ATLAS Muon Phase II upgrade for HL-LHC: Testing results of new ASD chips

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MPP Internal Rehearsal
Oliver Kortner
14.03.19

MAX-PLANCK-GESELLSCHAFT

Talk Overview

An update from ATLAS MDT electronics upgrade.

Replacement of MDT front end

- Preparation for HL-LHC

Verification tests of new ASD

- Varied gamma rate, standard operating parameters

Results at HL-LHC rates

- Efficiency performance consistent with current ASDs
- Resolution slightly improved

Results at even higher rates

- Looking beyond HL-LHC

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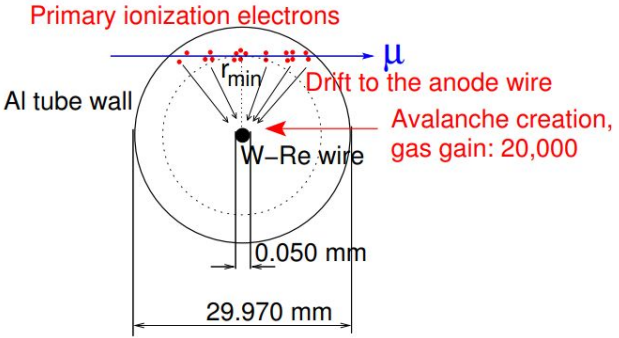
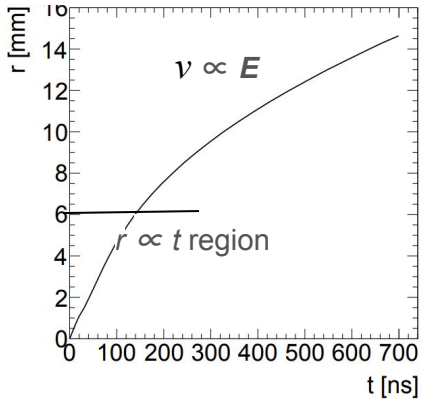
MDT front end electronics (I)

SIGNAL GENERATION IN ATLAS MDTS





- Muon passes at (minimum) distance r_{min}
- Primary ionization clusters drift to anode wire
- Drift time =
  time of avalanche detection
  - time of muon passage (from trigger)
- Nominal discriminator threshold is corresponds to signal from 11 primary electrons (~ fC)

- Known relation between radius and drift time
  $r_{min}(t)$
  - Some sensitivity to gas pressure etc
  - Chamber monitoring *(Monitored Drift Tubes)*

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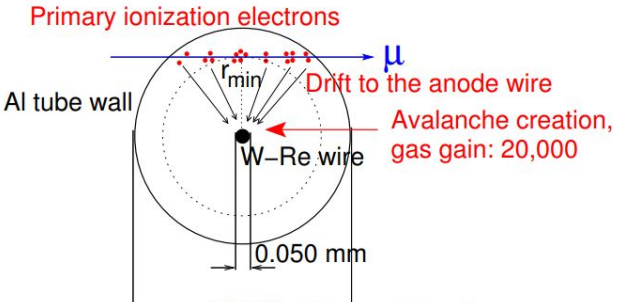
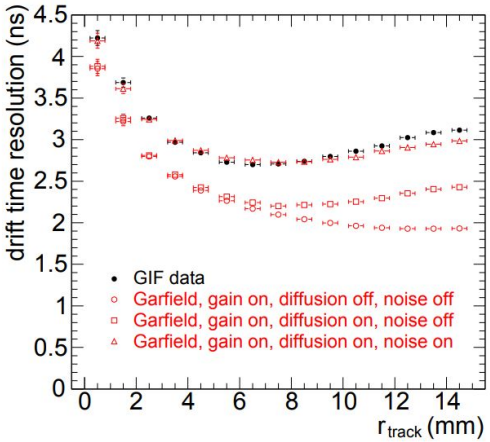
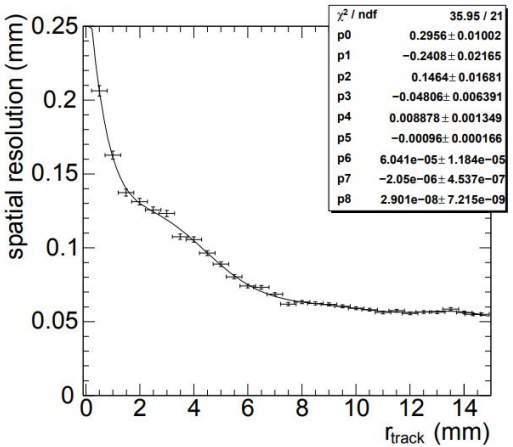
MDT front end electronics (II)

SPATIAL RESOLUTION OF SINGLE TUBE





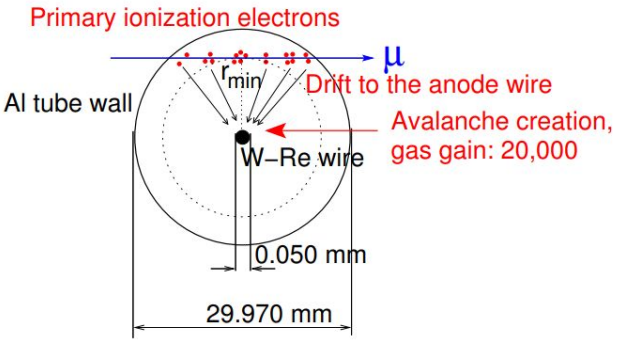


- Low r_{min}: resolution dominated by fluctuations in drift velocity
- High r_{min}: resolution dominated by diffusion
- Also: thermal noise sources

20 μm/ns avg. drift velocity → 500 ps systematic timing error

MDT front end electronics (III)

EFFECT OF HIGH γ RADIATION



BACKGROUND IN ATLAS MUON SYSTEM:

- Spallation neutrons & γ
- 'Fake' avalanches induced by Compton scattering of γ in tube walls

RATES:

- Up to 40 kHz / channel
- Expect up to 60 kHz / channel in HL-LHC

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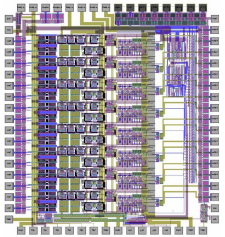
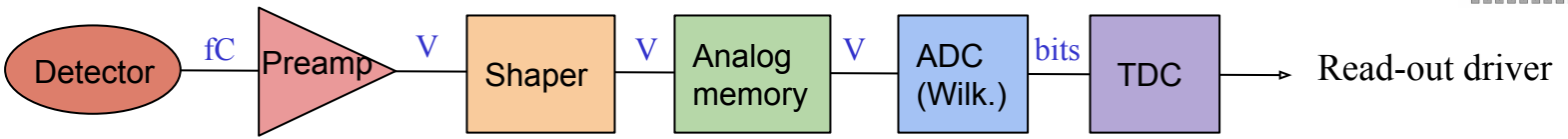
New ASD design



Amplifier - Shaper - Discriminator

Schematic view of front-end chain



integrating pre-amplifier measure charge in given time window (integration gate)

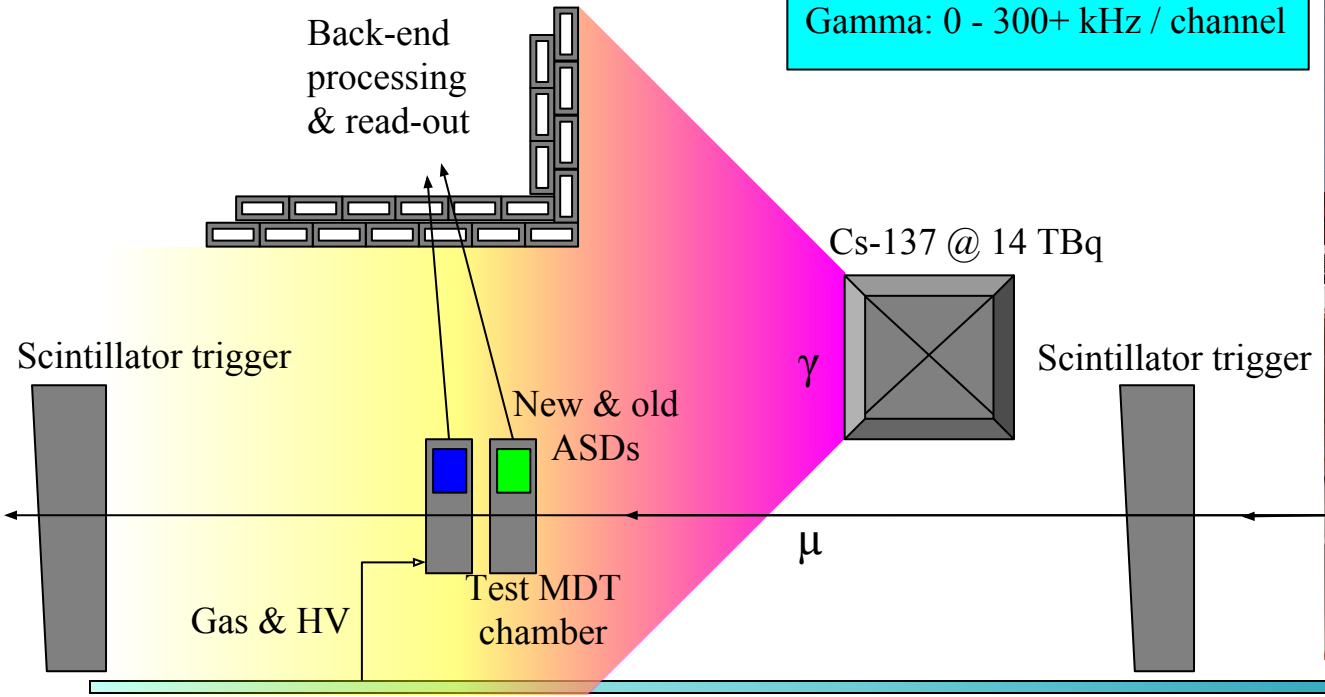
- Bipolar pulse shaping
- Programmable threshold
- Programmable time-encoding mode (rising edge vs time-over-threshold)
- Programmable dead time up to maximum drift time (800 ns)
- Smaller, modern components (130 nm)

→ TEST CAMPAIGN: Check design compatibility with SNR and resolution requirements (thermal, EMI, ground loops etc)

Tests of new ASDs in GIF++

CERN Testbeam and Gamma Irradiation Facility

Muons: ~ 500 Hz / channel
Gamma: 0 - 300+ kHz / channel



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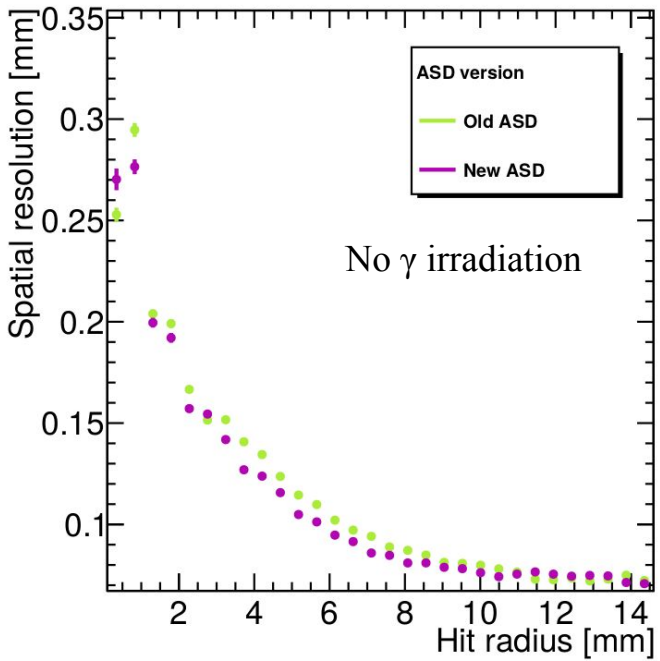
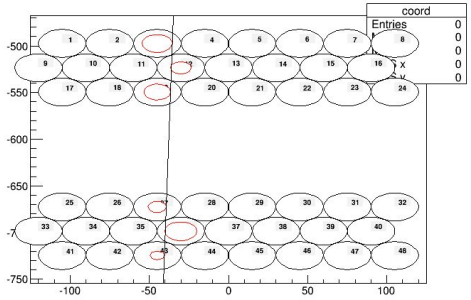
Results at HL-LHC rates (I)

RESOLUTION: NO GAMMA



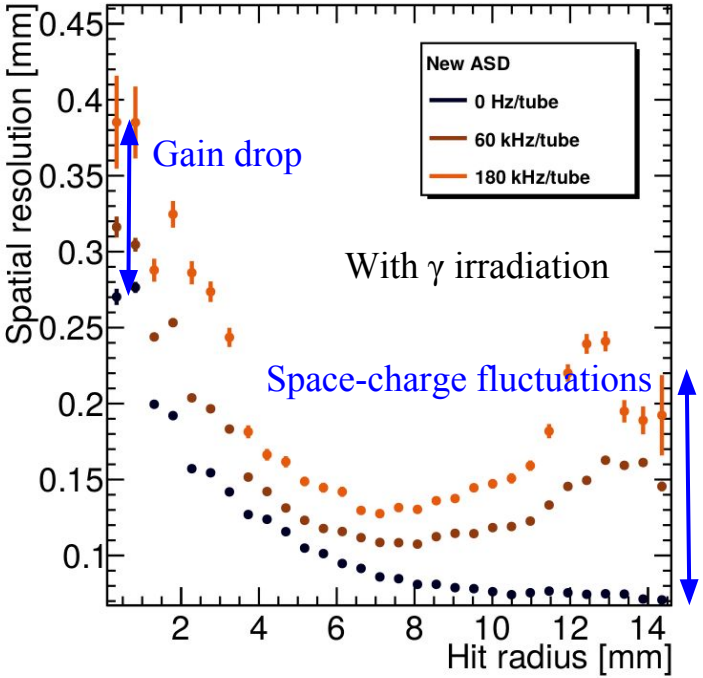
- Derived from residuals of reconstructed tracks
- New ASD slight improvement
- No significant benefit beyond 7mm



Track reconstruction with Hough transform

Results at HL-LHC rates (I)

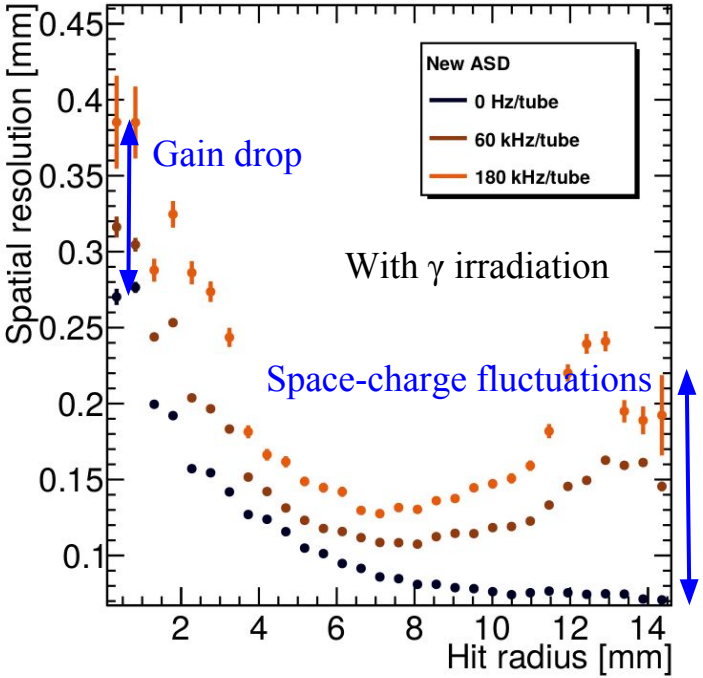
RESOLUTION: WITH GAMMA



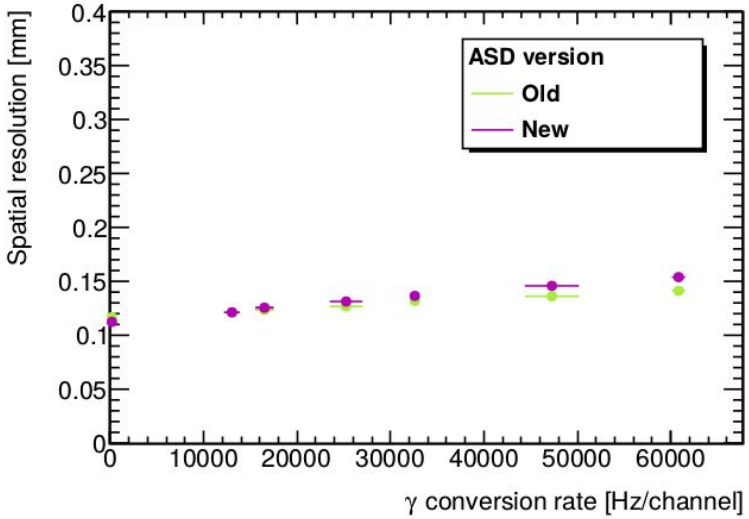
- Space charge of ion clouds in avalanche region near anode wire
  → gain drop
  → reduction of signal height
- Ar/CO2 mixture very non-linear
  → sensitive to space-charge fluctuations
  → deterioration at large *r* at high rates

Results at HL-LHC rates (I)

RESOLUTION: WITH GAMMA

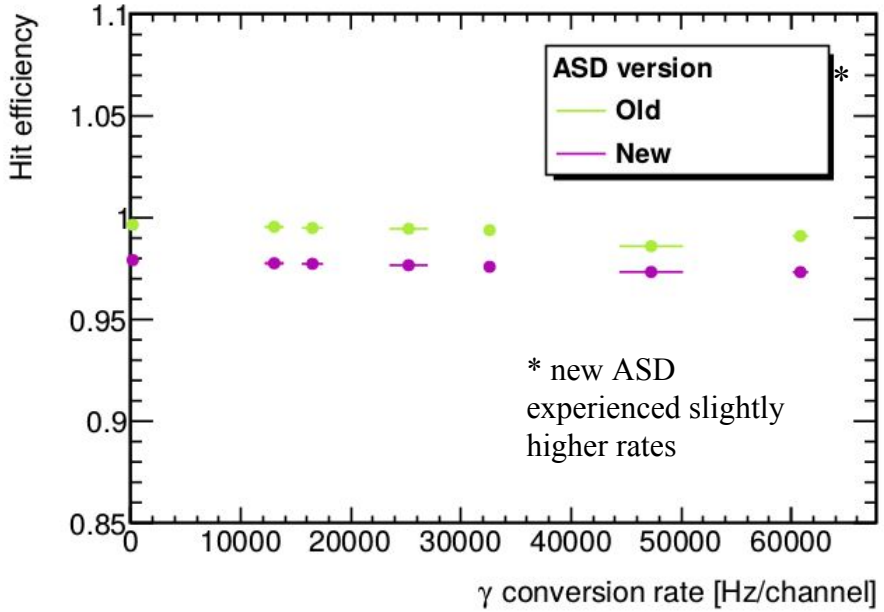


QUAD. MEAN RESOLUTION:



Results at HL-LHC rates (II)

EFFICIENCY VS GAMMA



- New ASD shows similar performance (& better aging characteristics)
- New ASD slightly closer to the source; reported rates are averages
- **GENERALLY:** Detection efficiency suffers at higher rate due to occupancy

→ Reduce tube diameter and operating voltage (typical gamma pulses smaller as fewer primary ionizations)

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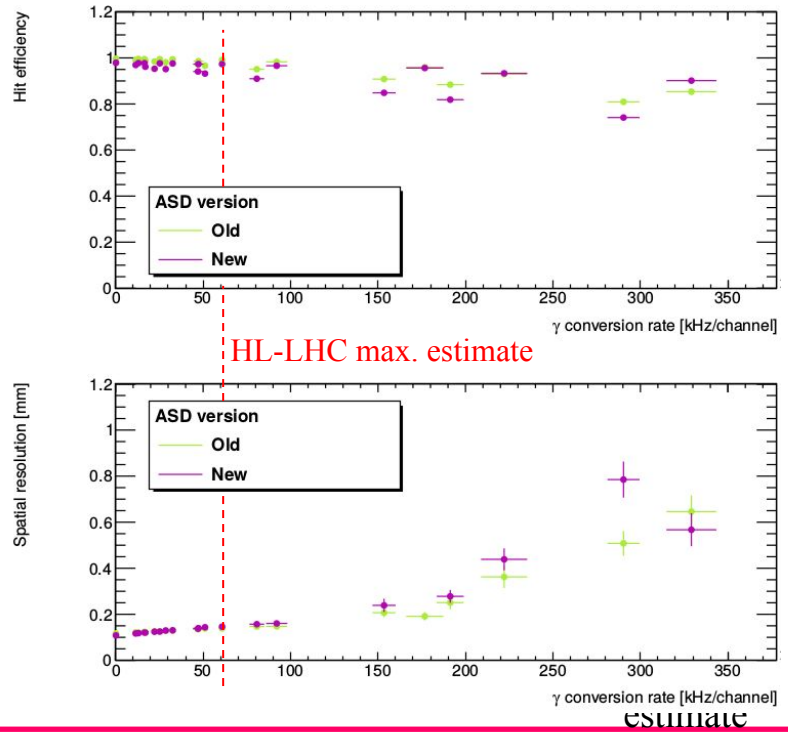
Tests at extremely high rates

With 1400 and 2000 Hz / cm2



- Occupancy:
  60 kHz: 10 +/- sigma hits per trigger
  180 kHz: 10 +/- sigma tubes occupied per trigger
- Resolution:
  60 kHz / channel: 60 - 100 um
  300 kHz / channel: ~ 600 um
  space charge fluctuations
- Efficiency:
  60 kHz / channel: 97 % +
  300 kHz / channel: 80% +
  dead time & occupancy

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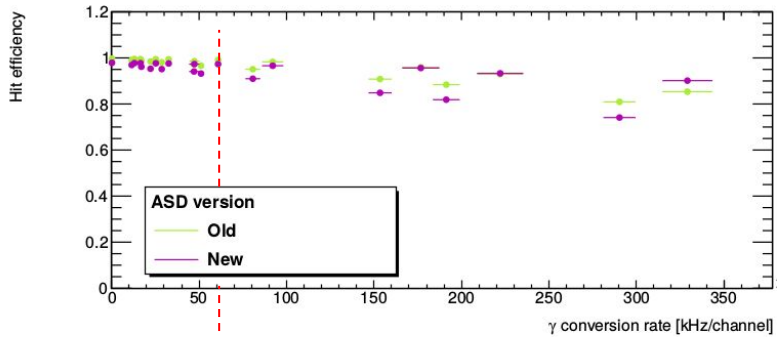

estimate

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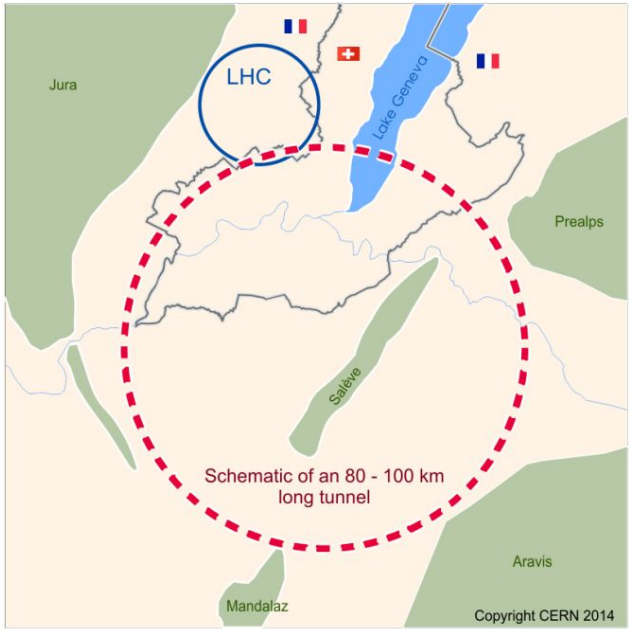
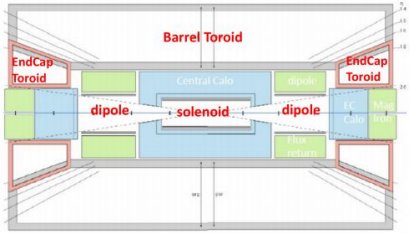
Potential technology for FCC

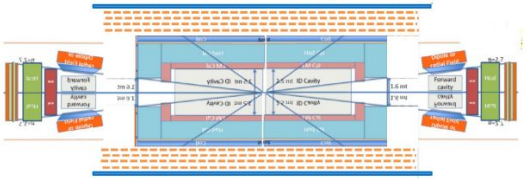


- Detector concept with 7x bending power:
  - ATLAS+
  - Twin solenoid
- Expect similar background rates to HL-LHC in low-η regions

ATLAS+



Twin solenoid



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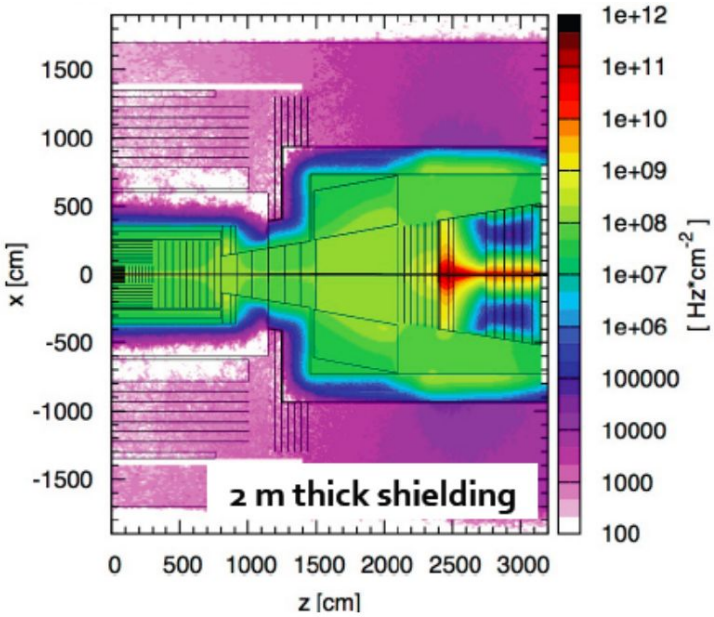
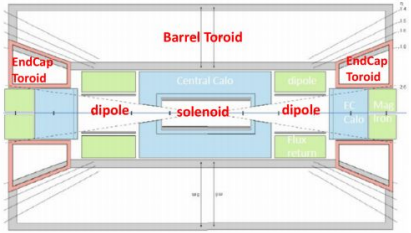


- Expect similar background rates to HL-LHC in low-η regions
- sMDTs option for muon tracking in purple region (several kHz/cm2)
- Mechanically robust and cost effective for covering large areas, mass production

ATLAS+



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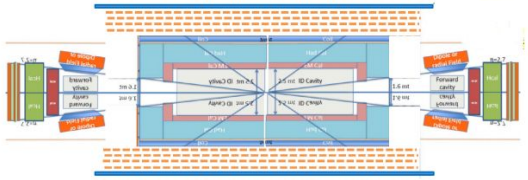

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Conclusions and Outlook

2018 ASD TESTS IN GAMMA IRRAD. FACILITY

- Minimal working setup with small test chamber and simple track fitting
- Comparison current ASD with new version for HL-LHC
- Resolution and efficiency comparable to old ASD

2019 - 2021: Production and commissioning
2023 - 2026: Installation in ATLAS

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Beyond HL-LHC: future colliders

- Current sMDT technology proven option for muon tracking
- ASD resolution acceptable even at highest rates
- >15% efficiency drop from 60 kHz to 300 kHz
- Mainly occupancy
- Potential efficiency improvements in signal processing e.g. baseline restoration