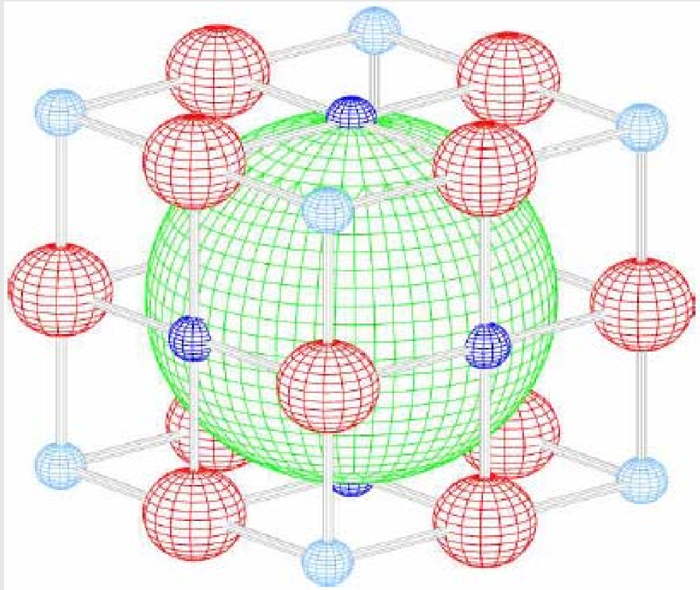
$\Delta f \approx 55$MHz

The 900ml must be produced (Bochum, trityl radical exists)
and it must be sure that the magnetic field homogeneity is about $3 \cdot 10^{-5}$

Target material ^{6}LiD

Preparation by irradiation with electrons
(E_e= 20 MeV, T=190K)
f = 4/8 = 0.5 (^{6}Li: α + D)





COMPASS 2006
P+ = +56%
P- = -52%

Comparison in measurement time

Calculations are made for same target volume

Proton materials

Targetmaterial	P	ρ[g/cm³]	f	F[10^{-2} g/cm³]	t/t_{HD}
Butanol	90%	0.94	0.14	1.39	0.46
NH3	90%	0.85	0.18	2.14	0.30
HD	63%	0.15	0.33	0.64	1.00

Deuteron materials

Targetmaterial	P	ρ[g/cm³]	f	F[10^{-2} g/cm³]	t/t_{HD}
D-Butanol °	80%	1.07	0.24	3.88	0.42
ND3 °°	44%	1.02	0.30	1.78	0.91
6Lid	50%	0.82	0.50	5.13	0.31

COMPASS

Summary / Outlook

- 2018 Target setup from 2015 is used
  - coils #3 and #8 are mounted also inside the cells
  - to fill up the lack of 2011 irradiated NH_3, material from SMC run 1996 is used

- 2021 SIDIS measurement Deuterated material will be used
  - ^{6}LiD is available last use 2006
  - D-Butanol doped with trityl must be produced (Bochum)

  - Man power and target experts must be available!