Upgraded Polarized target for polarized Drell-Yan measurement at COMPASS

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On behalf of COMPASS collaboration

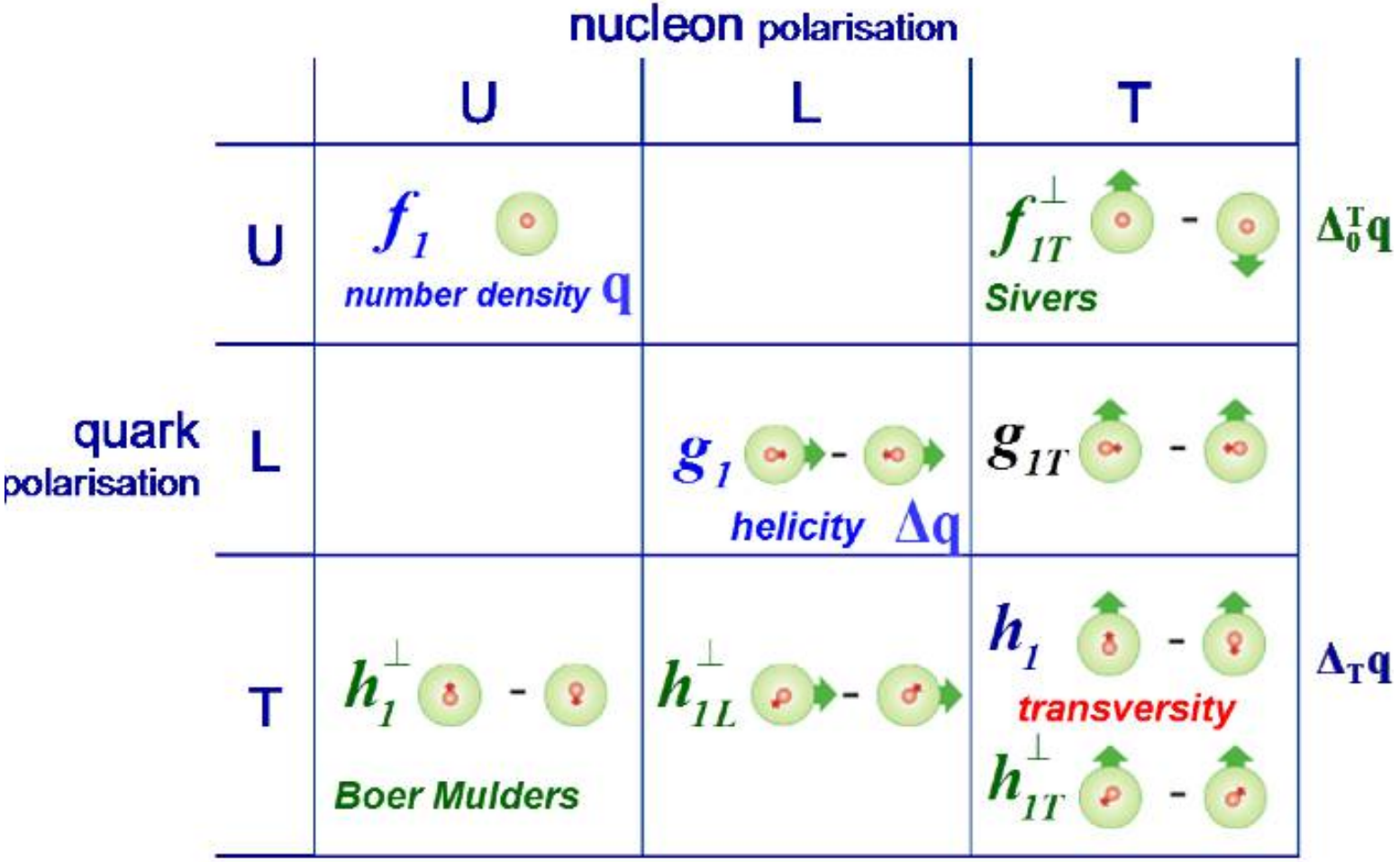
Outline

- Nucleon spin structure
- Drell-Yan process
- COMPASS experiment at CERN
- COMPASS Polarized target
- Needed modifications & Current status
- Conclusion

Nucleon spin structure

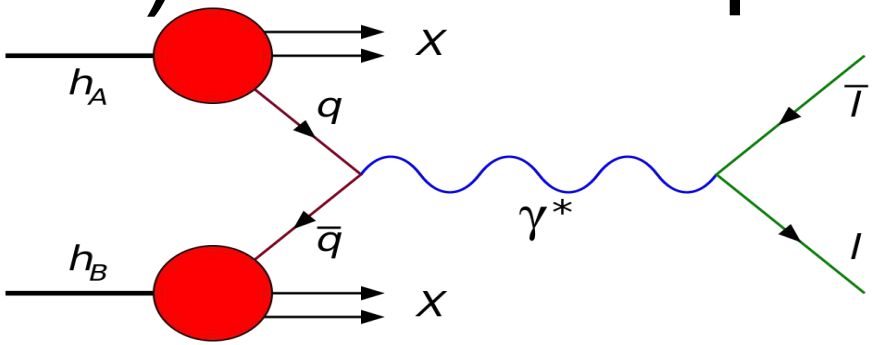
- Neglecting quarks transverse momentum – 3 functions – f_1, g_1, h_1
- Taking into account transverse momentum → 8 TMDs at LT
- 3 give f_1, g_1, h_1 when integrated over k_T
- Other vanish after integration
- 2 are T-odd (Sivers and Boer-Mulders)

TMDs



Can be measured e.g. in SIDIS or DY

(Polarized) Drell-Yan process



- Quark-antiquark annihilation to lepton pair in hadron-hadron collision
- Single-polarized cross-section:

$$\frac{d\sigma}{d^4q d\Omega} = \frac{\alpha_{em}^2}{Fq^2}\hat{\sigma}_U \mathcal{A}\Big\{\big(1 + A_U^1 \cos^2\theta + D_{[\sin 2\theta]} A_U^{\cos\phi}\cos\phi + D_{[\sin^2\theta]} A_U^{\cos 2\phi}\cos 2\phi\big)$$

$$\pm |\vec{S}_T| \Big[\big(D_{[1]} A_T^{\sin\phi_S} + D_{[\cos^2\theta]}\tilde{A}_T^{\sin\phi_S}\big)\sin\phi_S$$

$$+ D_{[\sin 2\theta]}\big(A_T^{\sin(\phi+\phi_S)}\sin(\phi+\phi_S) + A_T^{\sin(\phi-\phi_S)}\sin(\phi-\phi_S)\big)$$

$$+ D_{[\sin^2\theta]}\big(A_T^{\sin(2\phi+\phi_S)}\sin(2\phi+\phi_S) + A_T^{\sin(2\phi-\phi_S)}\sin(2\phi-\phi_S)\big)\Big]\Big\}$$

Polarized Drell-Yan process

- Amplitudes in cross-section are accessed via azimuthal asymmetries between two oppositely transversely polarized target cells and they give access to following TMDs:

$A_U^{\cos 2\phi}$: Boer-Mulders $h_1^\perp(\pi) \otimes$ Boer-Mulders $h_1^\perp(p)$

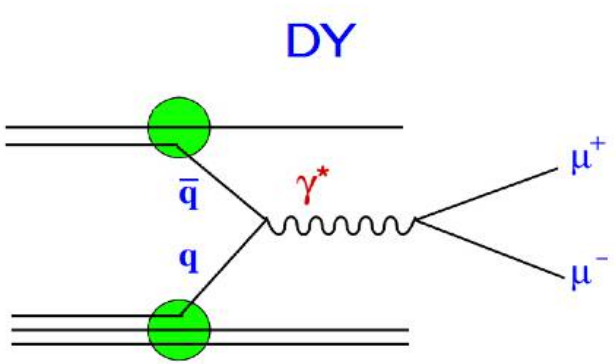
$A_T^{\sin \phi_S}$: unpolarised PDF $f_1(\pi) \otimes$ Sivers $f_{1T}^\perp(p)$

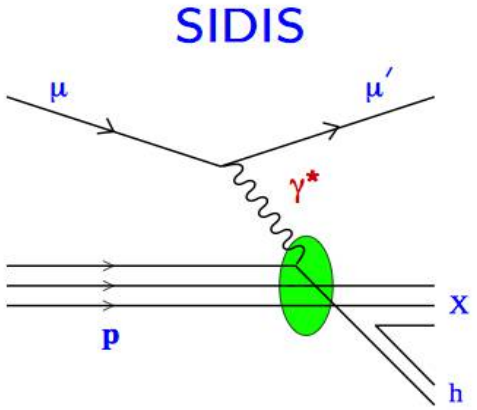
$A_T^{sin(2\phi+\phi_S)}$: Boer-Mulders $h_1^\perp(\pi) \otimes$ pretzelosity $h_{1T}^\perp(p)$

$A_T^{sin(2\phi-\phi_S)}$: Boer-Mulders $h_1^\perp(\pi) \otimes$ transversity $h_1(p)$

Polarized Drell-Yan process

- Crucial theoretical prediction: Sivers and Boer-Mulders function should change sign (T-odd functions):





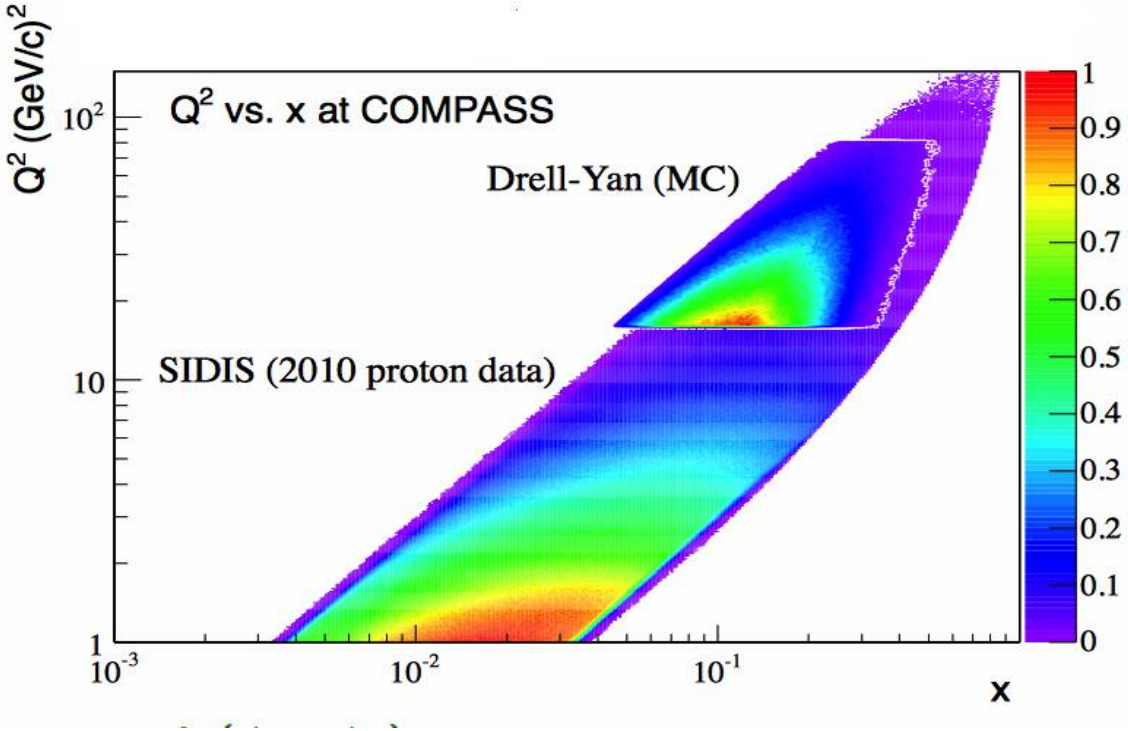
$$f_{1T}^{\perp}(x, k_T)|_{DY} = -f_{1T}^{\perp}(x, k_T)|_{SIDIS}$$

$$h_1^{\perp}(x, k_T)|_{DY} = -h_1^{\perp}(x, k_T)|_{SIDIS}$$

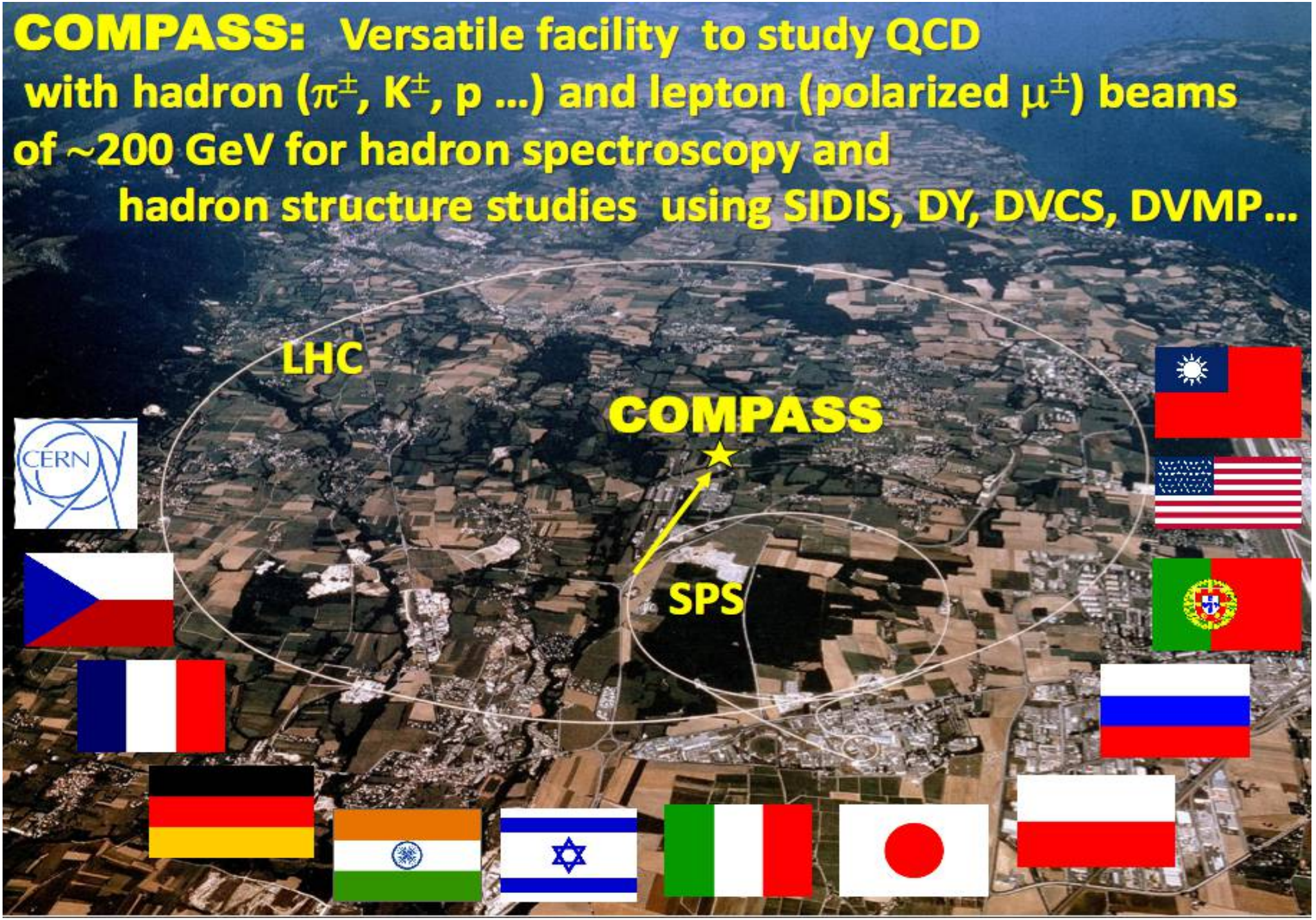
For more see Bakur Parsamyan talk

DY at COMPASS

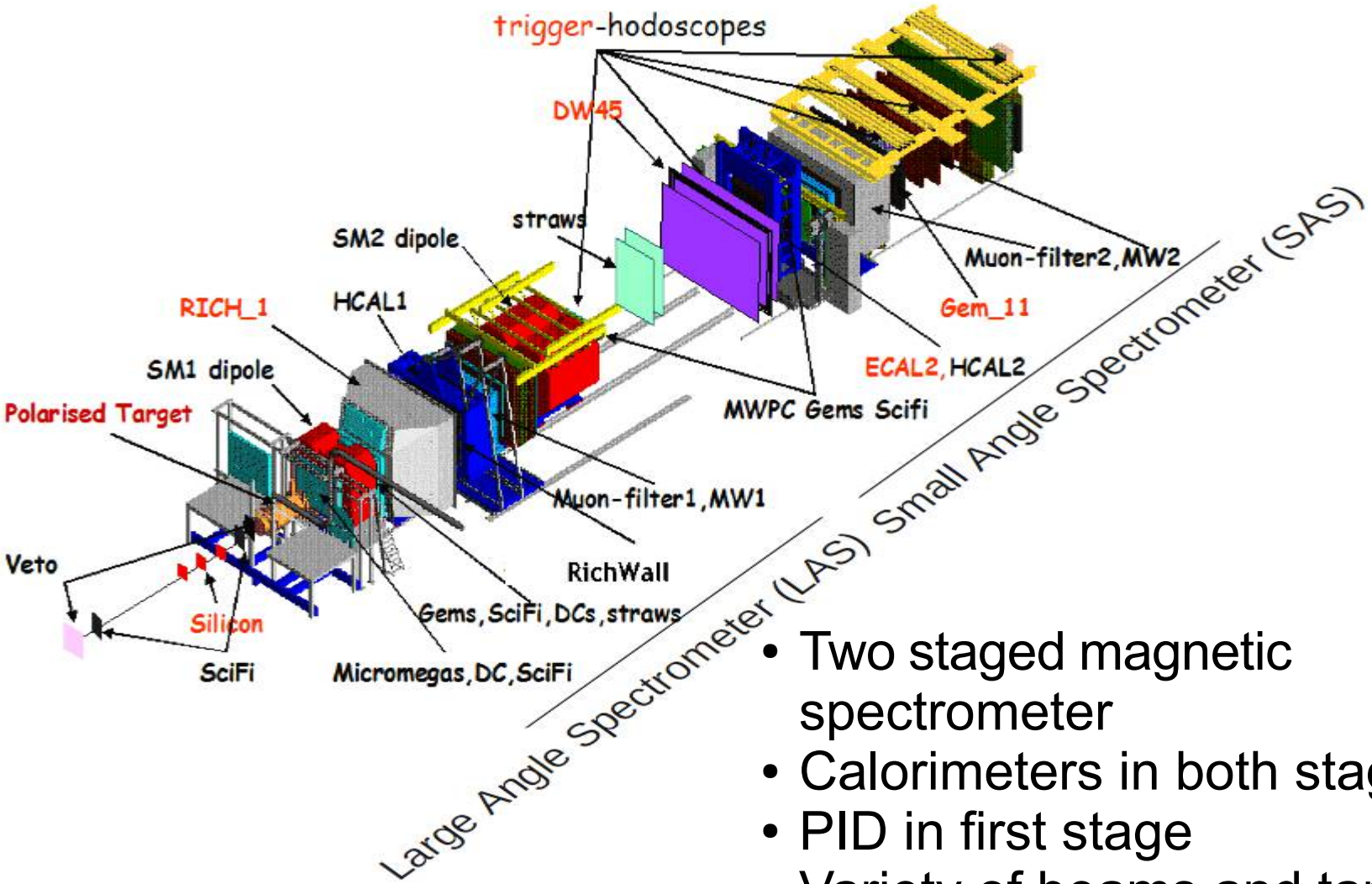
- We have opportunity to measure both SIDIS and DY at COMPASS
- There is a phase space overlap for the measurements



Measured for $M_{\mu\mu}$>4 GeV to stay in valid region for TMD approach i.e. $M_{\mu\mu} >> k_T$


COMPASS: Versatile facility to study QCD
with hadron ($\pi^{\pm}$, $K^{\pm}$, p ...) and lepton (polarized $\mu^{\pm}$) beams
of ~200 GeV for hadron spectroscopy and
hadron structure studies using SIDIS, DY, DVCS, DVMP...
LHC
COMPASS
SPS
CERN

COMPASS experiment



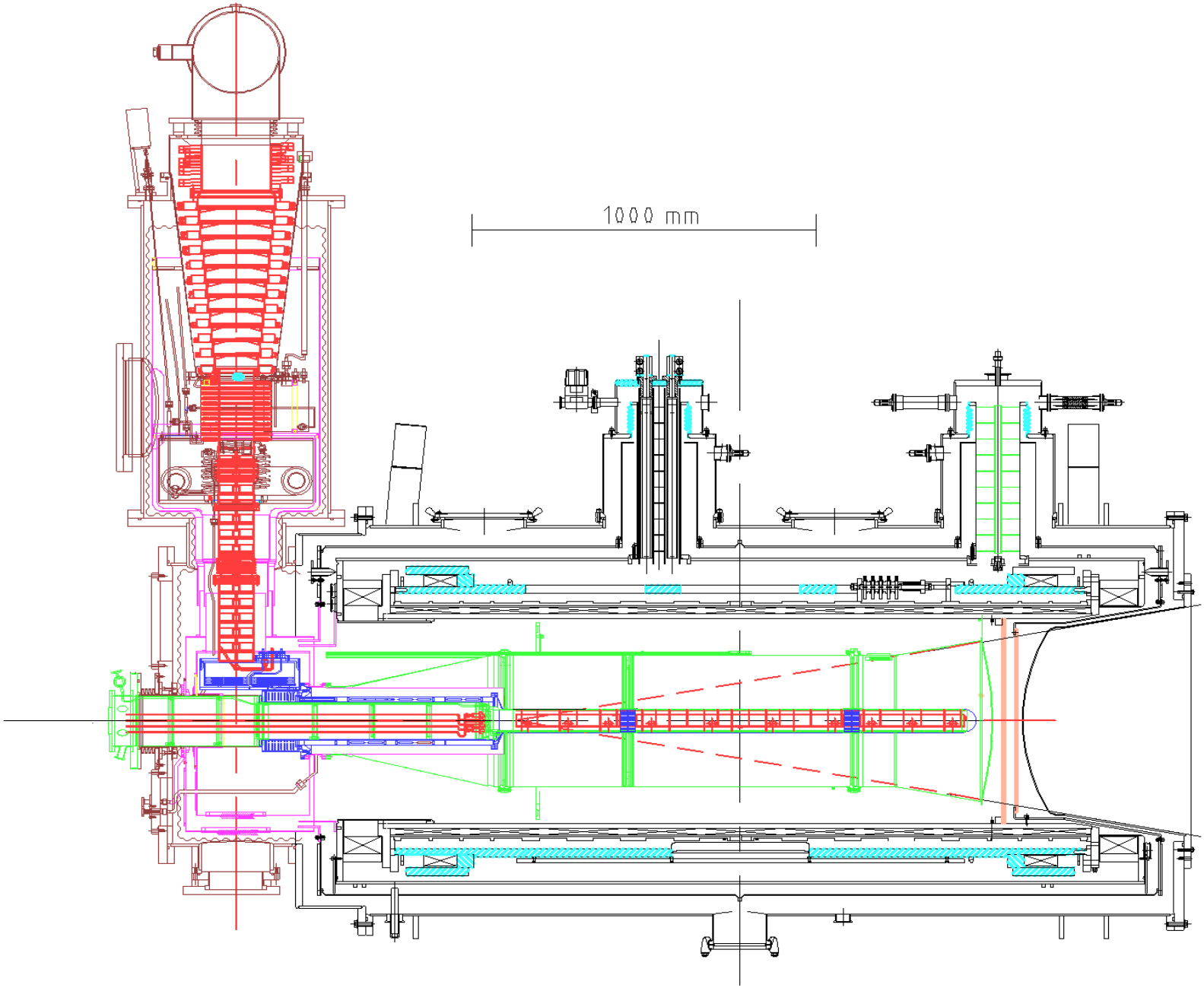
- Two staged magnetic spectrometer
- Calorimeters in both stages
- PID in first stage
- Variety of beams and targets
- ~300 tracking planes

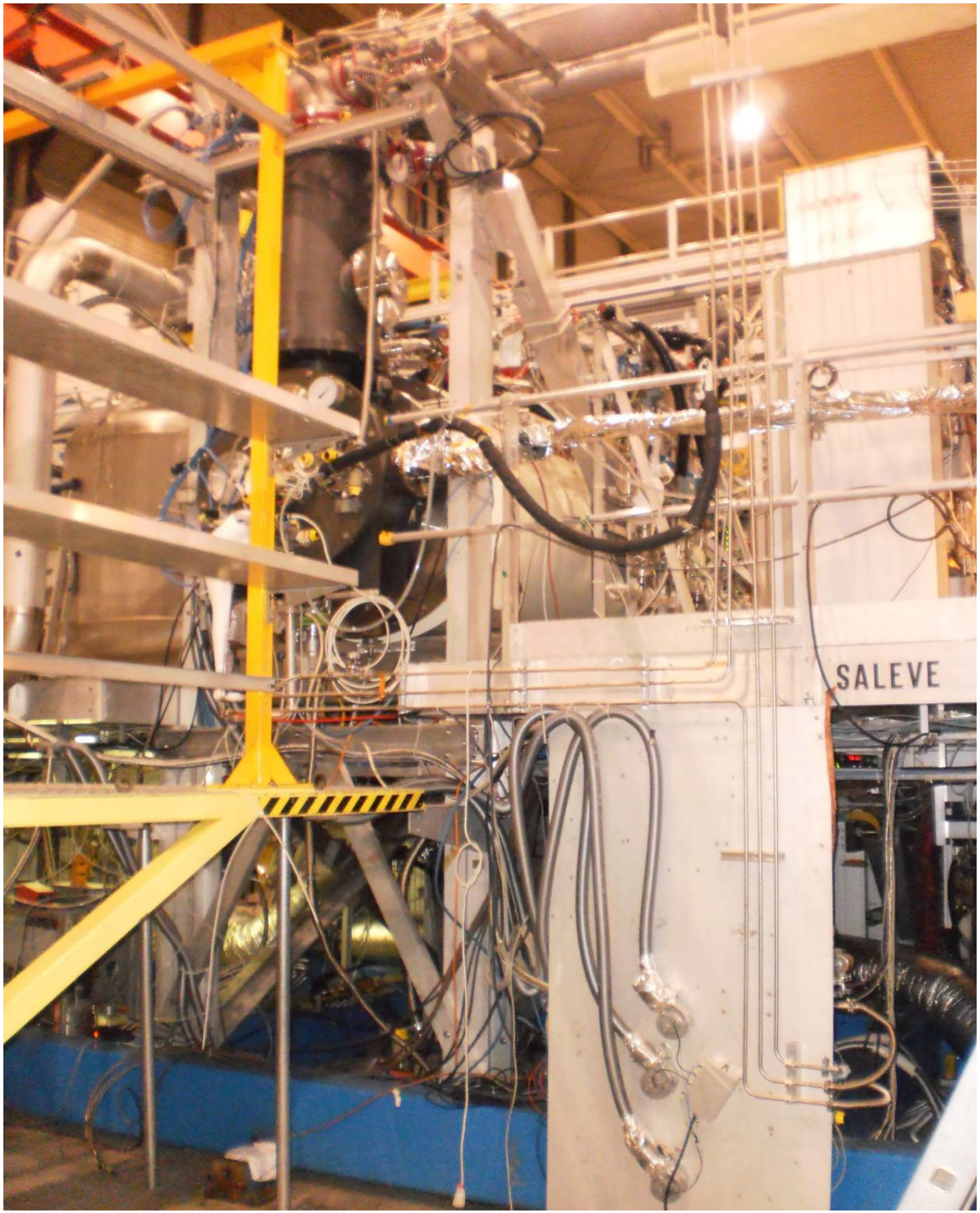
COMPASS Polarized target

- Target polarized by DNP
- (Probably) Most powerful DR in the world with cooling power of 5mW@75mK
- SC Magnet 2.5 T solenoid & 0.6 T dipole allows both transverse and longitudinal polarization
- Polarization measurement by cw NMR

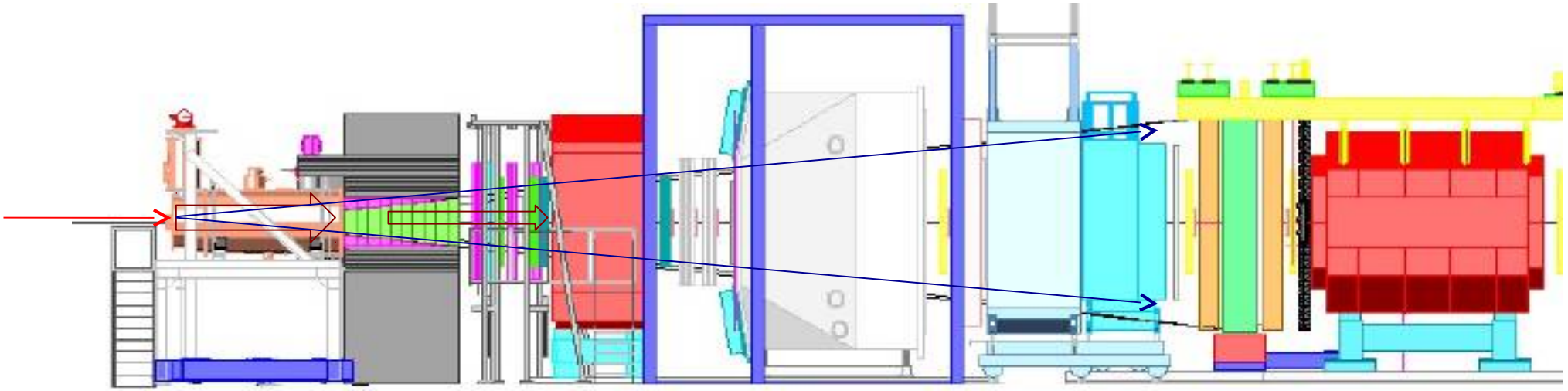
PT during 2010 & 2011

- μ beam with intensity 10^8 muons/s
- 3 cell design with 4 cm diameter
- 2 MW stoppers 5 cm long
- Solid NH_3
- 10 NMR coils
- Longitudinal and transverse polarization
- Maximum polarization ≈85%


1000 mm


SALEVE

Drell-Yan at COMPASS



High intensity π- beam
Transversely polarized proton target
Hadron Absorber
SciFi Vertex detector
Dedicated muon trigger
New Drift Chamber to improve tracking in LAS

Needed modifications for PT

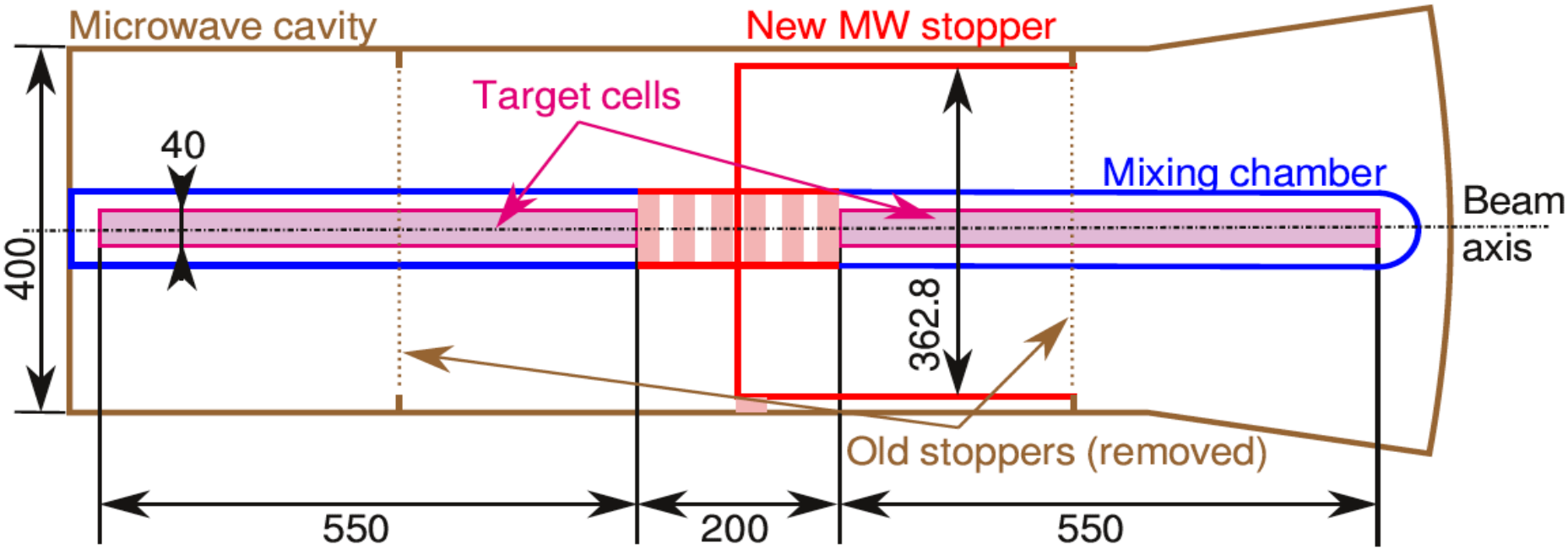
- **New cell design**=>
- **MW cavity modification**
- Hadron absorber=> **PT platform movement**
- **New remote control system**

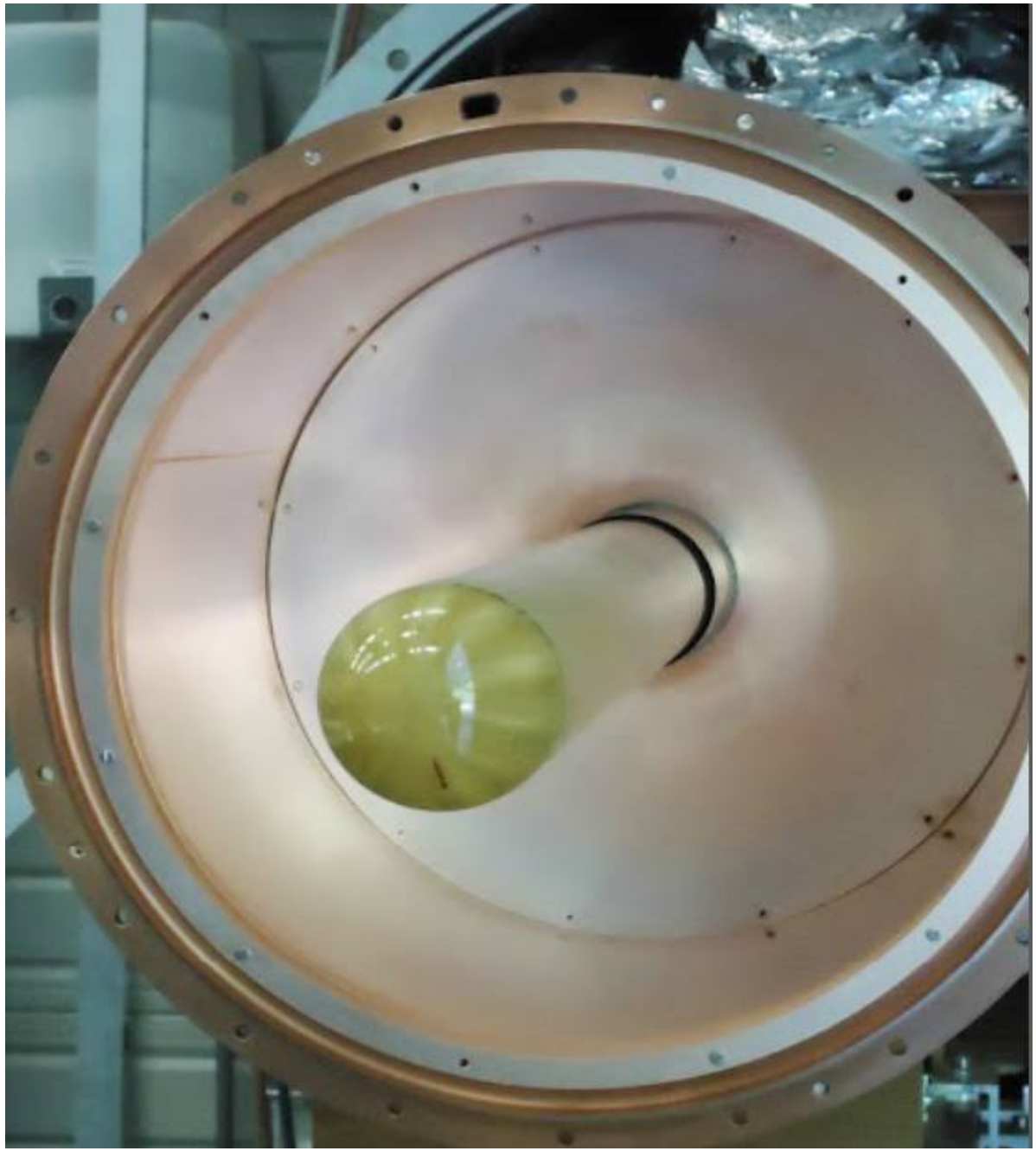
New target cell design

- 2 cells with 4 cm diameter 55 cm long
- 20 cm gap – to ensure proper vertex resolution
- 10 NMR coils – 3 outside, 2 inside the cell
- “Proton free” PCTFE material for the target cells

Cavity modification

- New 20 cm MW stopper needed



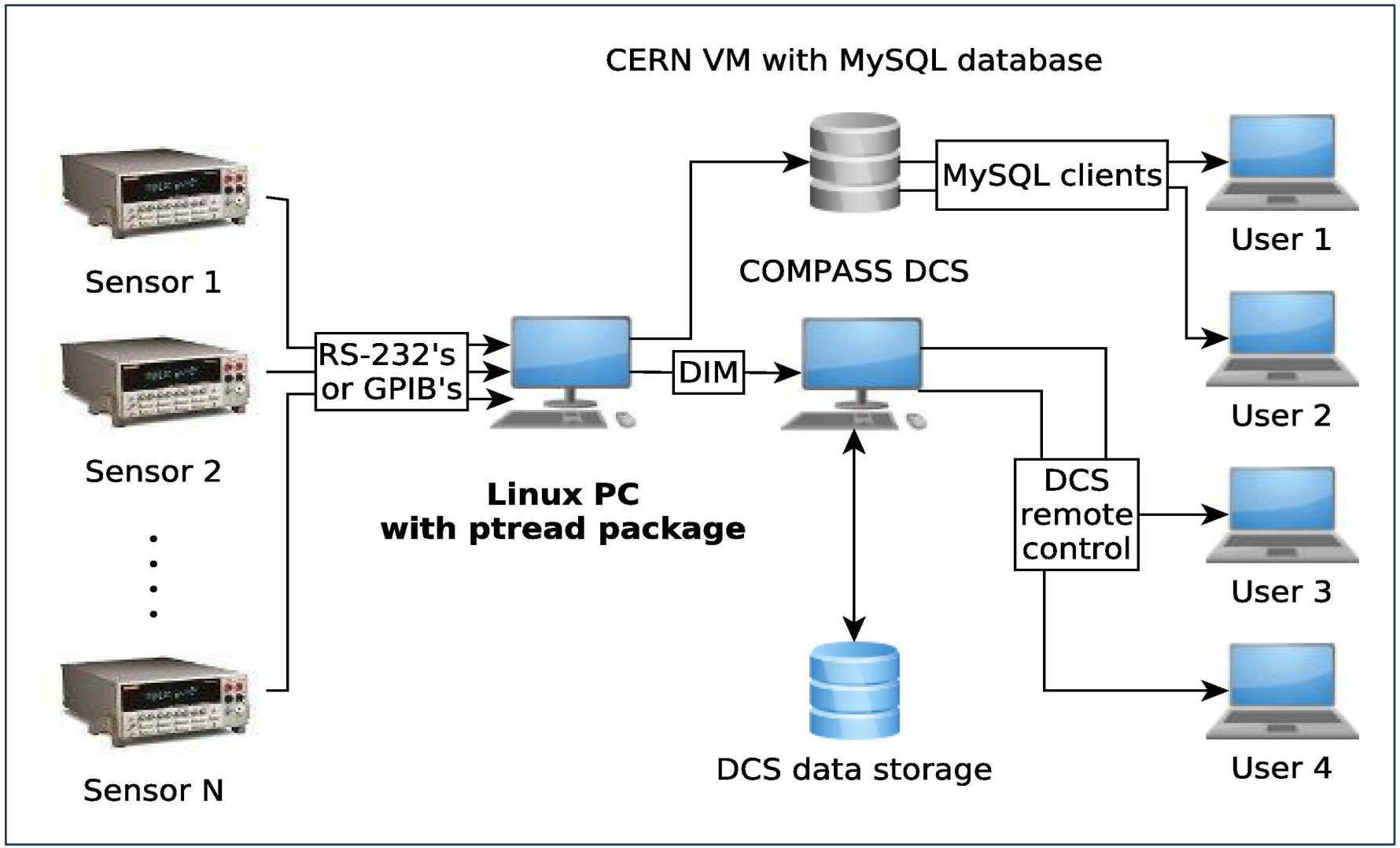


New remote control system

- Intense hadron beam (10^8 π-/s) => radiation dose in experimental hall exceeds permanent workspace area
- => control room moved in another building.
  => Remote control system necessary

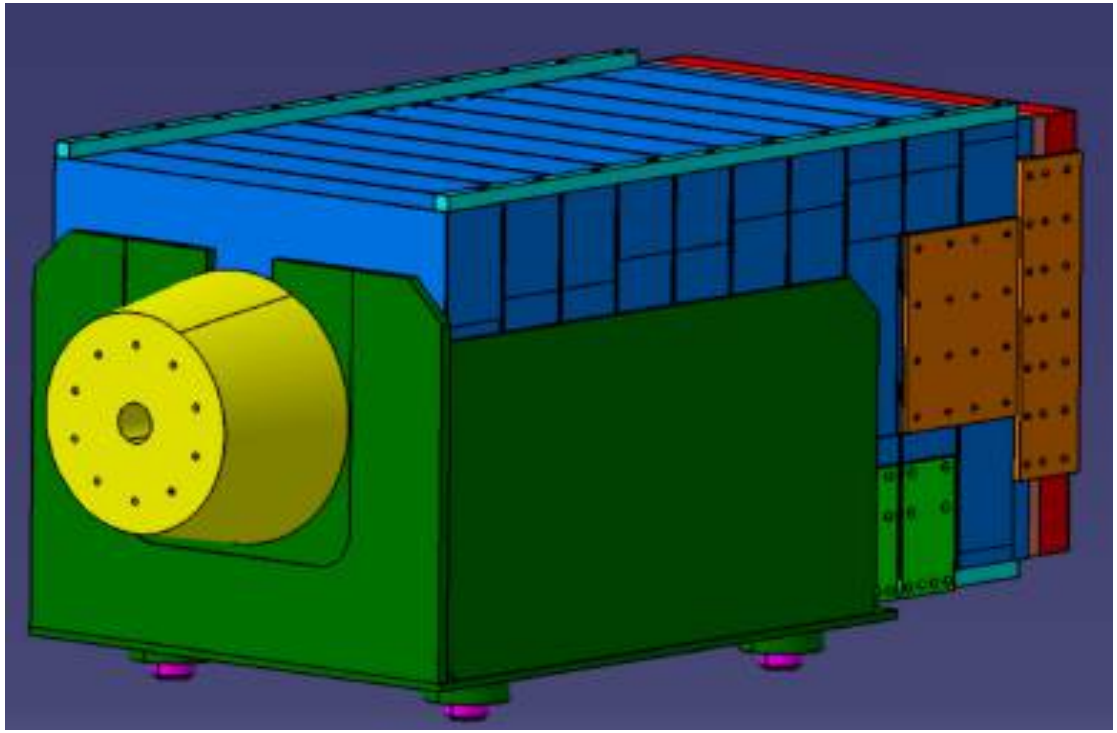
ptread package

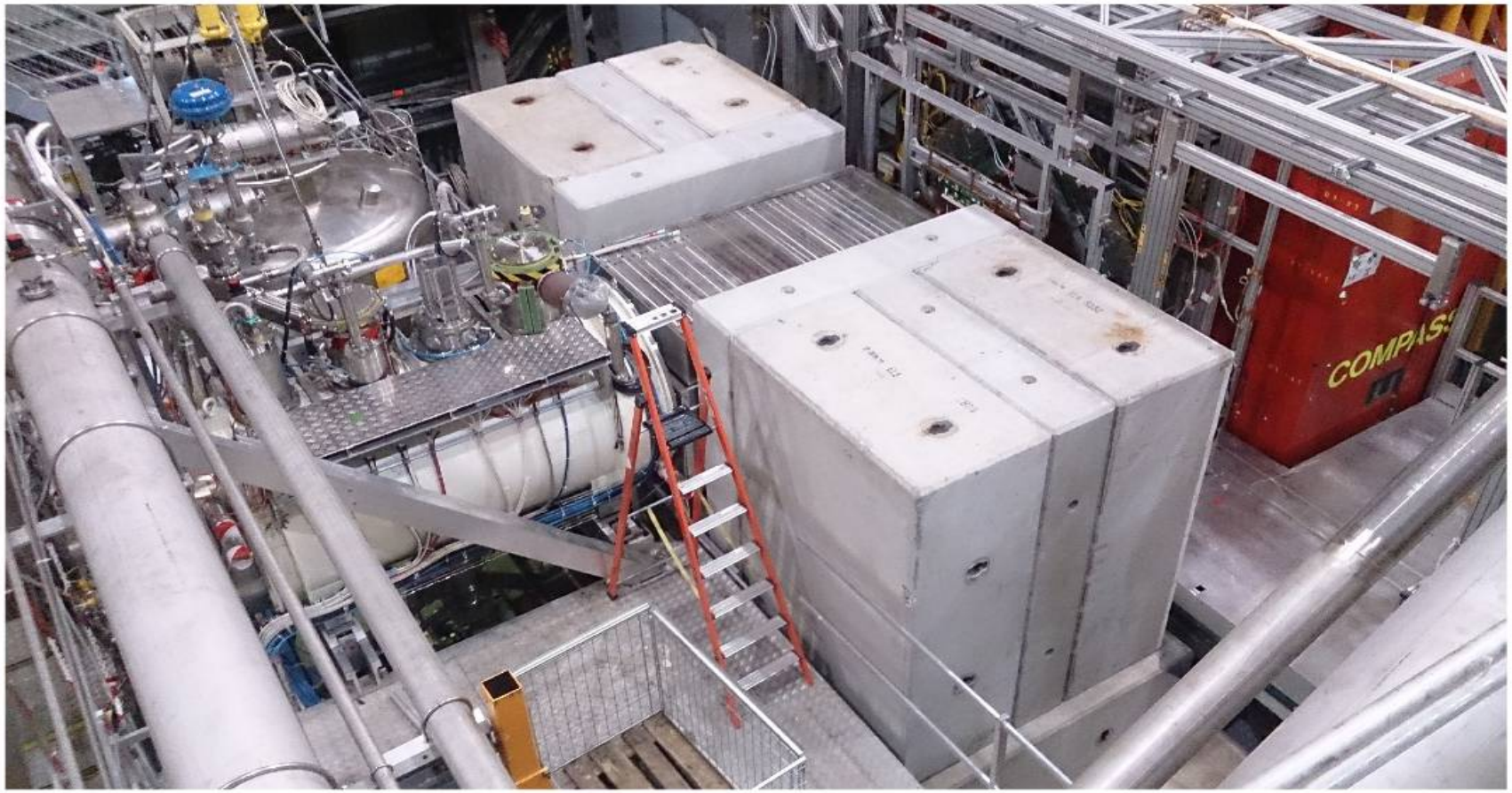
- Monitors dilution refrigerator (some pressure gauges, flow meters, > 30 thermometers...)
- Open-source, modular, easy to modify.
- Can communicate with COMPASS DCS (centralized Detector Control System)


CERN VM with MySQL database
MySQL clients
User 1
COMPASS DCS
Sensor 1
RS-232's
or GPIB's
DIM
User 2
Sensor 2
Linux PC
with ptread package
DCS
remote
control
User 3
User 4
DCS data storage
Sensor N

Hadron absorber & PT movement

- Made of concrete/stainless steel/alumina with tungsten beam plug
- Weights 22.5 tons (supplemented by other 140 t of concrete shielding)
- =>PT platform moved 230 cm upstream from previous position

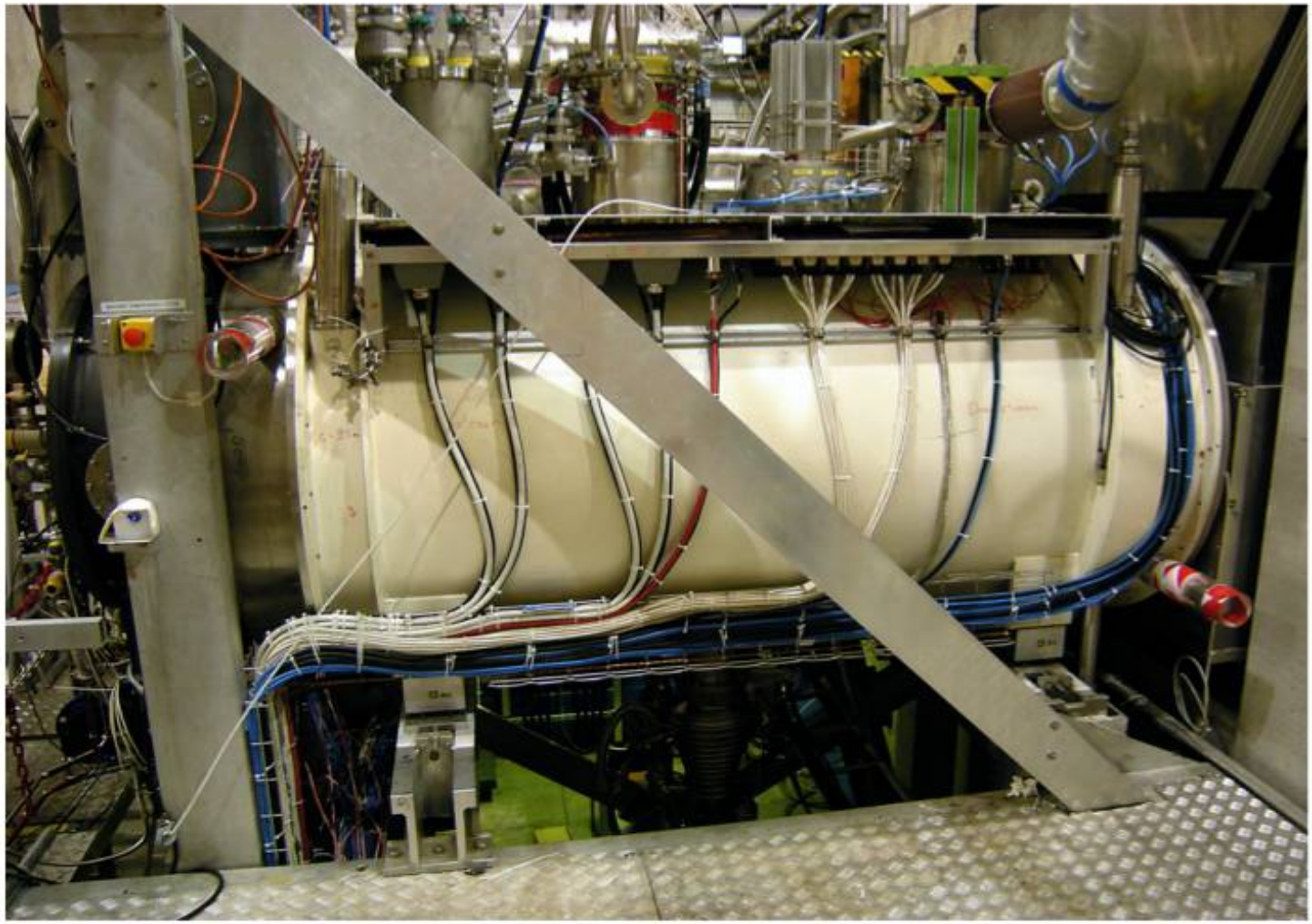


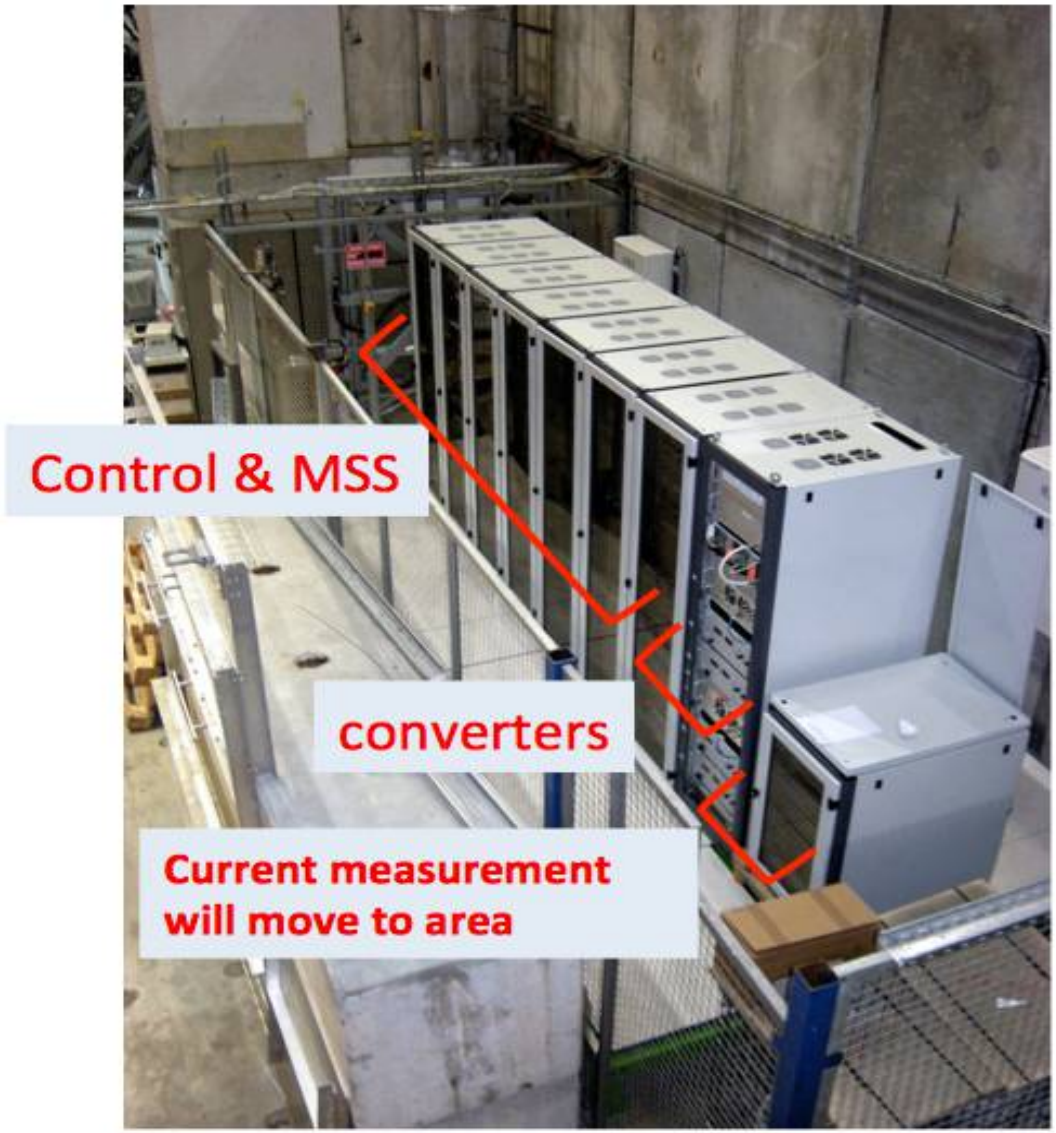

COMPASS

New magnet control system

- New control and safety system made by CERN magnet group
- Target magnet underwent heavy refurbishment
- Magnet final commissioning done late April 2015

Cable installation batch 3




Control & MSS
converters
Current measurement
will move to area

Current status & Plans

- Target is fully operational
- TE calibration performed during SPS scrubbing run in June
- Polarization build-up quite fast – maximum polarization reached in about 36 h
- Relaxation time seems to be shorter than expected – about 1000-1500 h (maybe radiation effect?)

Conclusion

- COMPASS has unique possibility to test predicted sign change by measuring both polarized SIDIS and polarized Drell-Yan using the same apparatus!
- COMPASS PT is fully operational after the upgrade!
- First ever polarized DY measurement is ongoing!!

Thank you for your attention!