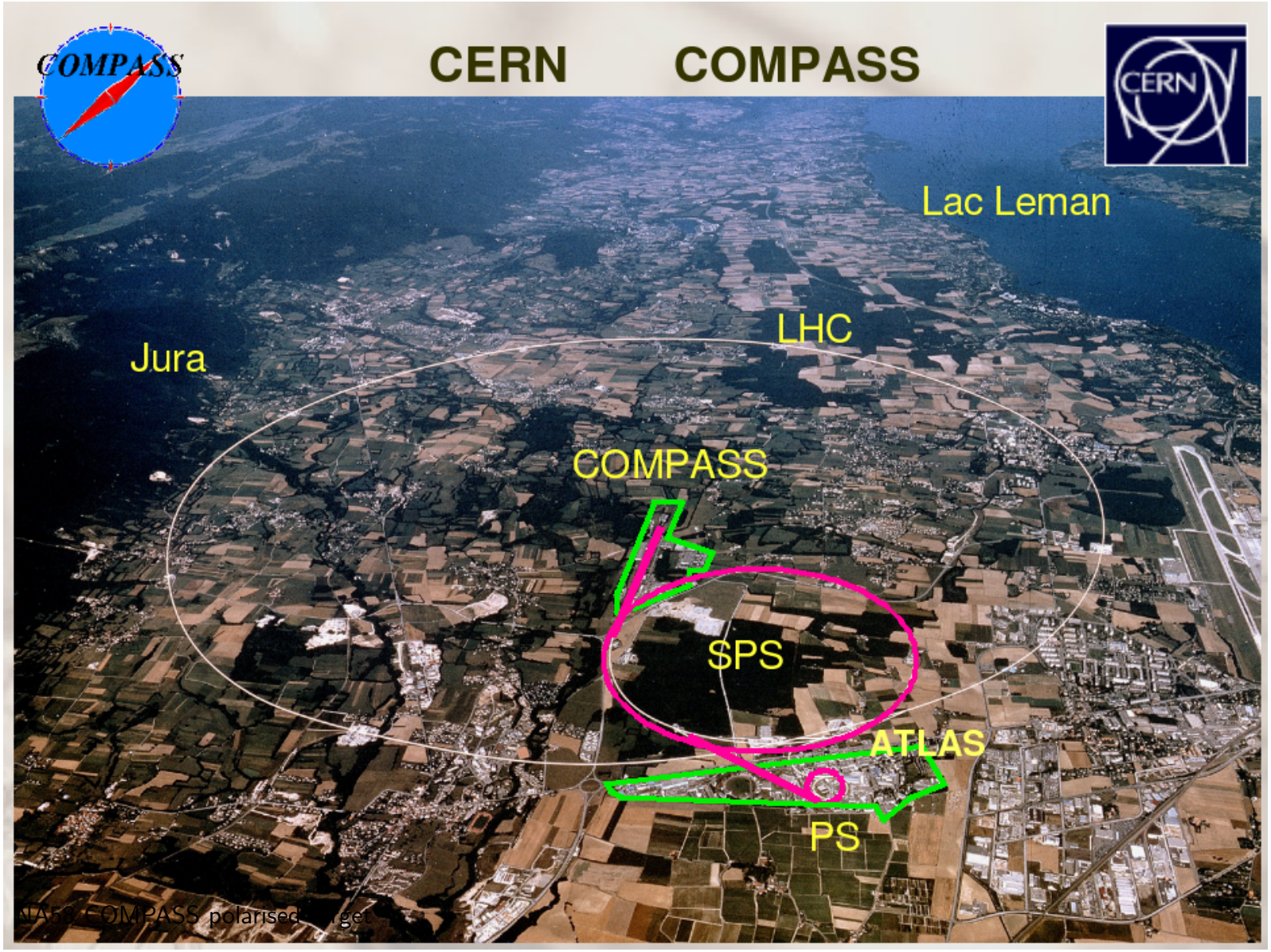
# Large COMPASS polarized solid state target for Drell-Yan physics

Jaakko Koivuniemi
CERN/PH

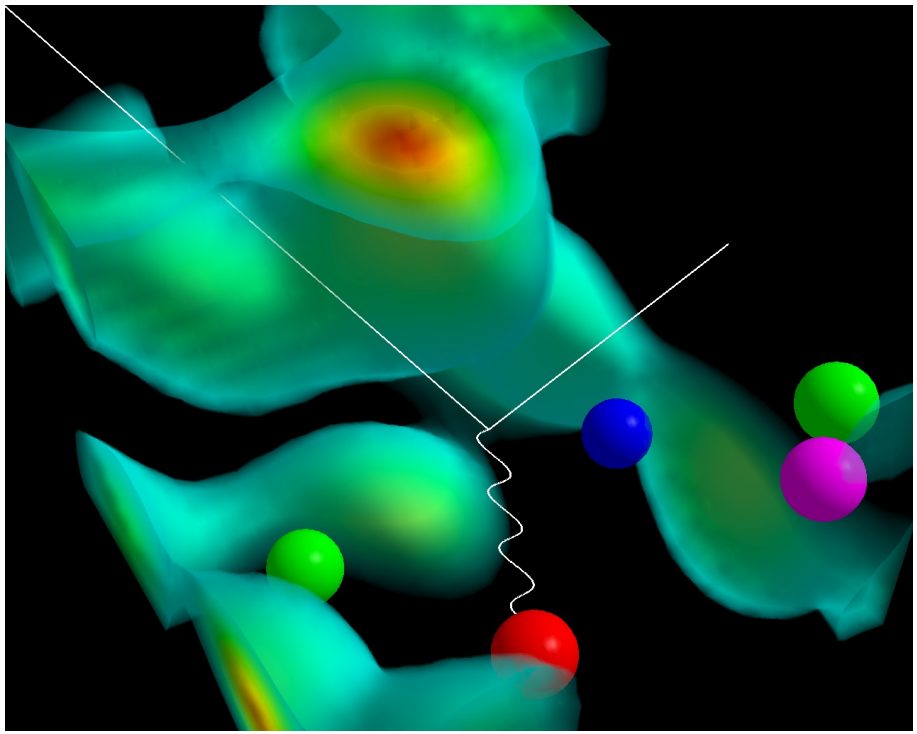
September 15, 2015

**Abstract**

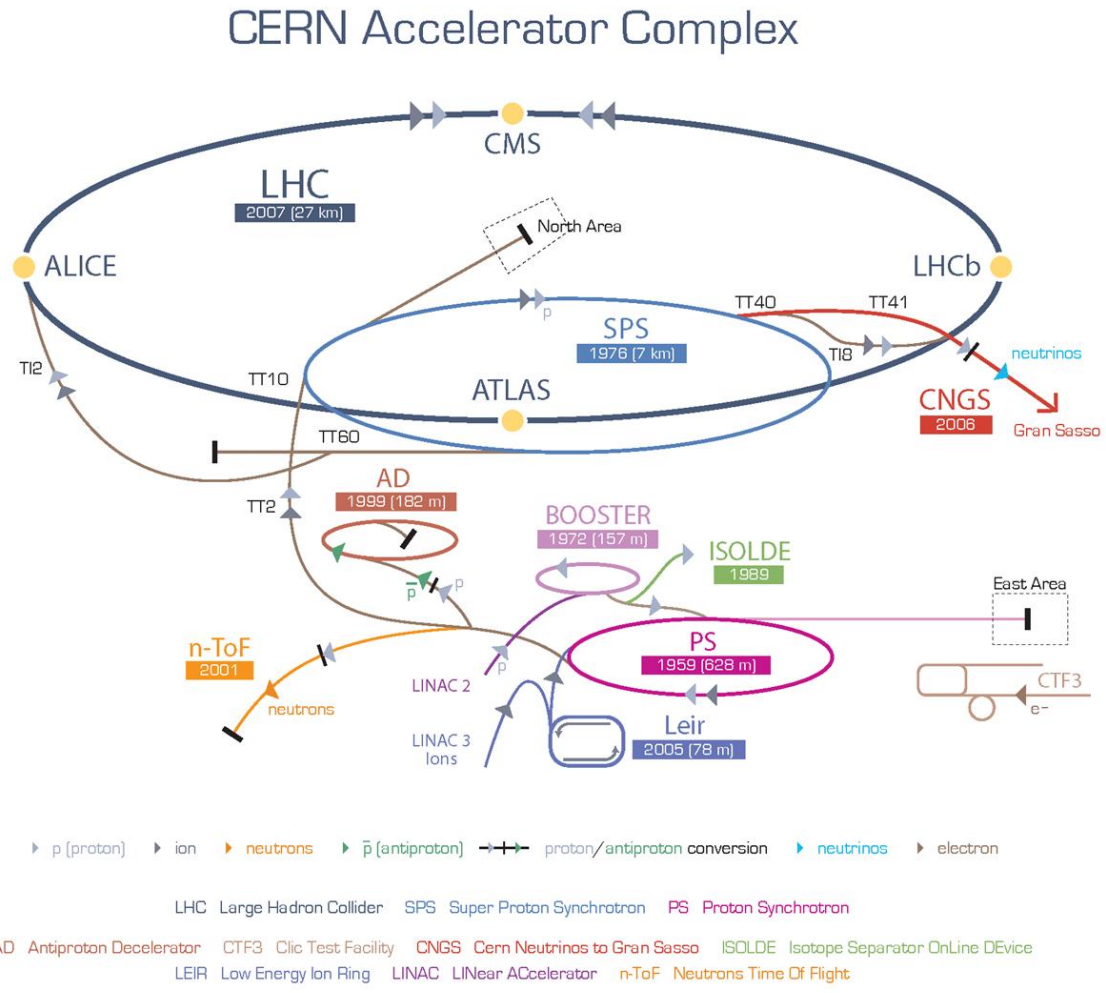
SPS, Drell-Yan physics, magnet, dilution cryostat, hadron absorber, target holder without hydrogen bonds, NMR, commissioning 2014, run 2015


CERN COMPASS
Lac Leman
LHC
Jura
COMPASS
SPS
ATLAS
PS

# Proton: view of an artist

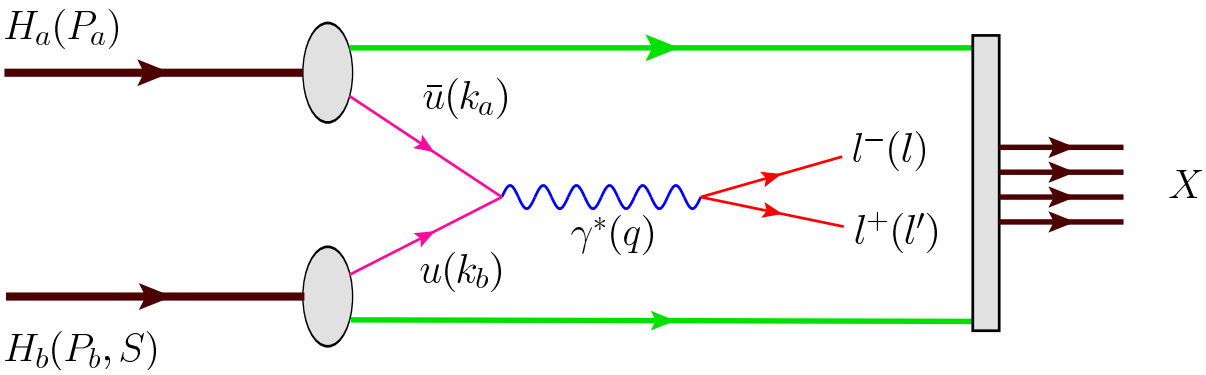


http://www.physics.adelaide.edu.au/theory/staff/leinweber/VisualQCD/QCDvacuum/welcome.html

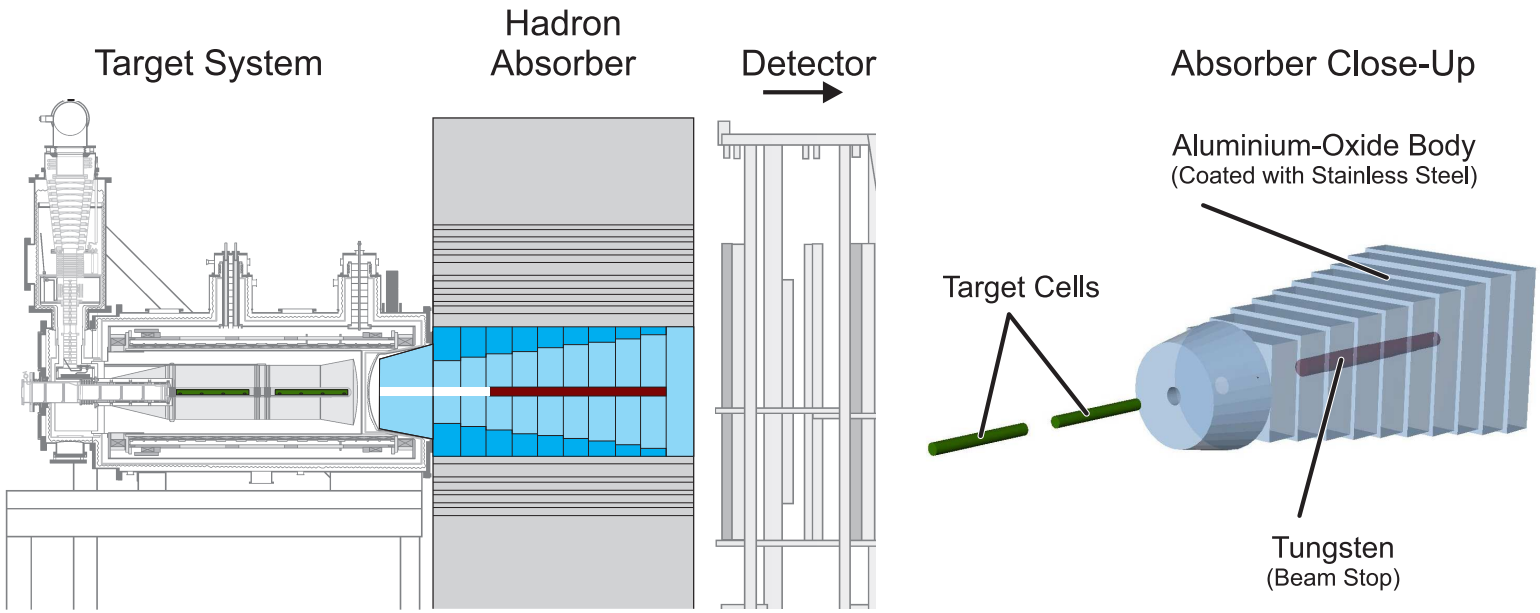

CERN Accelerator Complex
CMS
LHC
2007 (27 km)
North Area
ALICE
LHCb
TT40
TT41
p
SPS
1976 (7 km)
TI8
neutrinos
TI2
TT10
ATLAS
CNGS
2006
Gran Sasso
TT60
AD
1999 (182 m)
TT2
BOOSTER
1972 (157 m)
ISOLDE
1989
East Area
n-ToF
2001
PS
1959 (628 m)
CTF3
e−
neutrons
LINAC 2
LINAC 3
Ions
Leir
2005 (78 m)
p (proton)
ion
neutrons
p̄ (antiproton)
proton/antiproton conversion
neutrinos
electron
LHC Large Hadron Collider
SPS Super Proton Synchrotron
PS Proton Synchrotron
AD Antiproton Decelerator
CTF3 Clic Test Facility
CNGS Cern Neutrinos to Gran Sasso
ISOLDE Isotope Separator OnLine DEvice
LEIR Low Energy Ion Ring
LINAC LINear ACcelerator
n-ToF Neutrons Time Of Flight

# Super Proton Synchrotron (SPS) and COMPASS

- T6 Beryllium production target for North Area
- negative hadron beam with momentum 190 GeV/c: 97 % $\pi^-$, 2.5 % $K^-$ and 0.5 % $\bar{p}$
- beam intensity up to $10^8$ particles/s
- 2 $\times$ 55 cm long 4 cm diameter transversely polarized solid target with 20 cm separation
- hadron absorber aluminium and tungsten (also a target)

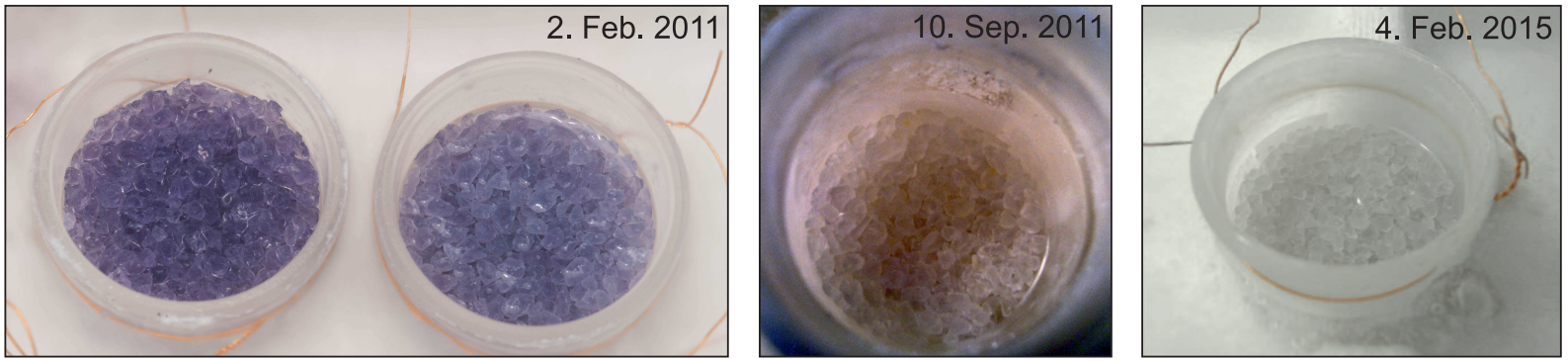

$H_a(P_a)$
$\bar{u}(k_a)$
$l^-(l)$
$X$
$\gamma^*(q)$
$l^+(l')$
$u(k_b)$
$H_b(P_b, S)$

# Hadron absorber



# Polarizable solid ammonia production 2011

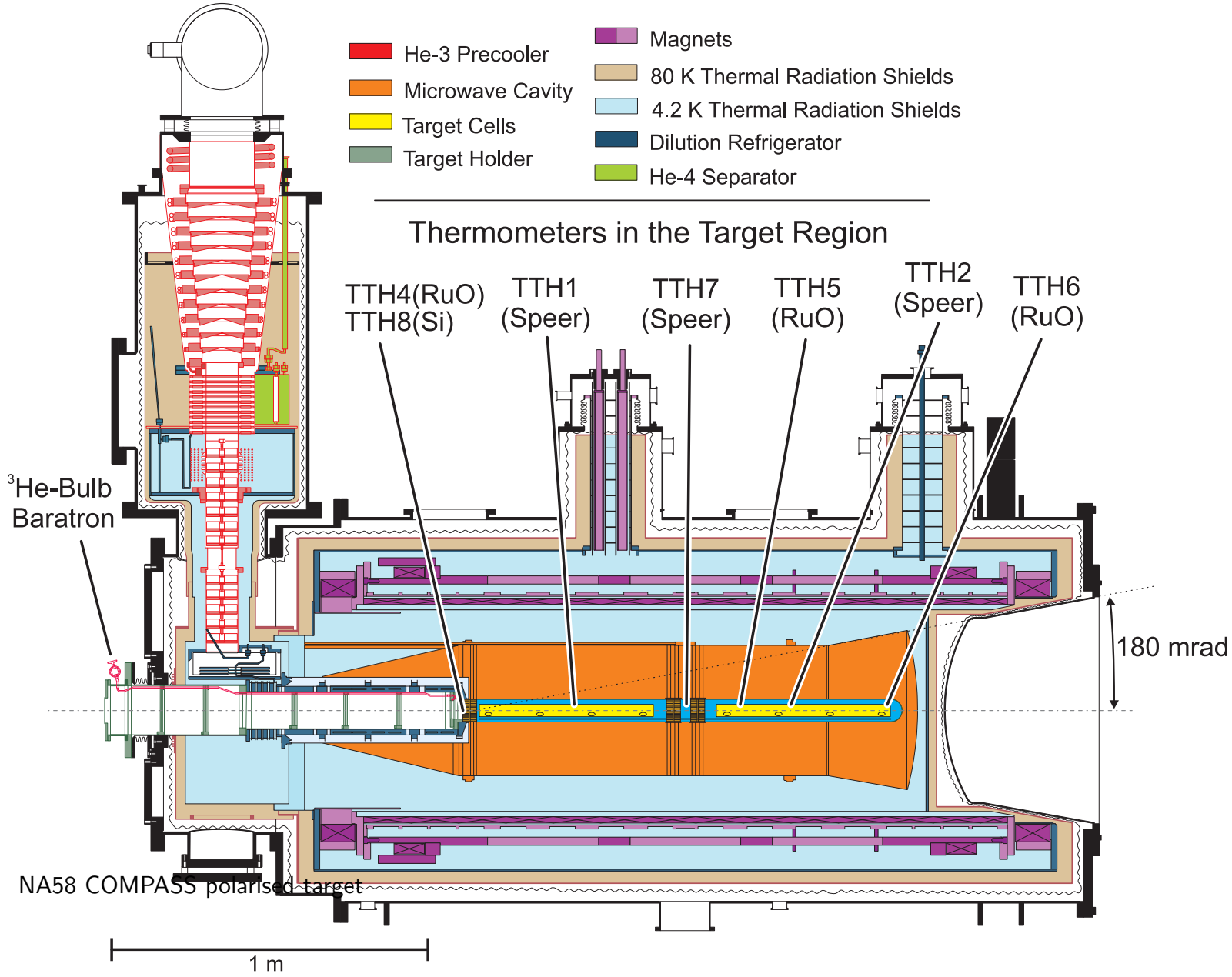
- June 2011: 9 samples were irradiated in Bonn linac
- total dose controlled from charge detector behind sample
- irradiation time 9 - 15 hours
- target cell volumes 691 ccm + 691 ccm
- material loaded for runs 2014 and 2015 with some old material
- EPR signal from $\dot{\mathrm{N}}$H2




1 week ... 2 weeks ... 7 month ... 4 years ... after irradiation

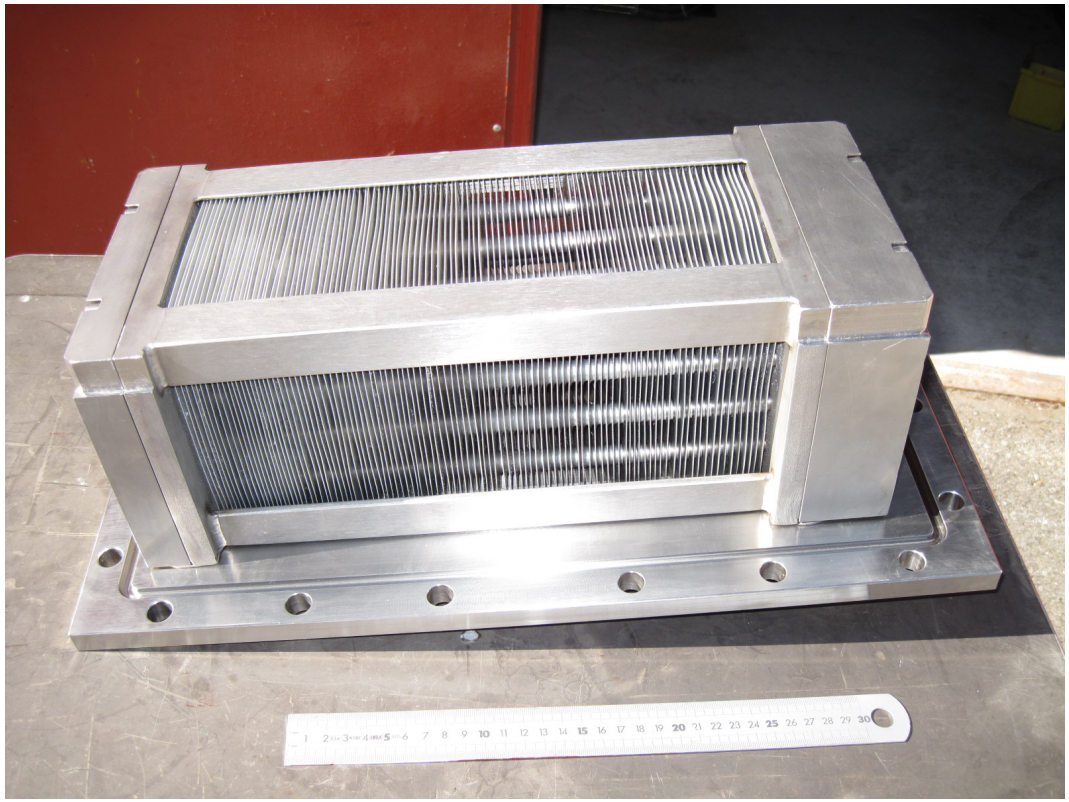
# Dilution cryostat

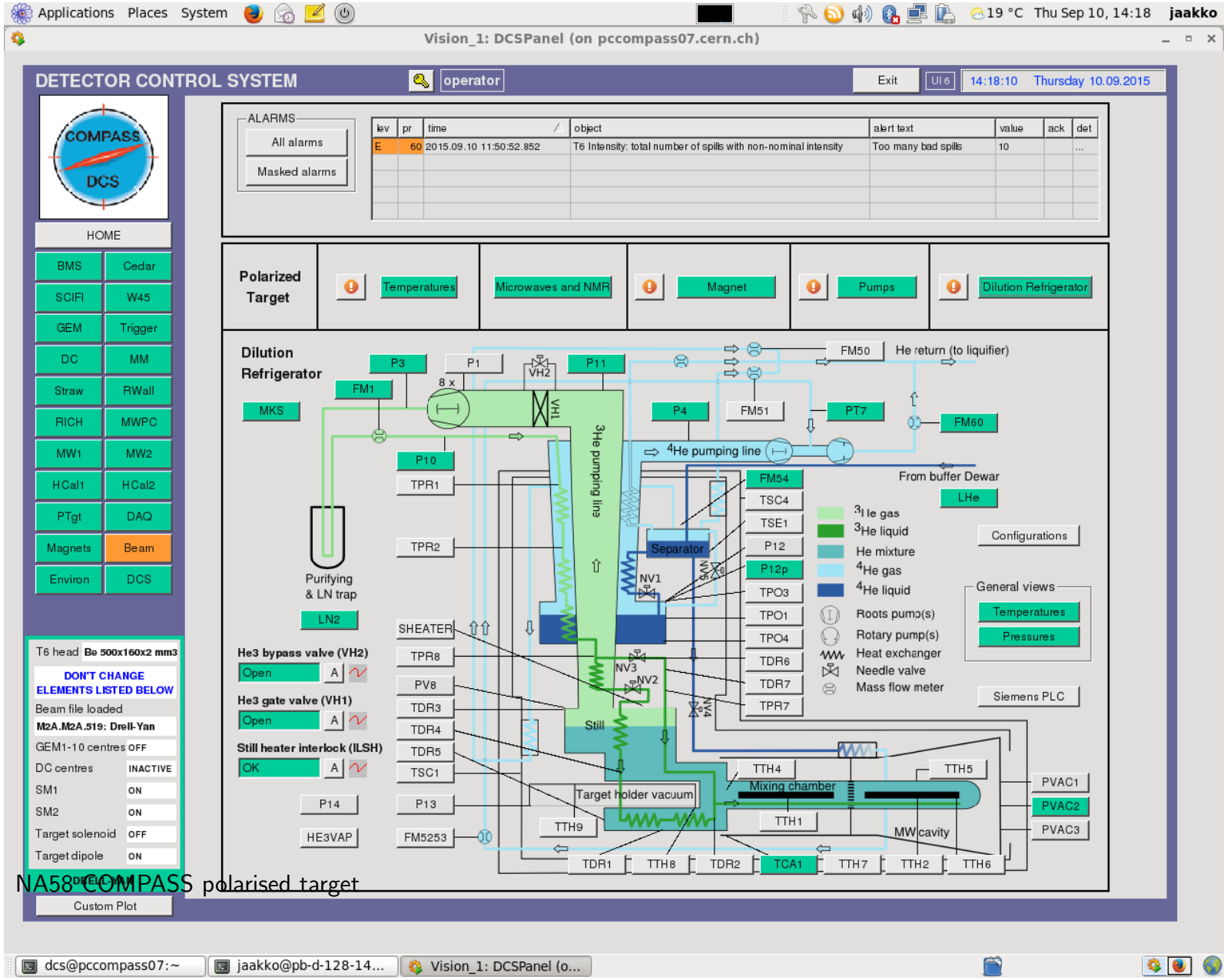
- high cooling power helium-3/4 dilution cryostat $\sim$ 350 mW at 300 mK
- base temperarure below $\sim$ 40 mK (no calibrated thermometers below 50 mK)
- new pumping lines welded 2014
- helium-4 pump system
- helium-3 pump system new water cooled heat exchangers
- isolation vacuum pump system


He-3 Precooler
Microwave Cavity
Target Cells
Target Holder
Magnets
80 K Thermal Radiation Shields
4.2 K Thermal Radiation Shields
Dilution Refrigerator
He-4 Separator
Thermometers in the Target Region
TTH4(RuO)
TTH8(Si)
TTH1
(Speer)
TTH7
(Speer)
TTH5
(RuO)
TTH2
(Speer)
TTH6
(RuO)
3He-Bulb
Baratron
180 mrad
1 m

# June 2014

# March 2015




Applications Places System
19 °C Thu Sep 10, 14:18 jaakko
Vision_1: DCSPanel (on pccompass07.cern.ch)
DETECTOR CONTROL SYSTEM
operator
Exit
UI 6
14:18:10 Thursday 10.09.2015
COMPASS DCS
HOME
BMS Cedar
SCIFI W45
GEM Trigger
DC MM
Straw RWall
RICH MWPC
MW1 MW2
HCal1 HCal2
PTgt DAQ
Magnets Beam
Environ DCS
ALARMS
All alarms
Masked alarms
lev pr time object alert text value ack det
E 60 2015.09.10 11:50:52.852 T6 Intensity: total number of spills with non-nominal intensity Too many bad spills 10
Polarized Target
Temperatures
Microwaves and NMR
Magnet
Pumps
Dilution Refrigerator
Dilution Refrigerator
MKS
FM1
P3
P1
VH2
P11
8 x
VH1
3He pumping line
P4
FM51
PT7
FM50
He return (to liquifier)
FM60
4He pumping line
From buffer Dewar
LHe
P10
TPR1
TPR2
Purifying & LN trap
LN2
SHEATER
TPR8
PV8
TDR3
TDR4
TDR5
TSC1
P14
P13
HE3VAP
FM5253
Separator
NV1
NV5
NV3
NV2
NV4
Still
Target holder vacuum
TTH9
TDR1
TTH8
TDR2
TCA1
TTH7
TTH2
TTH6
FM54
TSC4
TSE1
P12
P12p
TPO3
TPO1
TPO4
TDR6
TDR7
TPR7
TTH4
Mixing chamber
TTH1
TTH5
MW cavity
PVAC1
PVAC2
PVAC3
3He gas
3He liquid
He mixture
4He gas
4He liquid
Roots pump(s)
Rotary pump(s)
Heat exchanger
Needle valve
Mass flow meter
Configurations
General views
Temperatures
Pressures
Siemens PLC
He3 bypass valve (VH2)
Open A
He3 gate valve (VH1)
Open A
Still heater interlock (ILSH)
OK A
T6 head Be 500x160x2 mm3
DON'T CHANGE ELEMENTS LISTED BELOW
Beam file loaded
M2A.M2A.519: Drell-Yan
GEM1-10 centres OFF
DC centres INACTIVE
SM1 ON
SM2 ON
Target solenoid OFF
Target dipole ON
Custom Plot
dcs@pccompass07:~
jaakko@pb-d-128-14...
Vision_1: DCSPanel (o...

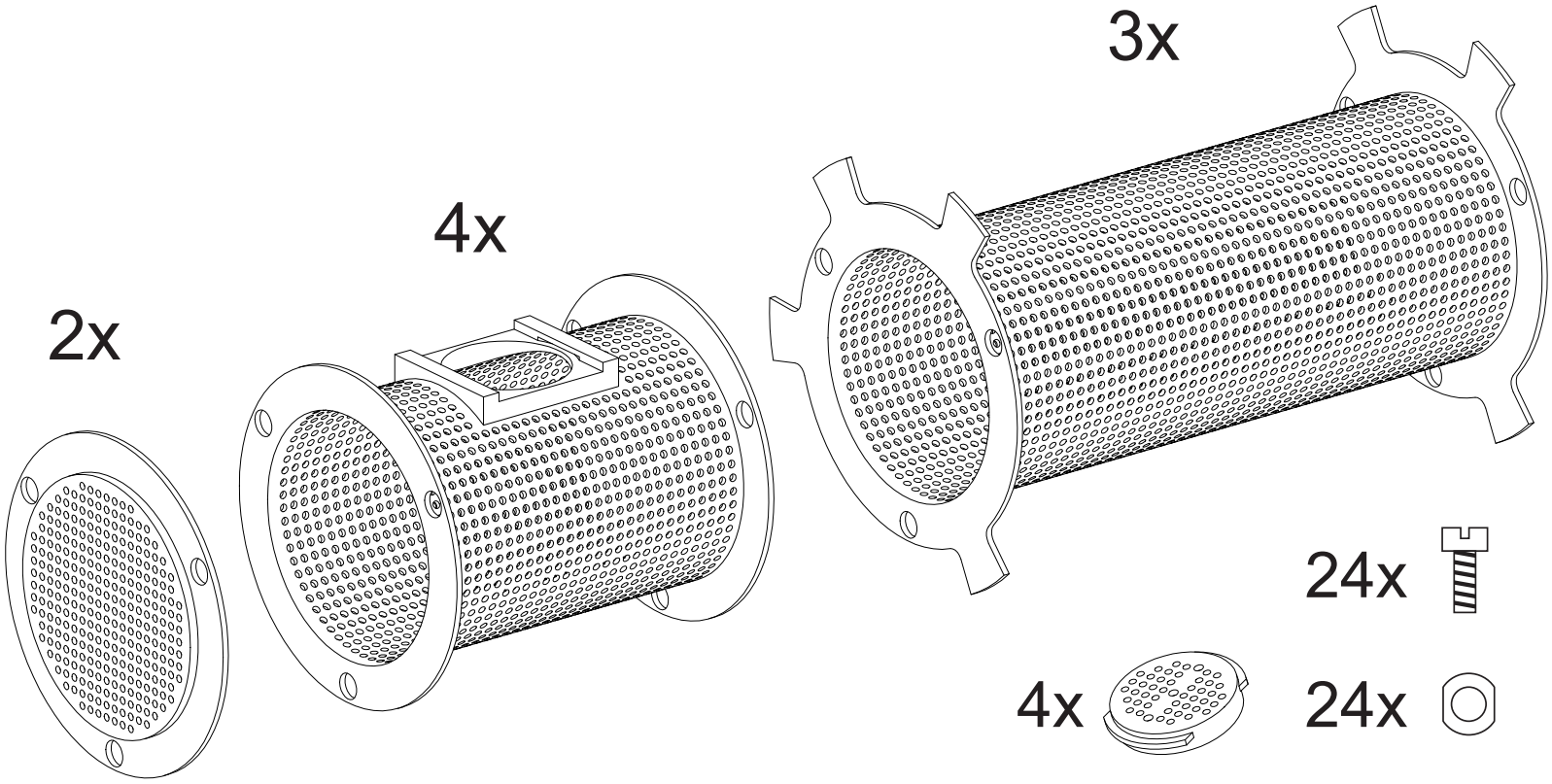
# 50 years of dilution cryostat

- H. London, G. R. Clarke and E. Mendoza, Phys. Rev. **128** (1962) 1992–2005 *Osmotic Pressure of $He^3$ in Liquid $He^4$, with Proposals for a Refrigerator to Work below 1 K*

- P. Das, R. de Bruyn Ouboter and K. W. Taconis, Low Temperature Physics LT9 (1965) 1253–1255, *A Realization of a London-Clarke-Mendoza type refrigerator*

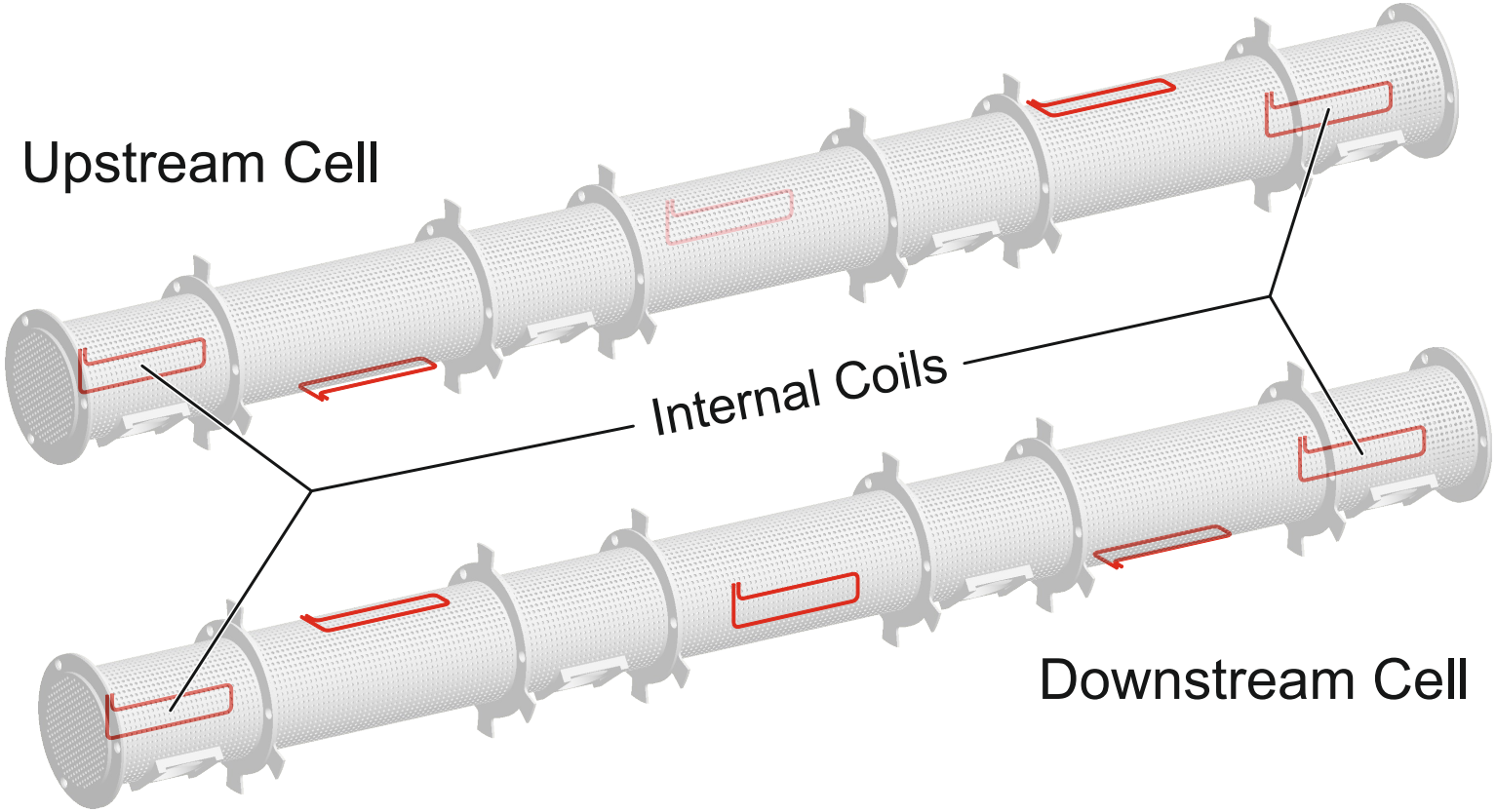
- T. O. Niinikoski, NIMA **97** (1971) 95–101, *A Horizontal dilution refrigerator with very high cooling power*

# PCTFE target cells

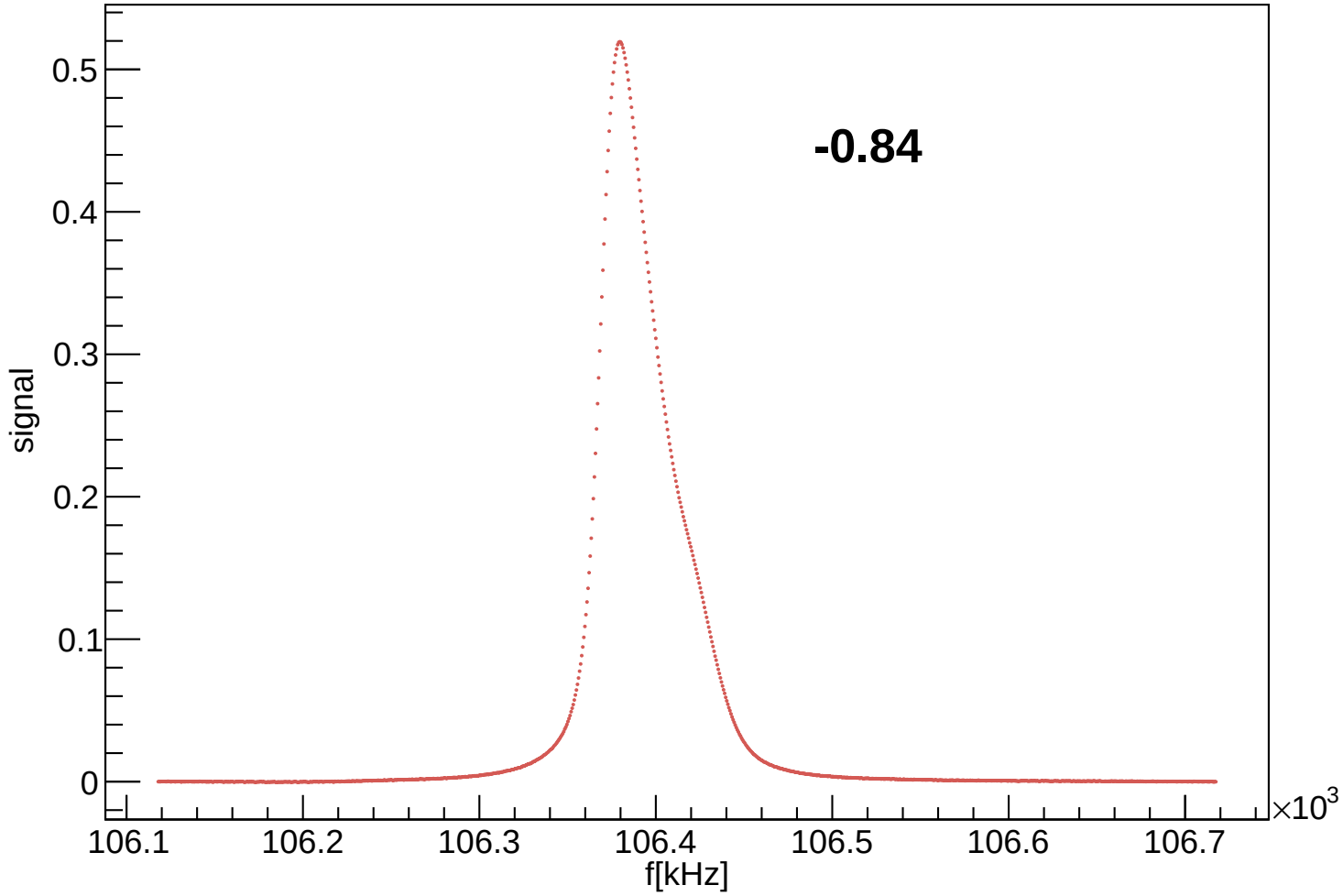


# NMR system

- LabVIEW and PXI crate moved to control room (radiation)
- NMR rack moved below target platform with lead shielding
- fixed firmly on floor due to magnetic field
- Liverpool Q-meters tuned on 106 MHz still in use
- integration with new magnet control system
- stable operation without problems so far


Upstream Cell
Internal Coils
Downstream Cell

# 150703_211139.sig coil 3



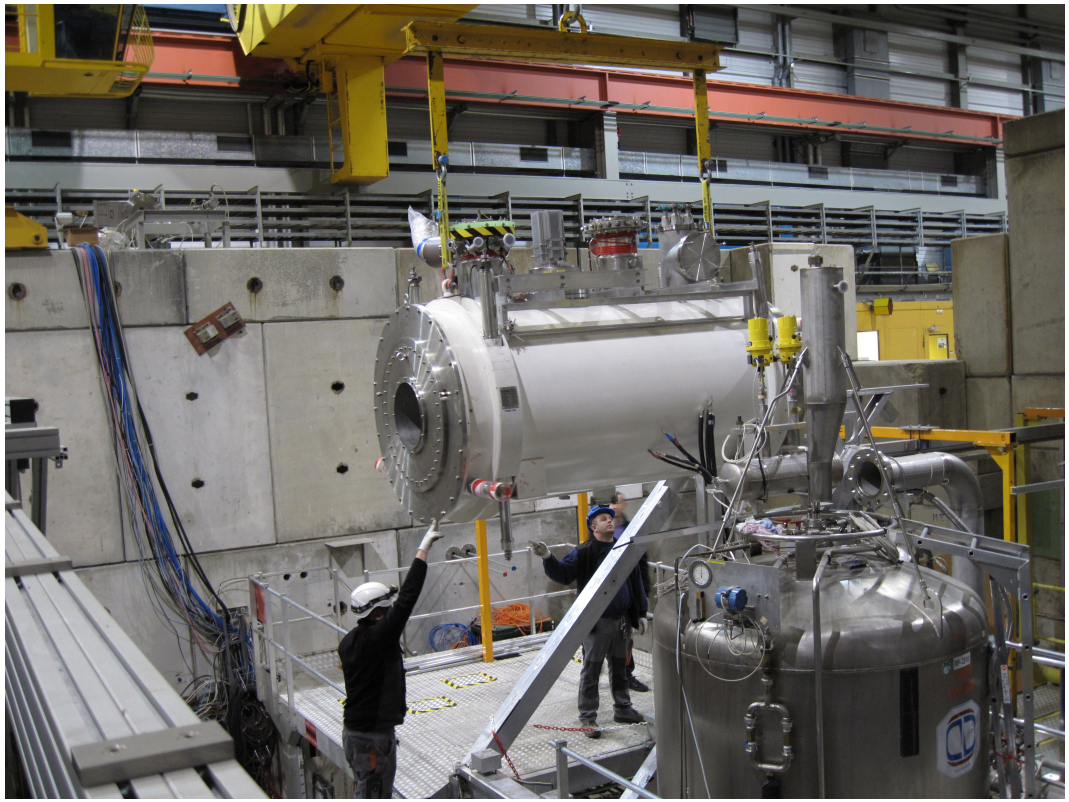
# Rebuild target magnet system

- 2.5 T longitudinal solenoid field
- 0.63 T transverse dipole field
- large acceptance of 180 mrad, large bore diameter of $\sim$620 mm
- run 2011: problems in magnet operation due to short in trim coils
- magnet opened, problems investigated and solved
- add cryocooler on radiation shield

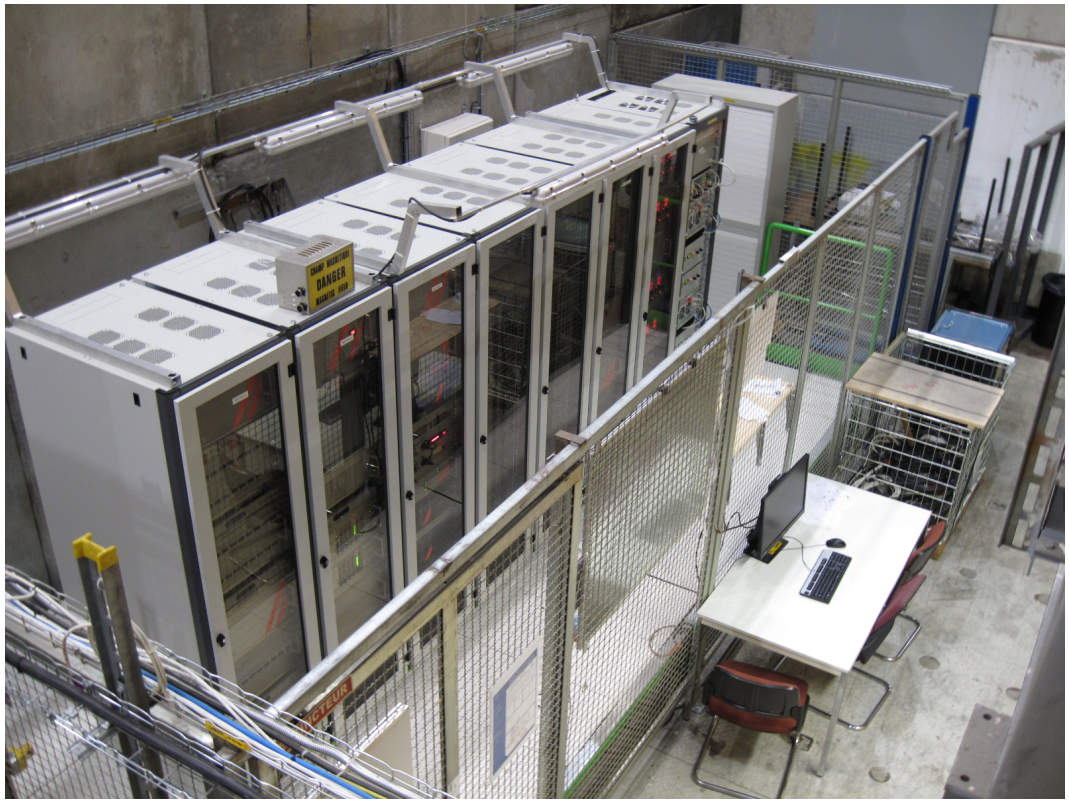
- rebuild cryogenic system with integration to CERN cryogenic controls
- new Magnet Safety System (MSS)
- new power converters with CERN support
- magnet to COMPASS March 2014
- first proton NMR signals seen December 2014
- automatic field operation procedures done with scripts

# March 2014

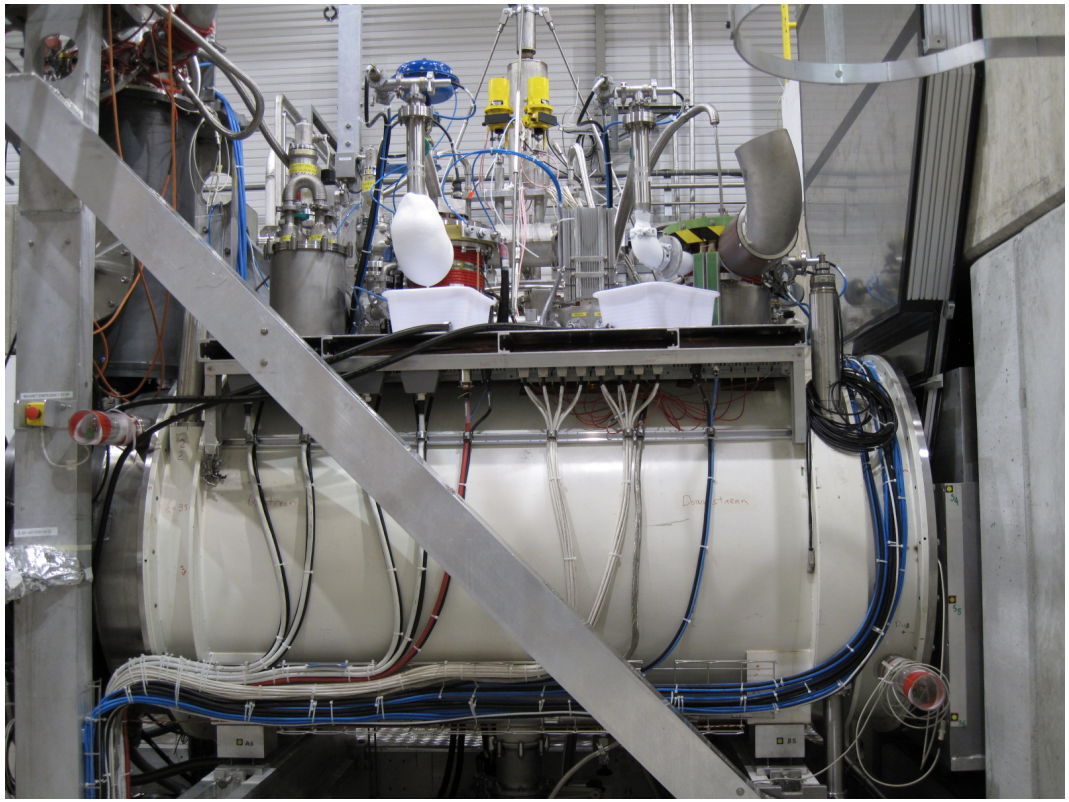
# March 2014

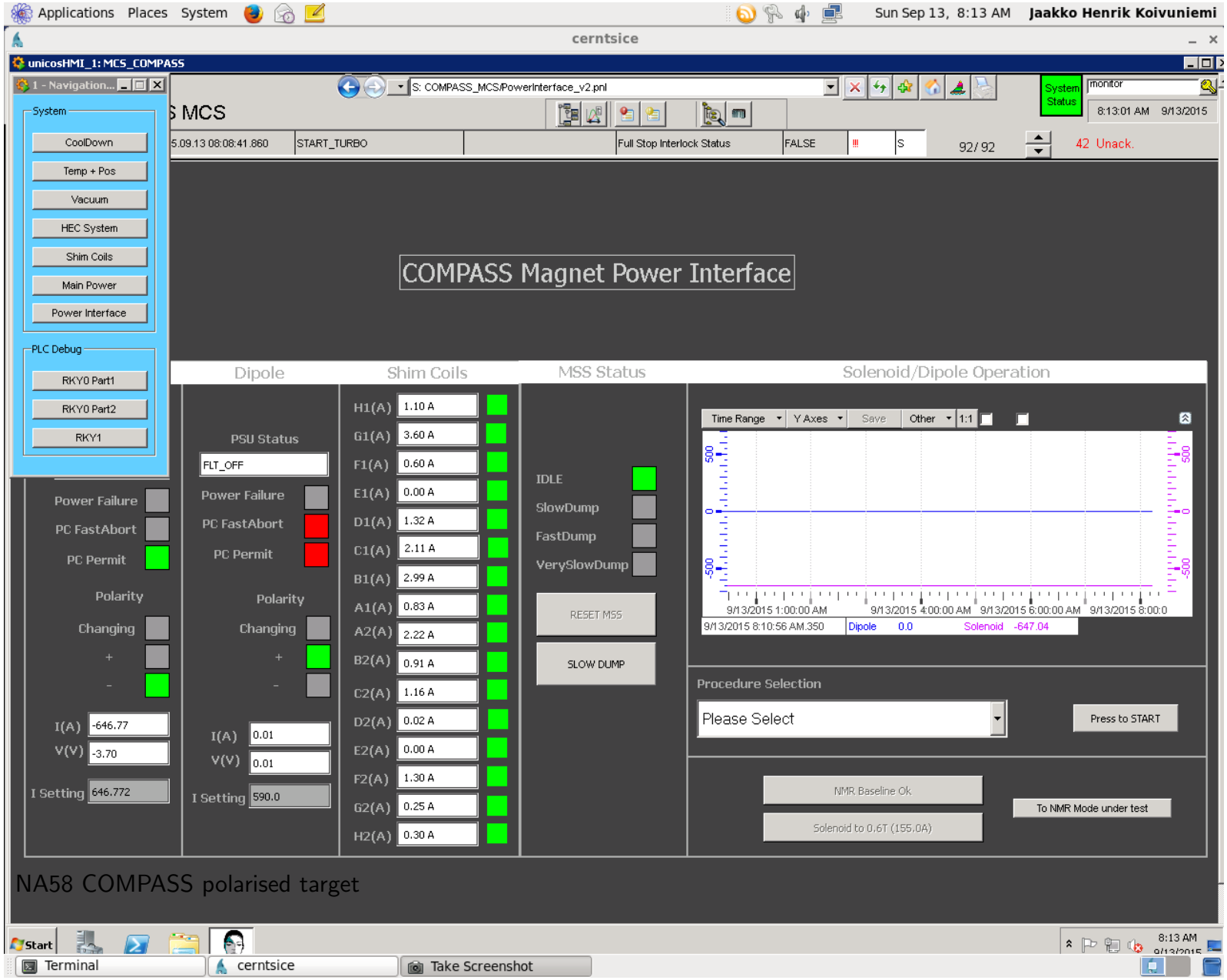


# September 2015



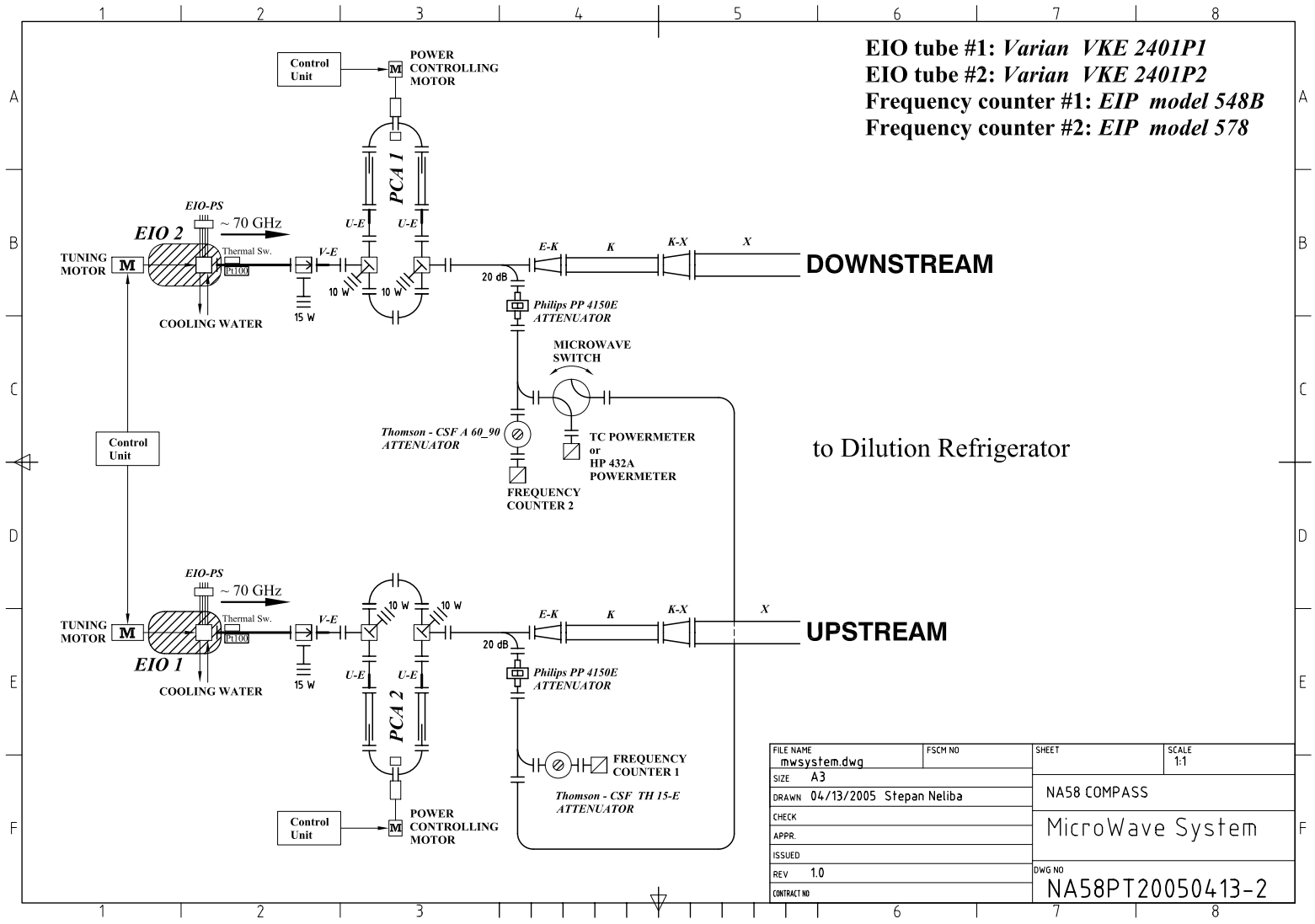
# September 2015



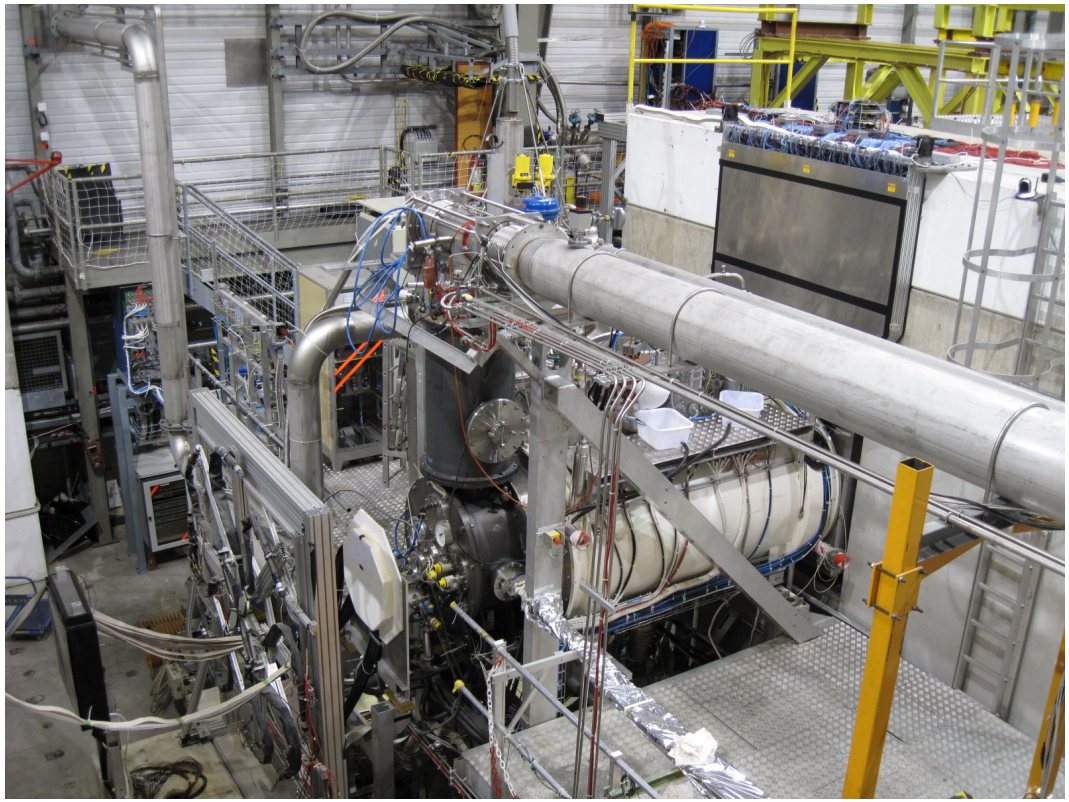

Applications Places System
Sun Sep 13, 8:13 AM Jaakko Henrik Koivuniemi
cerntsice
unicosHMI_1: MCS_COMPASS
1 - Navigation...
System
CoolDown
Temp + Pos
Vacuum
HEC System
Shim Coils
Main Power
Power Interface
PLC Debug
RKY0 Part1
RKY0 Part2
RKY1
S: COMPASS_MCS/PowerInterface_v2.pnl
MCS
System Status
monitor
8:13:01 AM 9/13/2015
5.09.13 08:08:41.860
START_TURBO
Full Stop Interlock Status
FALSE
92/ 92
42 Unack.
COMPASS Magnet Power Interface
Dipole
Shim Coils
MSS Status
Solenoid/Dipole Operation
Power Failure
PC FastAbort
PC Permit
Polarity
Changing
+
-
I(A) -646.77
V(V) -3.70
I Setting 646.772
PSU Status
FLT_OFF
Power Failure
PC FastAbort
PC Permit
Polarity
Changing
+
-
I(A) 0.01
V(V) 0.01
I Setting 590.0
H1(A) 1.10 A
G1(A) 3.60 A
F1(A) 0.60 A
E1(A) 0.00 A
D1(A) 1.32 A
C1(A) 2.11 A
B1(A) 2.99 A
A1(A) 0.83 A
A2(A) 2.22 A
B2(A) 0.91 A
C2(A) 1.16 A
D2(A) 0.02 A
E2(A) 0.00 A
F2(A) 1.30 A
G2(A) 0.25 A
H2(A) 0.30 A
IDLE
SlowDump
FastDump
VerySlowDump
RESET MSS
SLOW DUMP
Time Range
Y Axes
Save
Other
1:1
500
0
-500
9/13/2015 1:00:00 AM
9/13/2015 4:00:00 AM
9/13/2015 6:00:00 AM
9/13/2015 8:10:56 AM.350
Dipole 0.0
Solenoid -647.04
Procedure Selection
Please Select
Press to START
NMR Baseline Ok
Solenoid to 0.6T (155.0A)
To NMR Mode under test
Start
Terminal
cerntsice
Take Screenshot
8:13 AM

# 70 GHz EIO microwave generator tubes

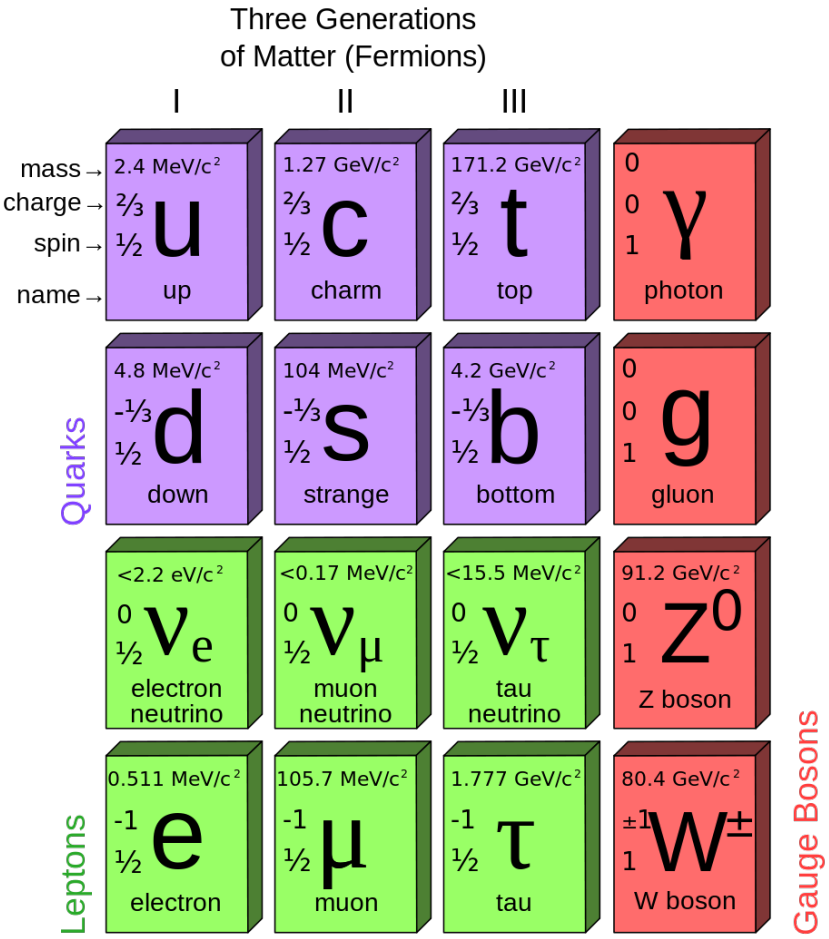
- two 20 W extended interaction oscillator (EIO) tubes
- Varian VPW2838 and CPI VPW2827 power supplies
- microwave guides from control room to dilution cryostat
- remote monitoring from COMPASS DCS
- wiki/Extended_interaction_oscillator

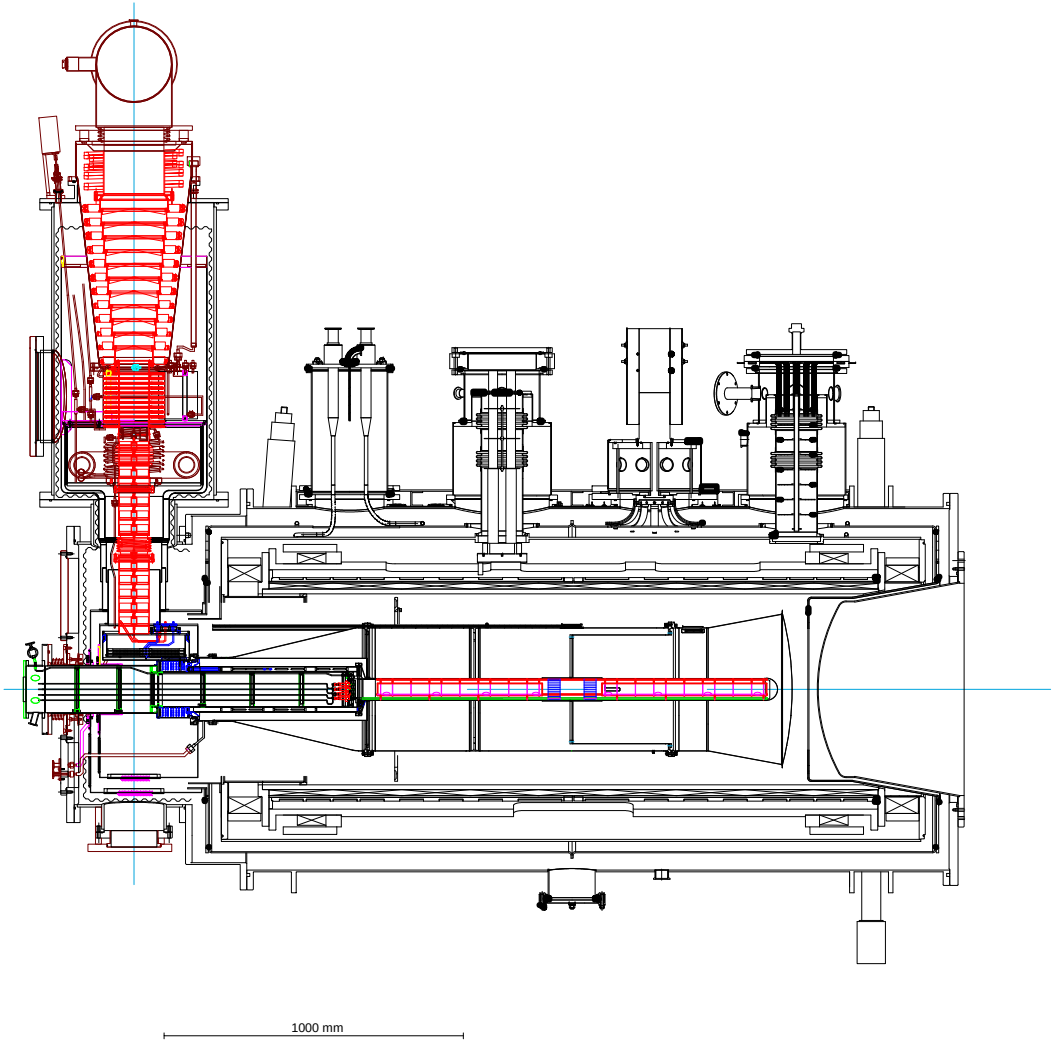

EIO tube #1: Varian VKE 2401P1
EIO tube #2: Varian VKE 2401P2
Frequency counter #1: EIP model 548B
Frequency counter #2: EIP model 578
Control Unit
POWER CONTROLLING MOTOR
PCA 1
EIO-PS
~ 70 GHz
EIO 2
TUNING MOTOR
Thermal Sw.
COOLING WATER
U-E
V-E
10 W
15 W
E-K
K
K-X
X
DOWNSTREAM
20 dB
Philips PP 4150E ATTENUATOR
MICROWAVE SWITCH
Thomson - CSF A 60_90 ATTENUATOR
TC POWERMETER or HP 432A POWERMETER
FREQUENCY COUNTER 2
to Dilution Refrigerator
EIO 1
PCA 2
FREQUENCY COUNTER 1
Thomson - CSF TH 15-E ATTENUATOR
UPSTREAM
FILE NAME mwsystem.dwg
FSCM NO
SHEET
SCALE 1:1
SIZE A3
DRAWN 04/13/2005 Stepan Neliba
CHECK
APPR.
ISSUED
REV 1.0
CONTRACT NO
NA58 COMPASS
MicroWave System
DWG NO NA58PT20050413-2

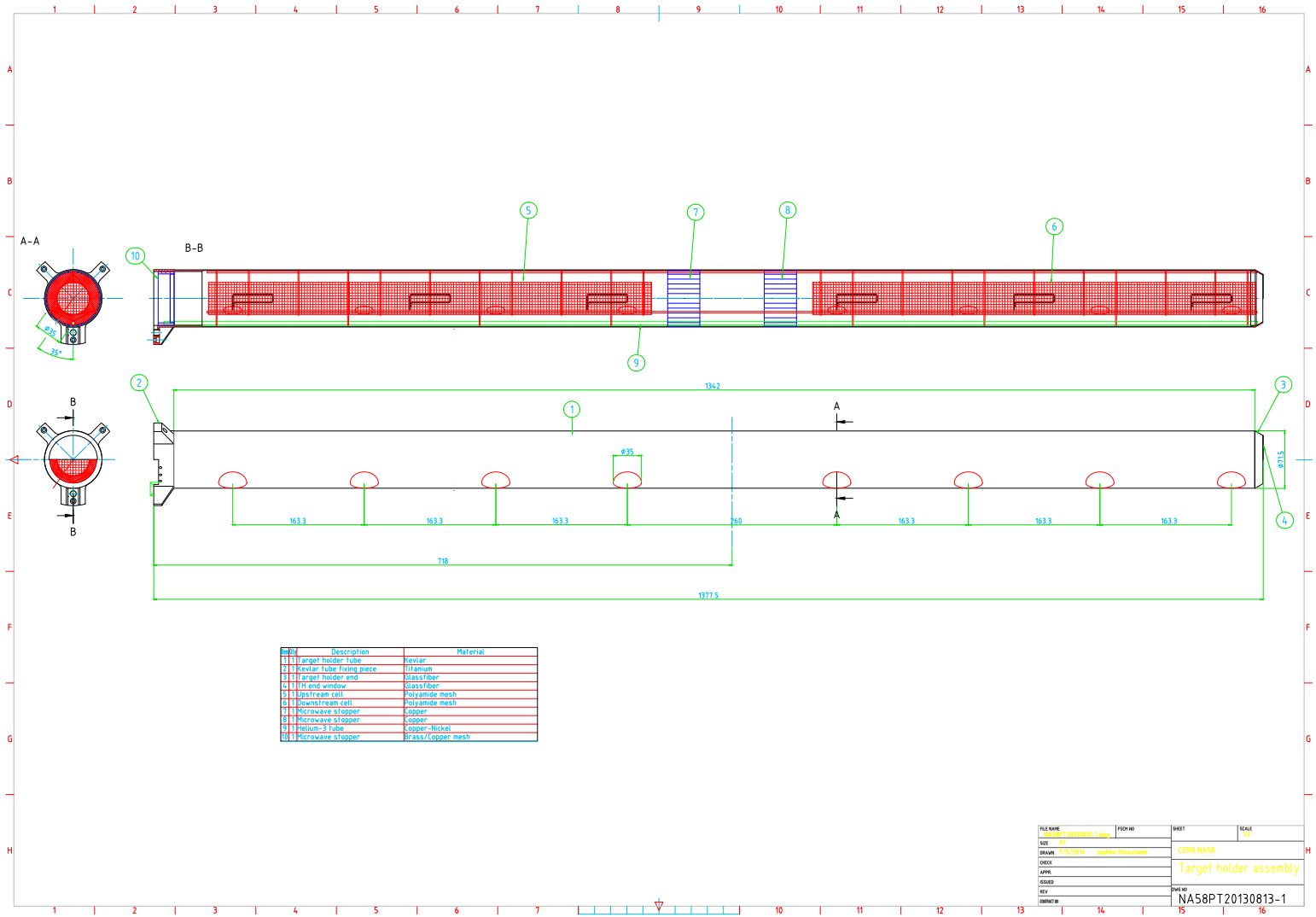
# Drell-Yan 2015



# Backup slides


Three Generations
of Matter (Fermions)
I
II
III
mass →
charge →
spin →
name →
2.4 MeV/c²
⅔
½
u
up
1.27 GeV/c²
⅔
½
c
charm
171.2 GeV/c²
⅔
½
t
top
0
0
1
γ
photon
Quarks
4.8 MeV/c²
-⅓
½
d
down
104 MeV/c²
-⅓
½
s
strange
4.2 GeV/c²
-⅓
½
b
bottom
0
0
1
g
gluon
<2.2 eV/c²
0
½
νe
electron neutrino
<0.17 MeV/c²
0
½
νμ
muon neutrino
<15.5 MeV/c²
0
½
ντ
tau neutrino
91.2 GeV/c²
0
1
Z⁰
Z boson
Leptons
0.511 MeV/c²
-1
½
e
electron
105.7 MeV/c²
-1
½
μ
muon
1.777 GeV/c²
-1
½
τ
tau
80.4 GeV/c²
±1
1
W±
W boson
Gauge Bosons

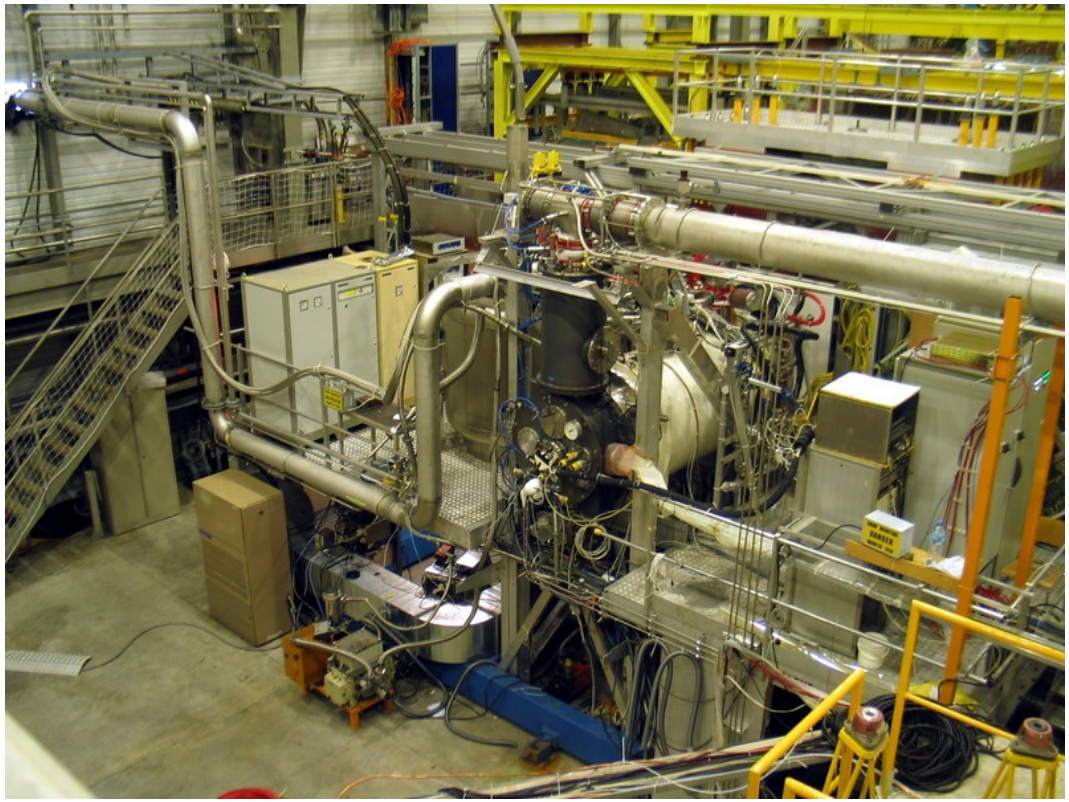

1000 mm




| Item | Qty | Description | Material |
|---|---|---|---|
| 1 | 1 | Target holder tube | Kevlar |
| 2 | 1 | Kevlar tube fixing piece | Titanium |
| 3 | 1 | Target holder end | Glassfiber |
| 4 | 1 | TH end window | Glassfiber |
| 5 | 1 | Upstream cell | Polyamide mesh |
| 6 | 1 | Downstream cell | Polyamide mesh |
| 7 | 1 | Microwave stopper | Copper |
| 8 | 1 | Microwave stopper | Copper |
| 9 | 1 | Helium-3 Tube | Copper-Nickel |
| 10 | 1 | Microwave stopper | Brass/Copper mesh |

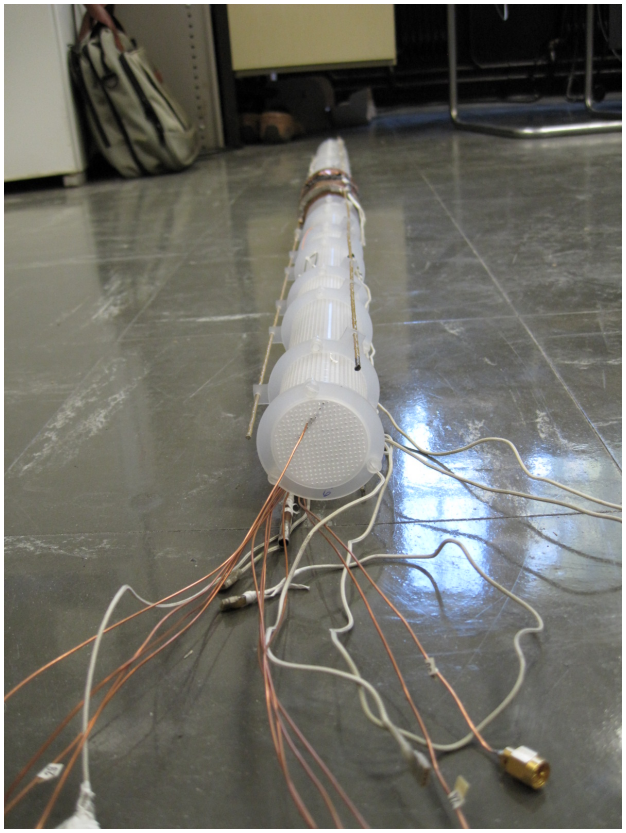
| | |
|---|---|
| FILE NAME | NA58PT20130813-1.dwg |
| SIZE | A1 |
| DRAWN | 7/5/2014 Jaakko Koivuniemi |
| CHECK | |
| APPR. | |
| ISSUED | |
| REV. | |
| CONTRACT NO | |
| SHEET | |
| SCALE | 1/2 |
| | CERN NA58 |
| | Target holder assembly |
| DWG NO | NA58PT20130813-1 |

# SIDIS 2007

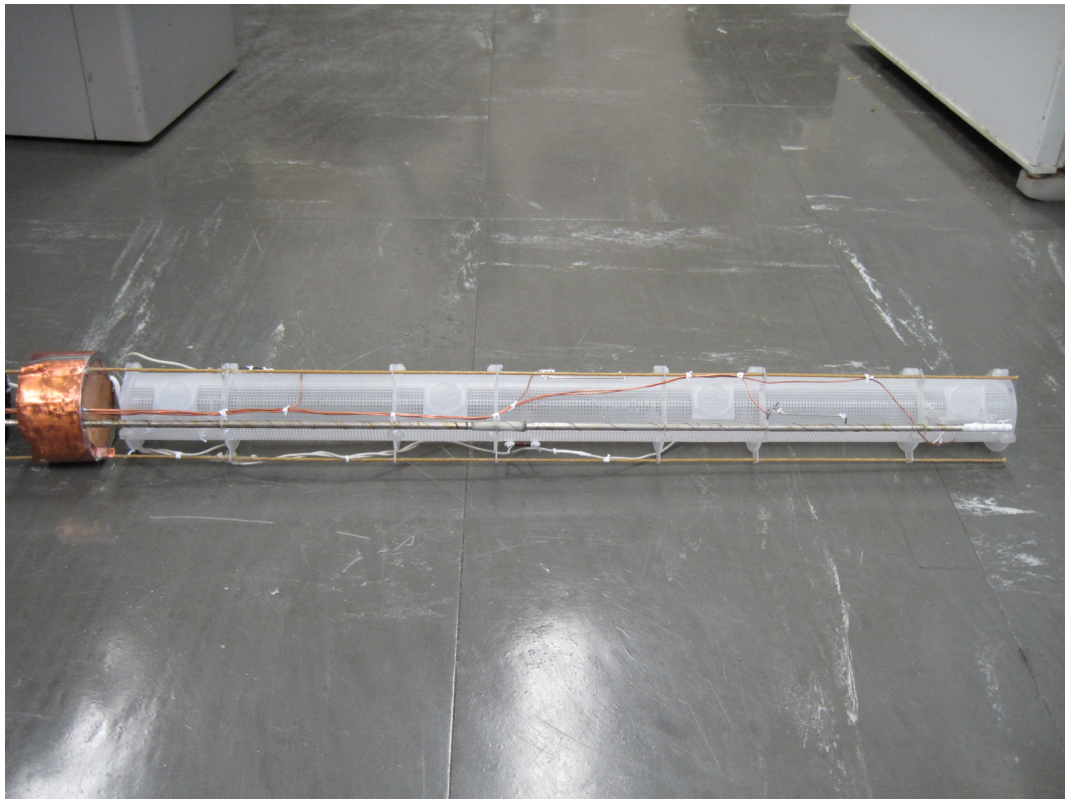


# March 2015

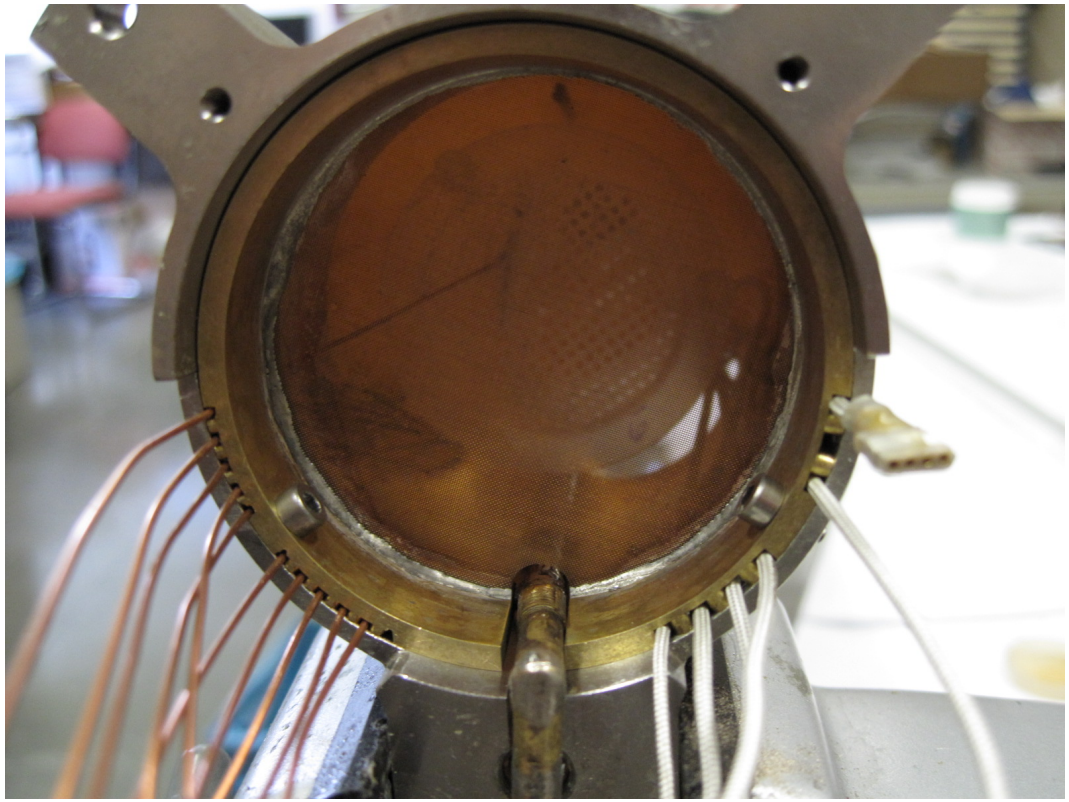
# April 2015



# April 2015



# April 2015



# April 2015