Investigation and improvements of the behavior of sMDT chambers in the environment of high gamma radiation conditions

Proseminar: Physics at the Large Hadron Collider

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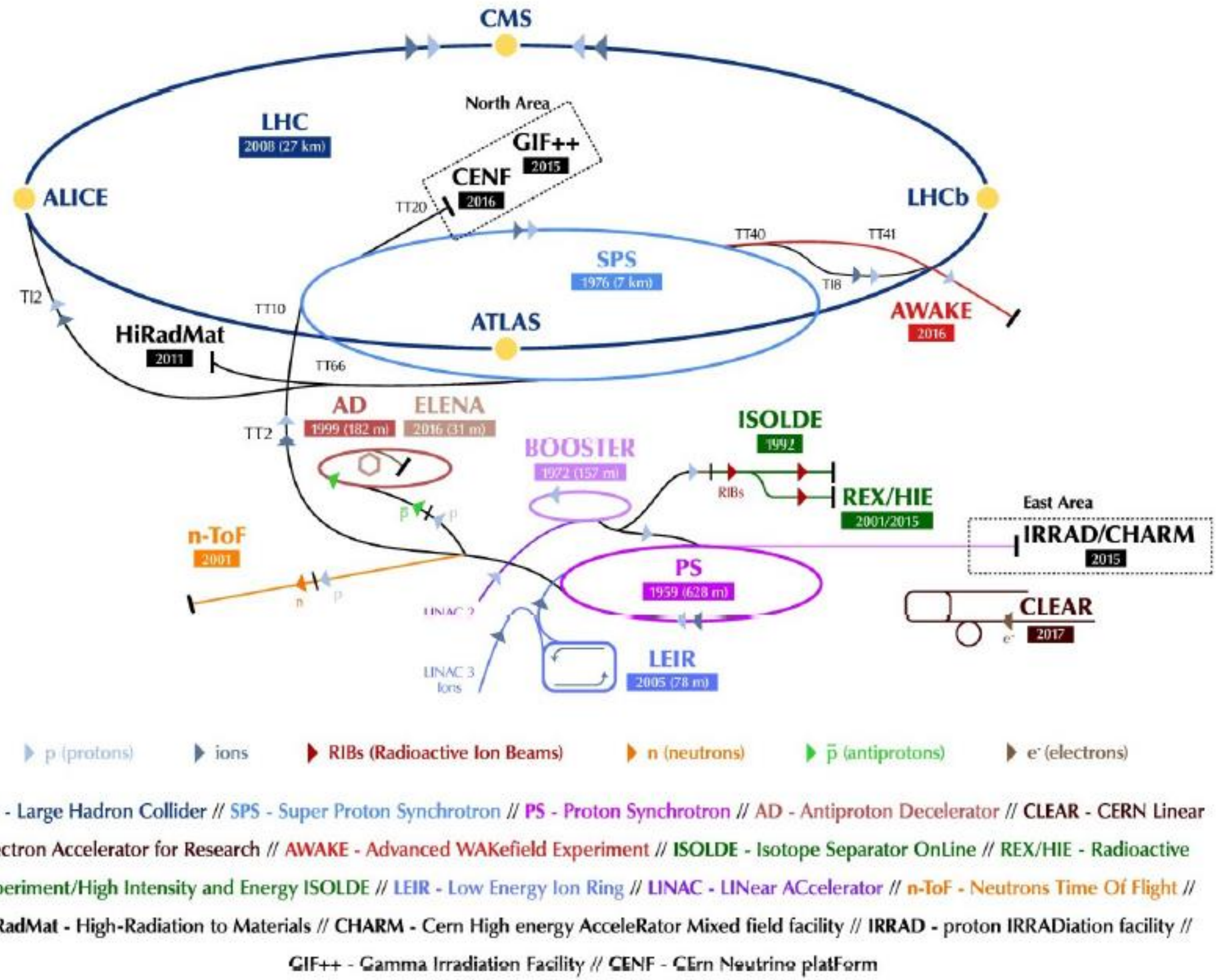
Outline

1. Motivation
   a) LHC-overview
   b) Future collider experiments
   c) sMDT chambers for muon precision tracking
   d) High-rate performance of sMDT chambers
2. Topic of the bachelorthesis: Measurement of the high-rate performance with sMDT chambers using a new ASD chip
   a) Preparatory studies with simulated data
   b) Teast beam measurement with GIF++ @CERN
3. Summary and outlook

CERN-overview

LHC:
- Most powerful hadron collider
- circumference: 27 km
- centre-of-mass energy: 14 TeV

Acceleration process @LHC:
- LINAC2
- PSB
- PS
- SPS



HL-LHC

– Physics motivation

a) Precision measurement of the properties of the SM Higgs boson

b) Search for physics beyond the SM, e.g. search for supersymmetry and dark matter

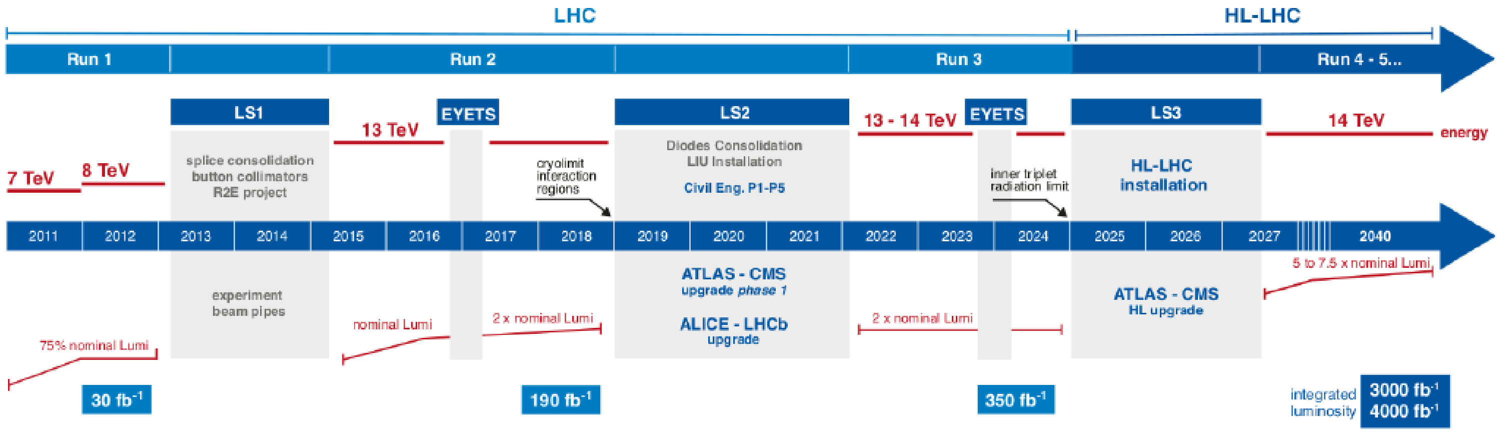
– Upgrade of the LHC to the HL-LHC:

a) With the existing dipole magnets no increase of the centre-of-mass energy possible

b) But almost tenfold increase of the instantaneous luminosity will provide sensitivity to rare processes and collisions at high centre-of-mass energies in the parton-parton system

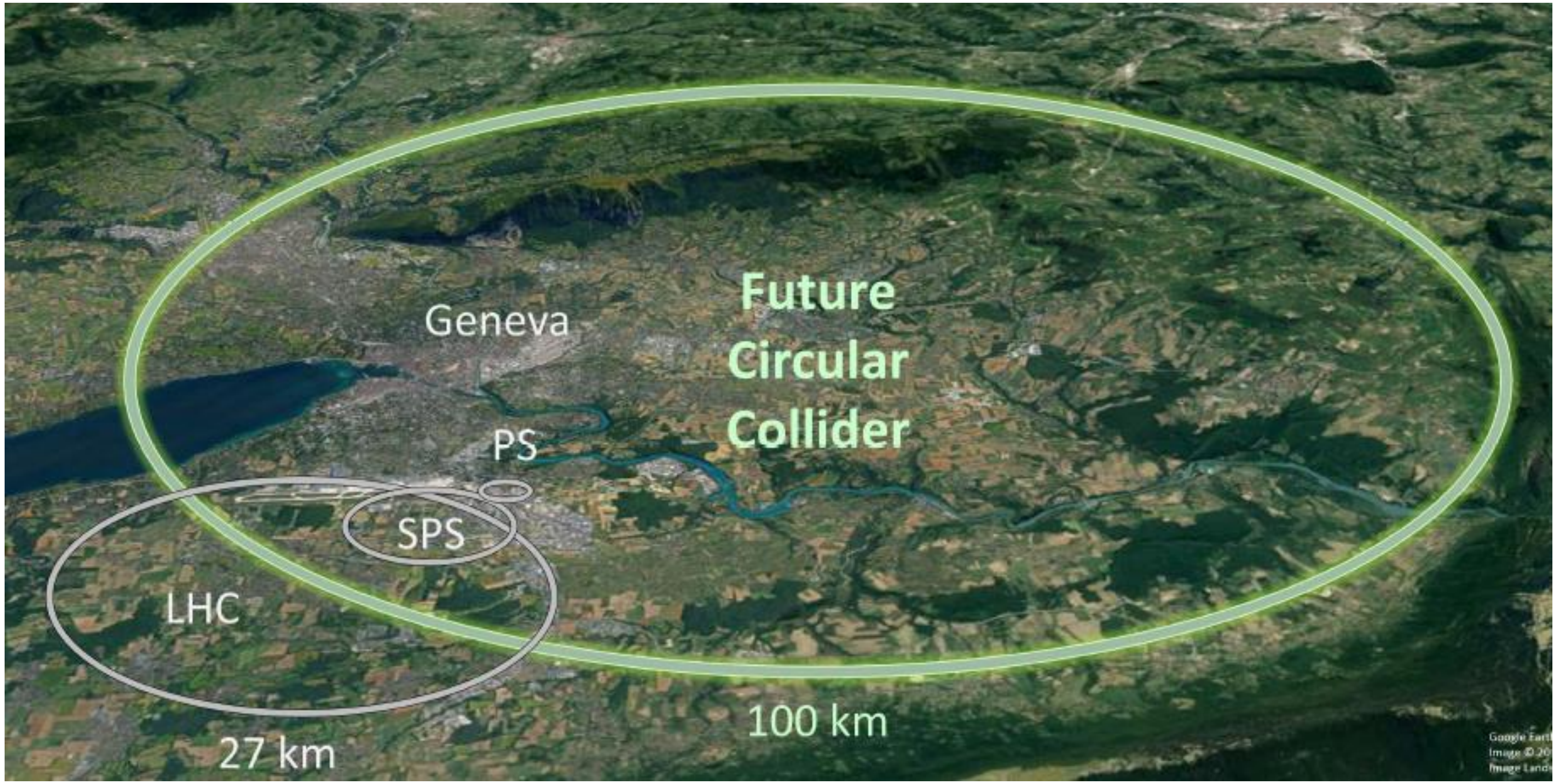
c) Increased luminosity will lead to increase particle fluences in the LHC detectors

- Therefor: Upgrade all the LHC detectors necessary



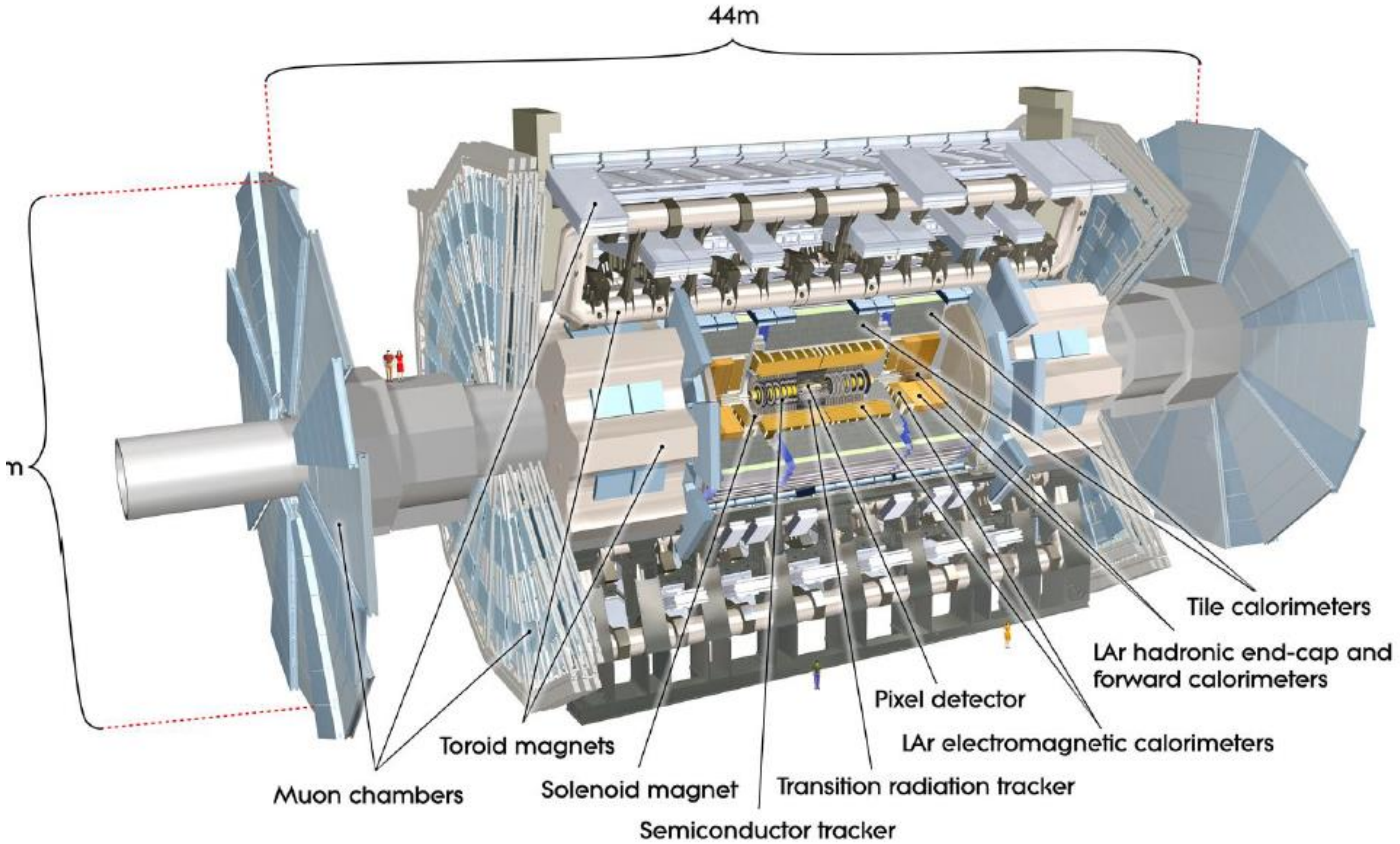
Future Circular Collider (FCC)

- Planned for post-LHC-era
- Circumference: 100km
- Centre-of-mass energy: 100 TeV
- 16 T field strength



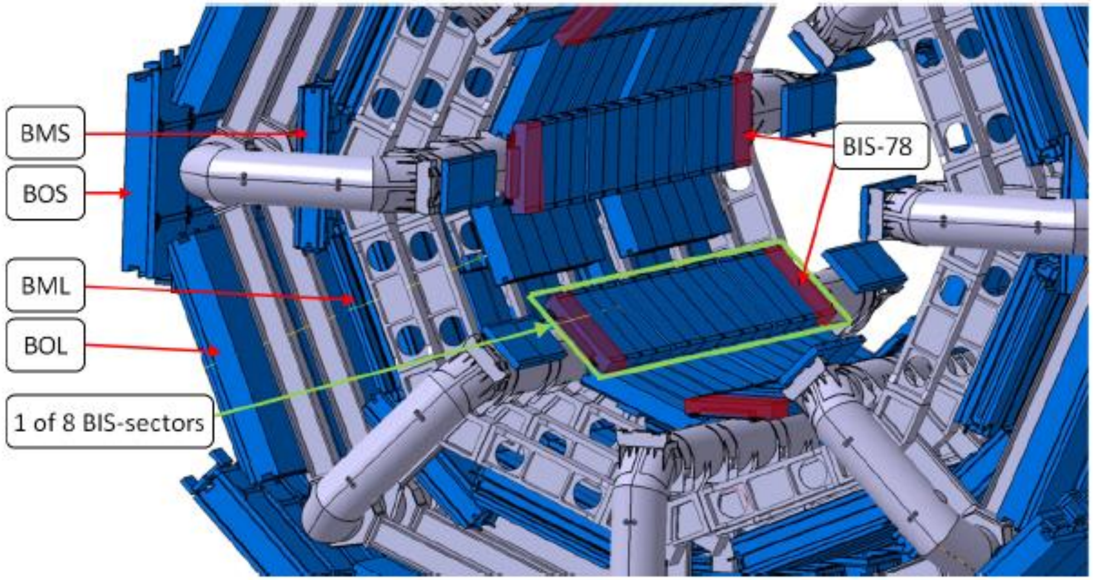
ATLAS-Detector

- ATLAS: **A T**oroida **L**HC **A**pparatu**S**
- Multiple layers of different detectors
- Forward-backward-symmetric architecture
- Three main subsystems of detector types: inner tracker, the calorimeter system and the muon spectrometer



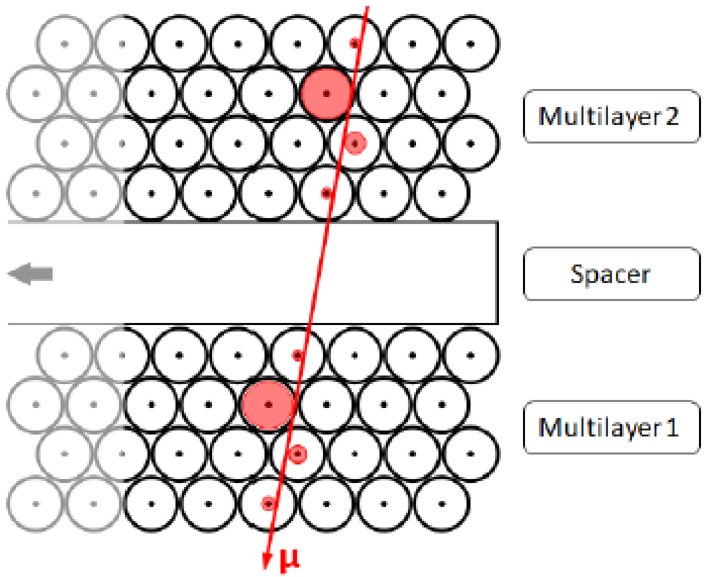
Muon Spectrometer

- occupies the largest volume of the ATLAS detector
- superconducting toroidal magnets provide a magnetic field of approx. 0.5 T
- bent particle trajectories measurements are performed by precision monitored drift tube (MDT) detectors
- MDT detectors contain 6-8 layers of single drift tubes with 30 mm diameter



sMDT chambers for muon precision tracking

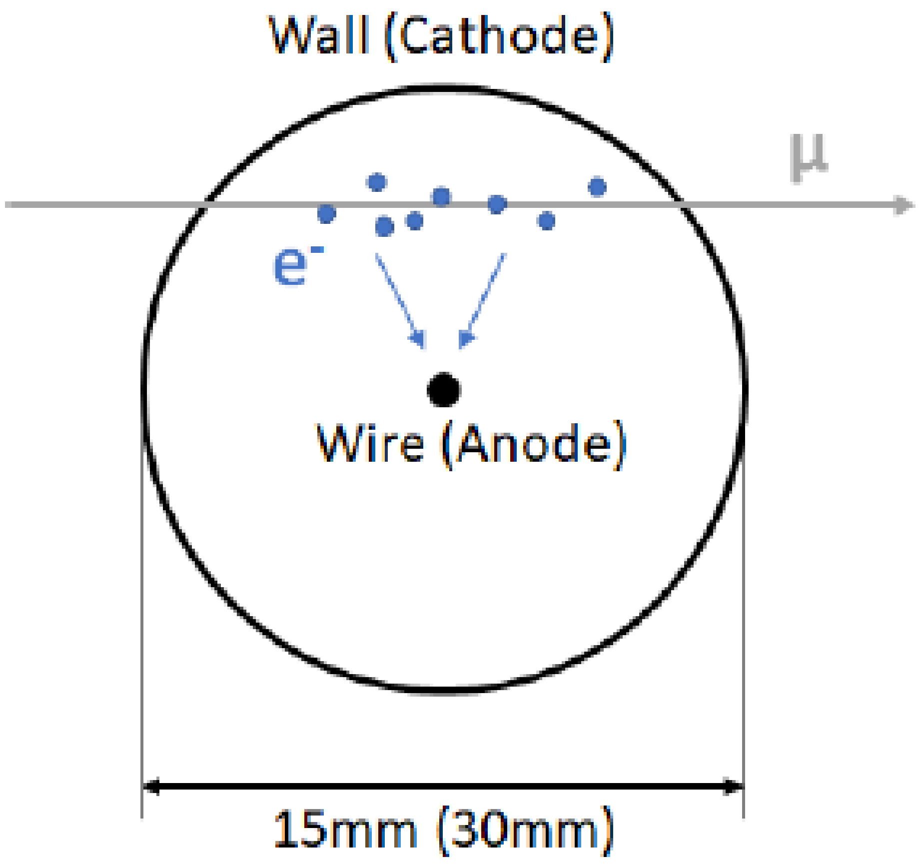
- BIS sector of muon spectrometer is updated: MDT -> sMDT
- Main difference: diameter reduction from 30 mm to 15 mm
- Apart from gain in physical space: better performance at high background irradiation
- Muon chambers consist of many tubes mounted together (4 layers + spacer)



Parameter	MDT	sMDT
Tube material	Aluminium	Aluminium
Tube outer diameter	29.97 mm	15.00 mm
Tube wall thickness	0.4 mm	0.4 mm
Wire material	W-Re, gold plated	W-Re, gold plated
Wire diameter	50 μm	50 μm
Gas mixture	Ar/CO_2 (93/7)	Ar/CO_2 (93/7)
Gas pressure	3 bar (abs.)	3 bar (abs.)
Gas gain	2×10^4	2×10^4
Wire potential	3080 V	2730 V
Maximum drift time	720 ns	190 ns
Wire positioning acccuracy	20 μm RMS	10 μm RMS
Spatial resolution*		
without background irradiation	83 μm	106 μm
280 Hz/cm^2 background rate	115 μm	108 μm
Efficiency*		
without background irradiation	95%	94%
65 kHz/tube counting rate	86%	92%

Working principle of sMDT chambers

- Charged particle (muon) passes through the detector
- Ionization of gas atoms inside the chamber
- Electric field between cathode and anode affects the particles
- electrons close to the anode wire (strong electric field): gained enough energy to ionize other atoms
- The process multiplies → avalanche of ionized electrons
- measurable pulse on the electrodes



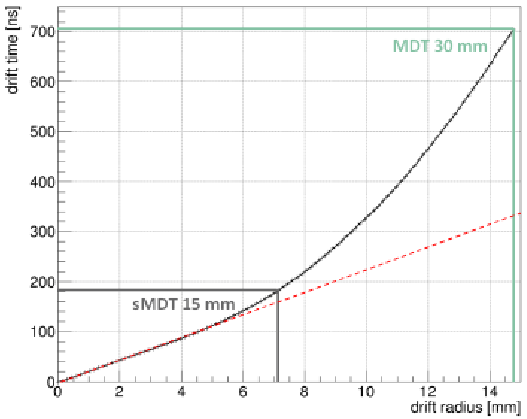
High-rate performance of sMDT chambers

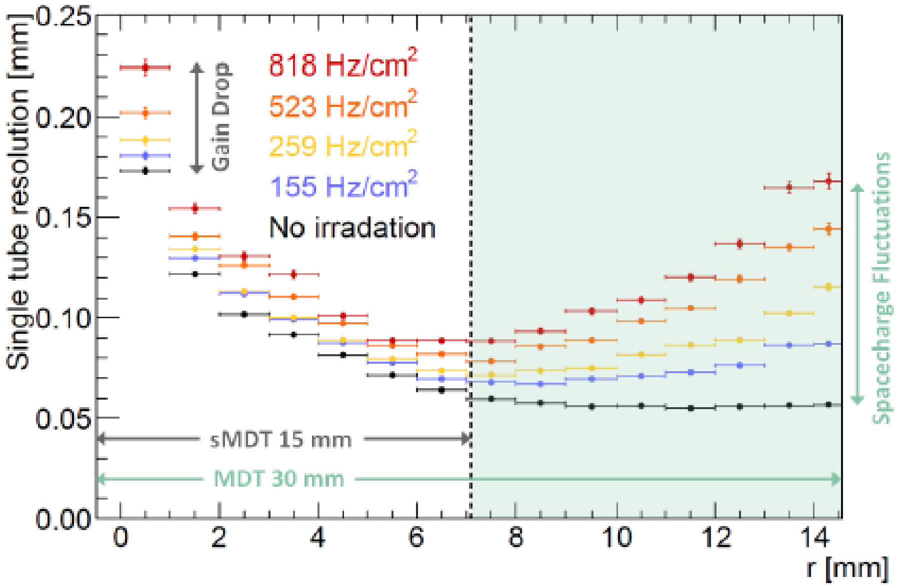
- High background counting rates expected @HL-LHC
- Muon chambers will be exposed to a large background of gamma rays
- delta-electrons are created via compton scattering when a photon hits the tube wall
- Slow drift of the ions from the avalanche at the anode wire to tube walls (1ms)
- modification of the electrical field inside the tube leading to:

  1) Space charge fluctuations

  2) Deat time effect

  3) a reduction of the gas gain (Gain Drop)

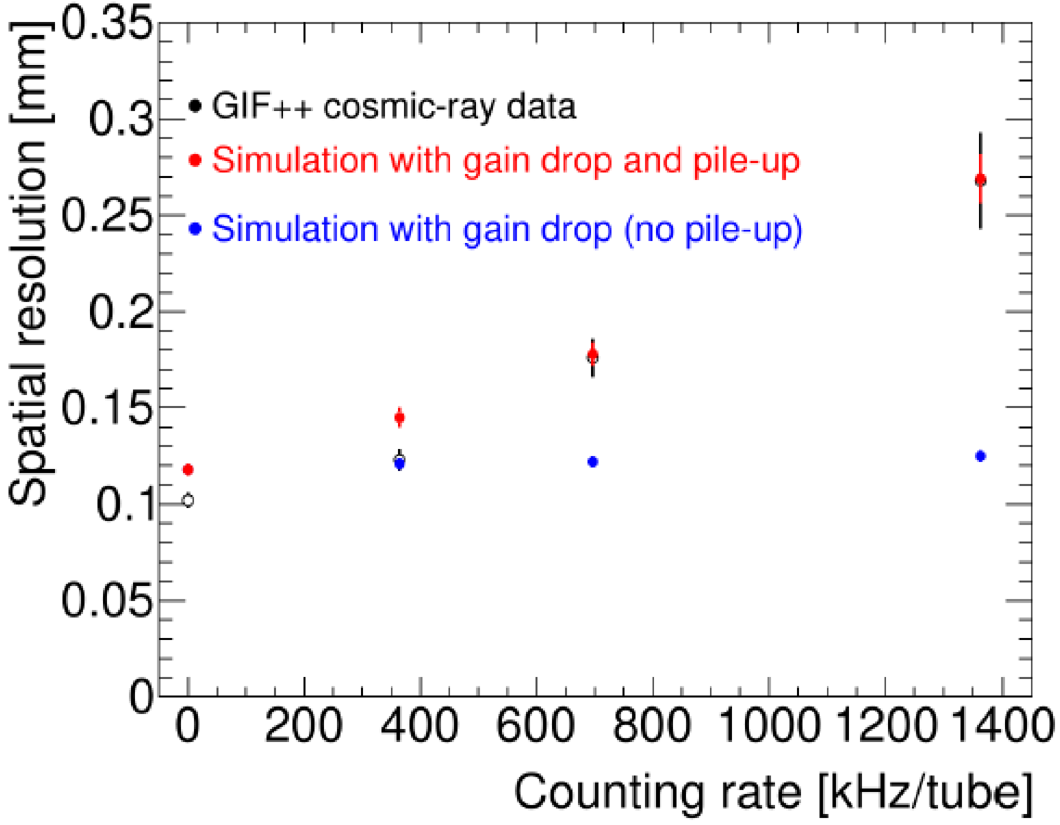




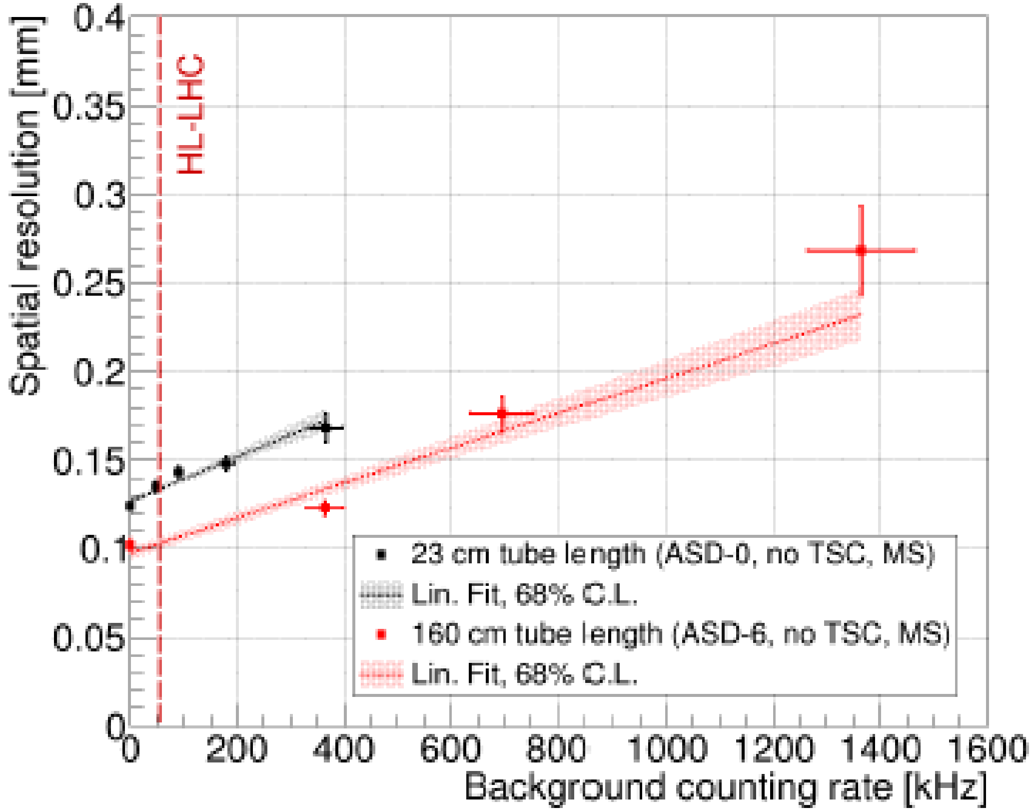
Bachelor‘s Thesis: Measurement of the high-rate performance with sMDT chambers using a new ASD chip

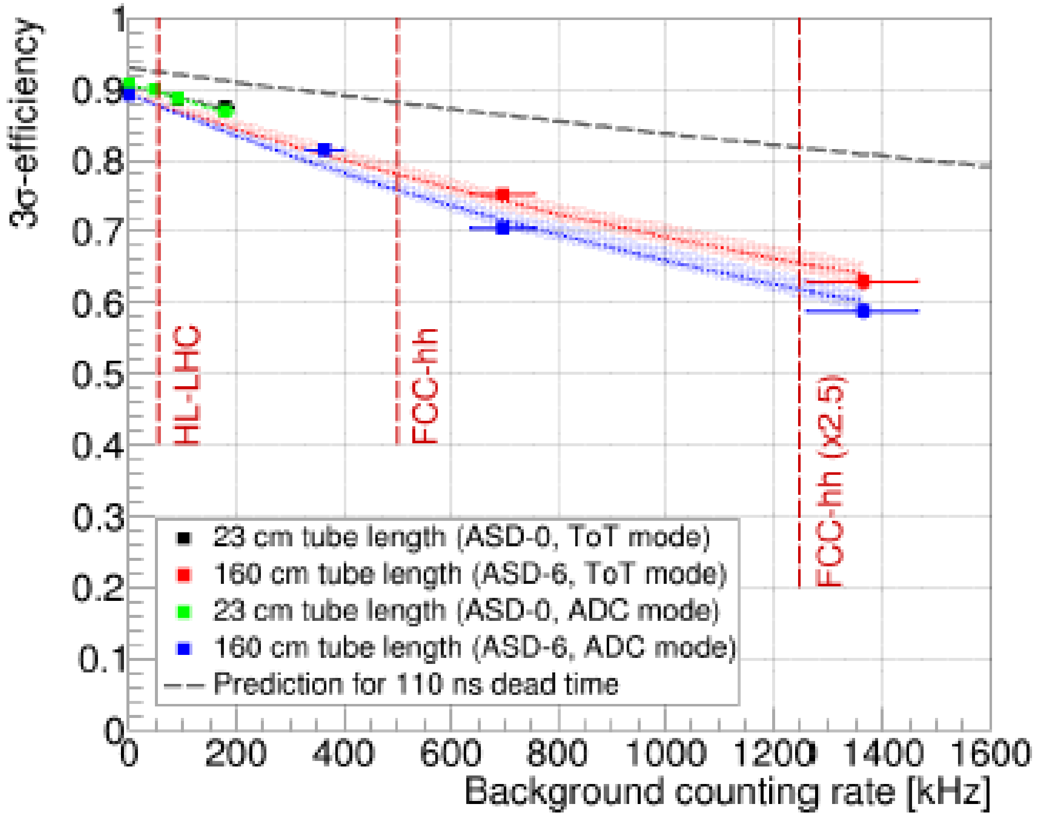
Preparatory studies with simulated data

- idea: simulate behavior of a single sMDT chamber with high gamma background radiation using Garfield++
- Ionization process + drift of electrons can be simulated really precisely
- Settings:
    1) inner tube radius: 7.1 mm
    2) radius of anode wire: 0.025 mm
    3) gasmixture in the tube: Ar/CO2 (ratio: 93/7)
    4) voltage: 2730 V
    5) pressure of gas: 3000 mbar
    6) temperature of gas: 24 °C



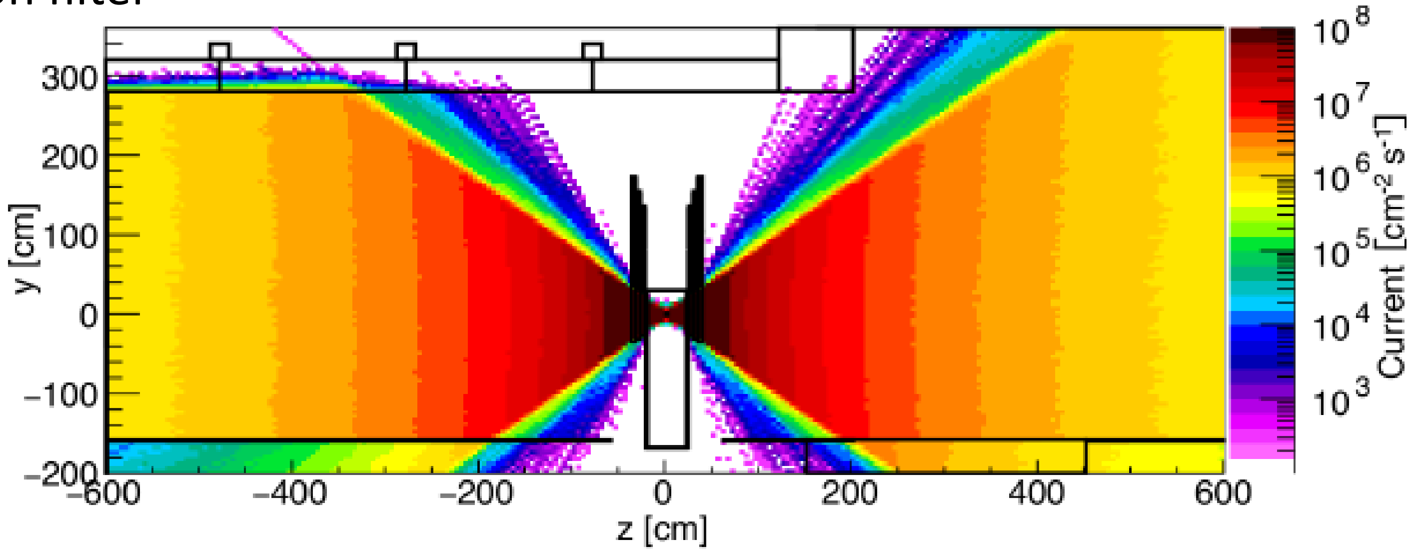
Motivation for test beam measurements

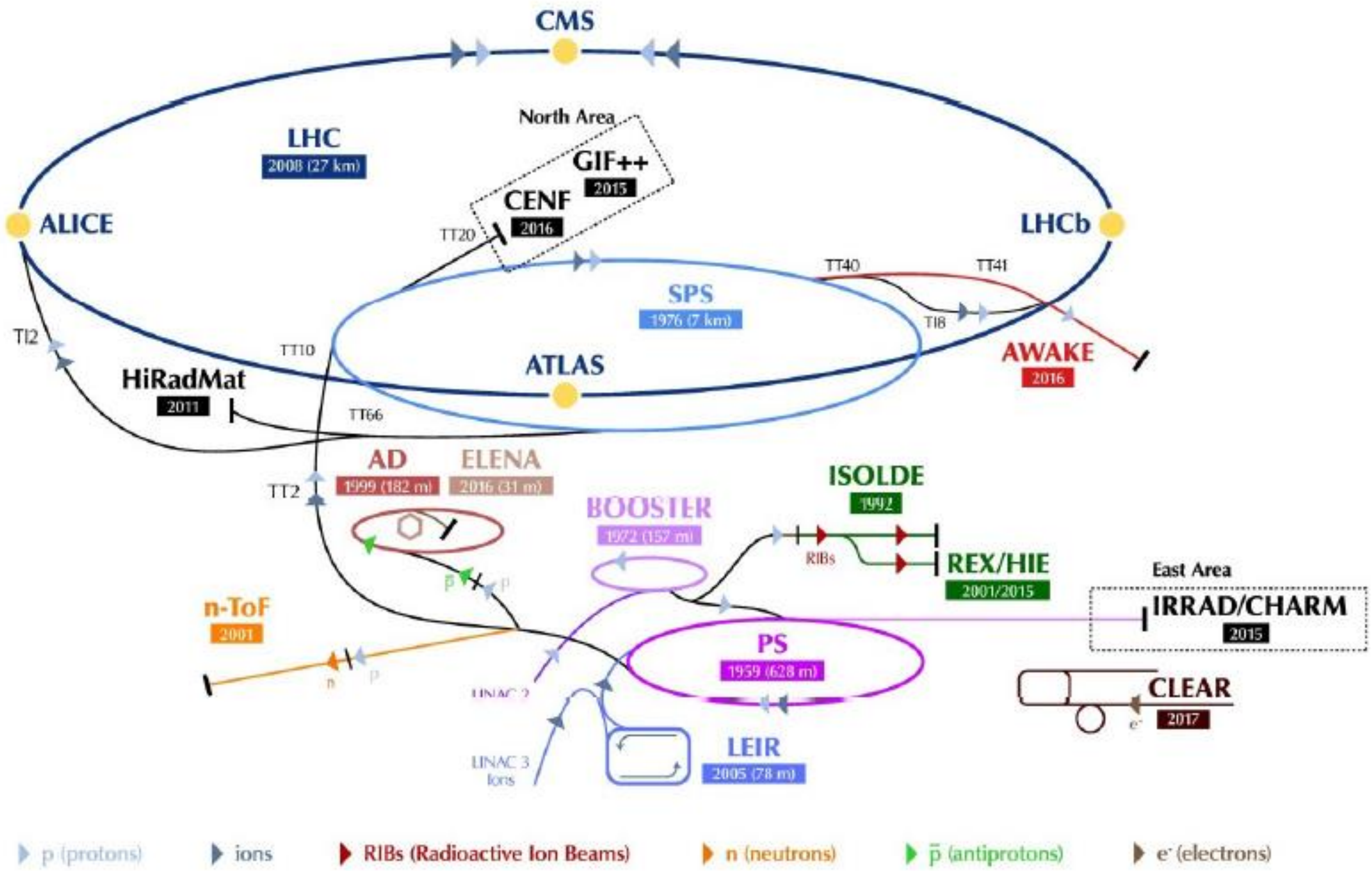




Teast beam measurement with GIF++ @CERN

- Experiment is located in the “Experimental Hall North” (EHN)
- Beam production: protons from SPS shot at tungstic target, creation of pions which decay to muons
- radioactive Caesium source positioned directly in the muon beam: simulation of a high gamma-background expected at HL-LHC
- Angular correction filter





LHC - Large Hadron Collider // SPS - Super Proton Synchrotron // PS - Proton Synchrotron // AD - Antiproton Decelerator // CLEAR - CERN Linear Electron Accelerator for Research // AWAKE - Advanced WAKefield Experiment // ISOLDE - Isotope Separator OnLine // REX/HIE - Radioactive EXperiment/High Intensity and Energy ISOLDE // LEIR - Low Energy Ion Ring // LINAC - LINear ACcelerator // n-ToF - Neutrons Time Of Flight // HiRadMat - High-Radiation to Materials // CHARM - Cern High energy AcceleRator Mixed field facility // IRRAD - proton IRRADiation facility // GIF++ - Gamma Irradiation Facility // CENF - CErn Neutrino platForm

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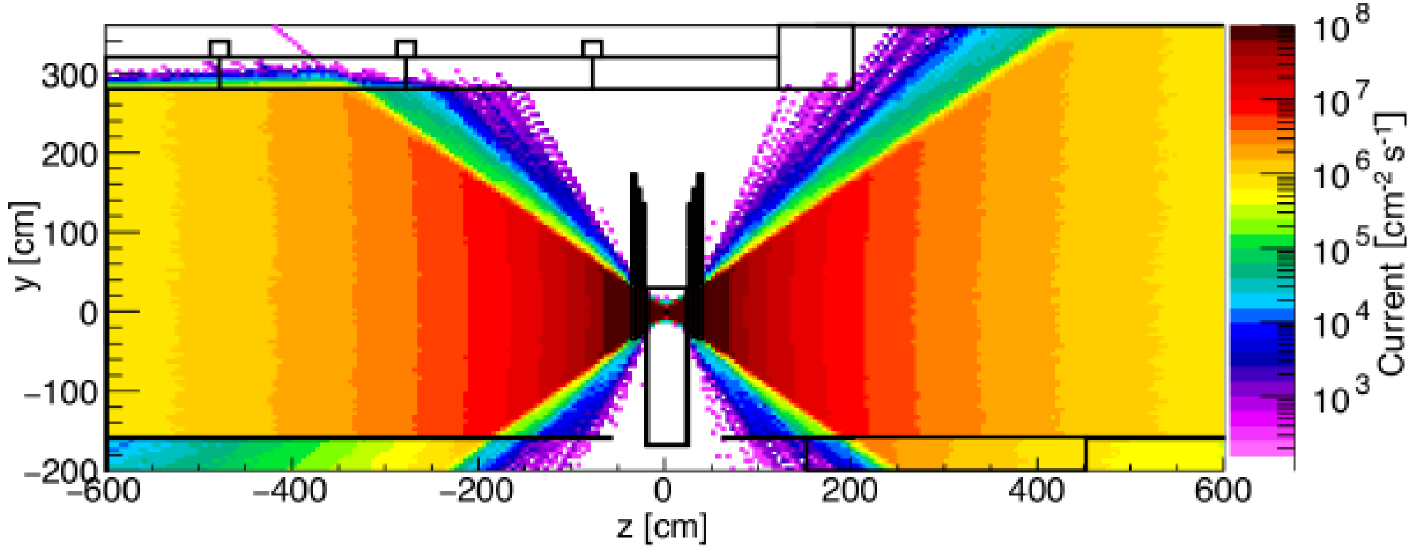

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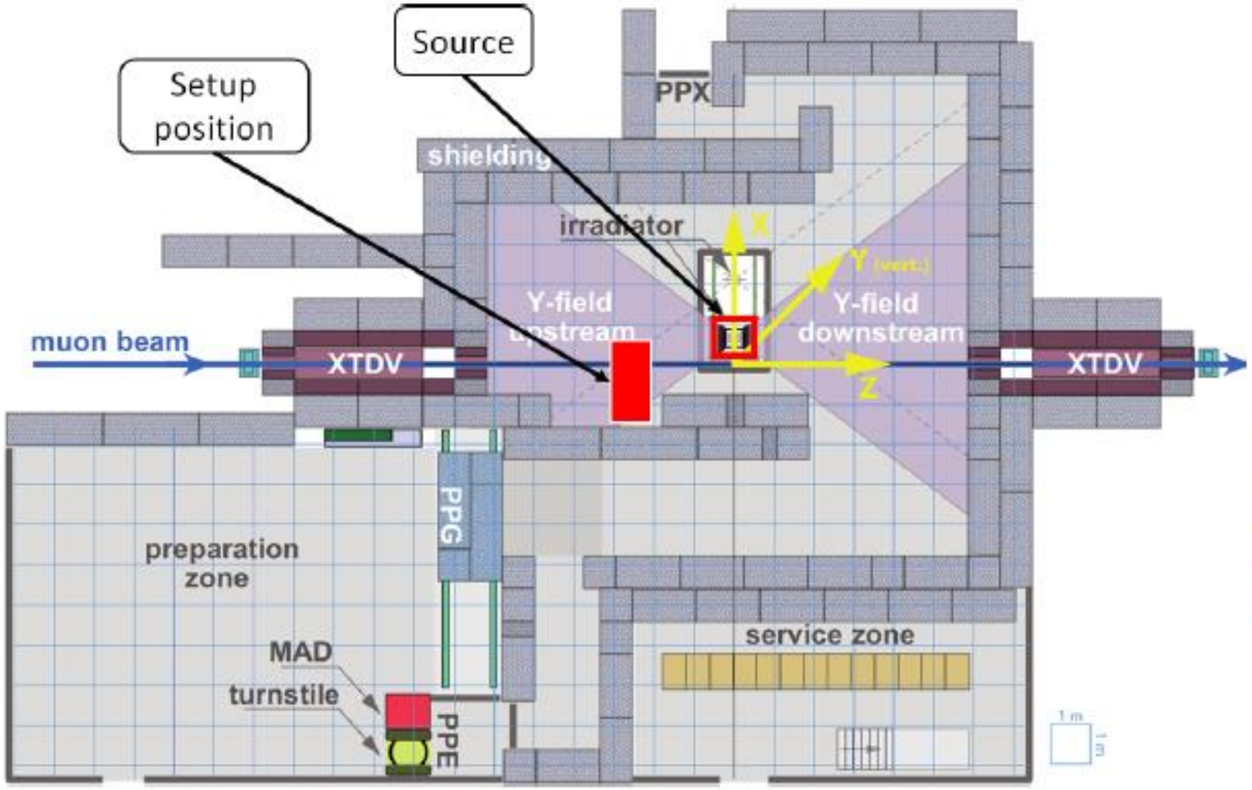

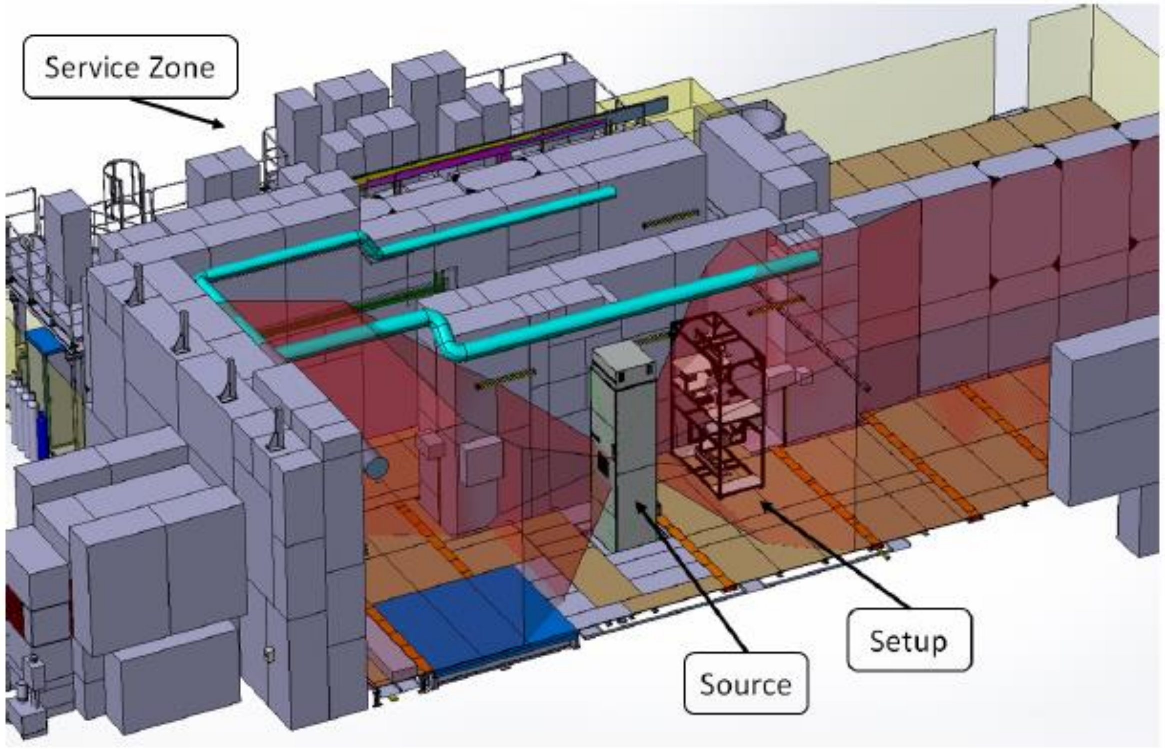

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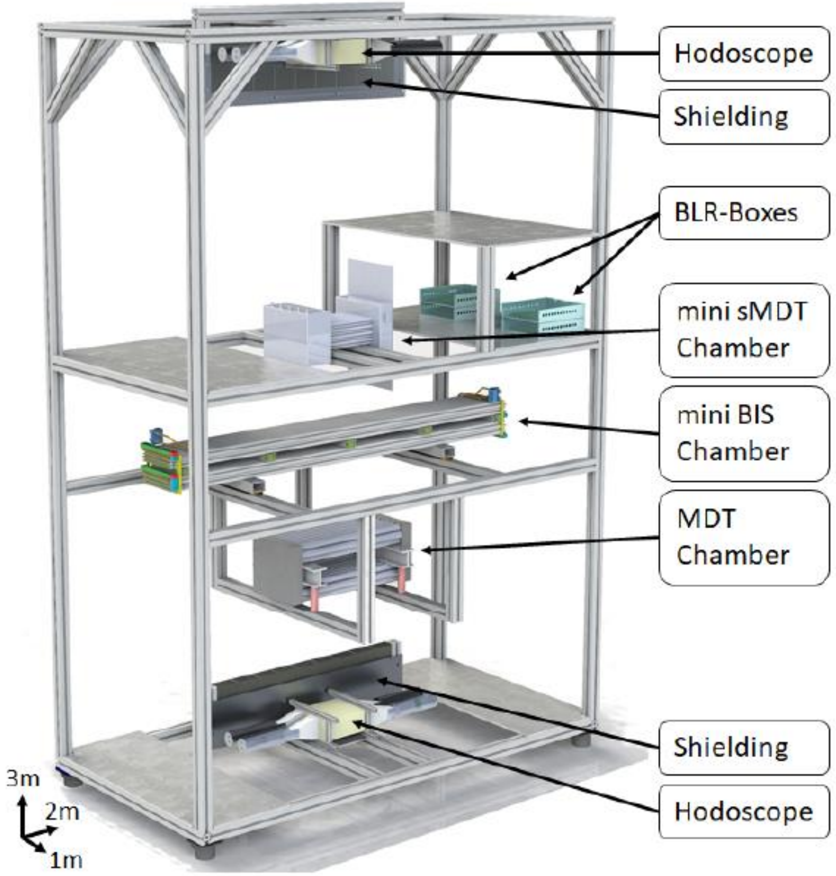

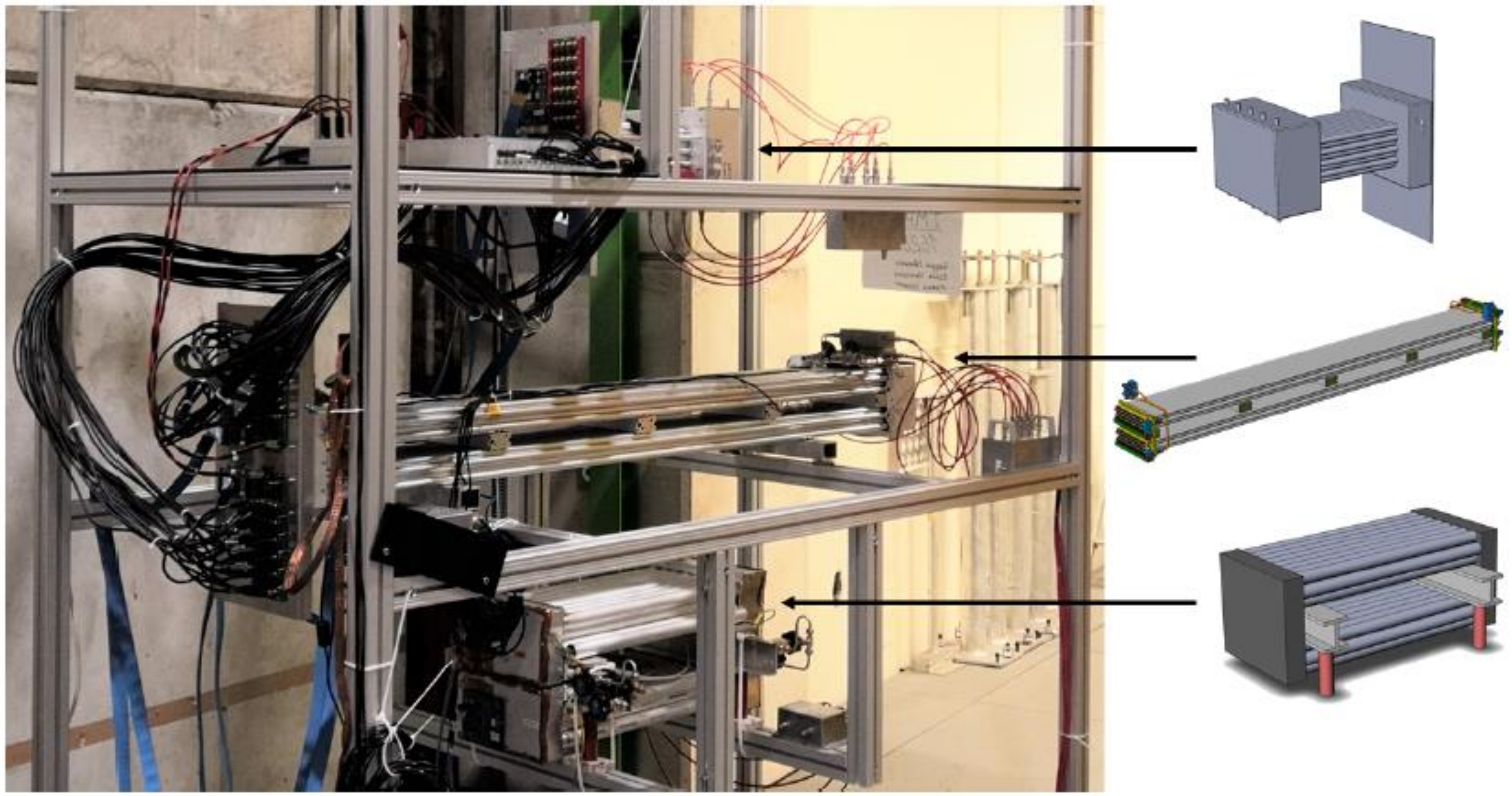

Teast beam measurement with GIF++ @CERN

- Adjustment of irridation filter (cf. matrix)
- Taking as many data as possible with different levels of gamma radiation
- Approximate duration of a data taking run per filter: 50min -2h
- Goal: achieving at least 100.000 events per run

	A	B	C
1	1.0	1.0	1.0
2	10.0	1.5	2.2
3	100.0	100.0	4.6

Summary and outlook

- Due to increasing luminosities at HL-LHC all detector systems ned to be updated and adjusted
- Good chance of sMDT chambers to be able to cope with increasing background radiation
- Reduced tube diameter: strongly reduced drift time and thus dead time and 8x reduced gain drop
- Elimination of space charge fluctuations due to nearly linear r(t) relation in regime of Ar/CO2
- During the week of test beam much data can be taken in order to guarantee proper statistics (compared to cosmic muons)
- Analysis of the taken data, especially concerning spatial resolution and efficiency at different levels of radiation
- Comparison to simulated data