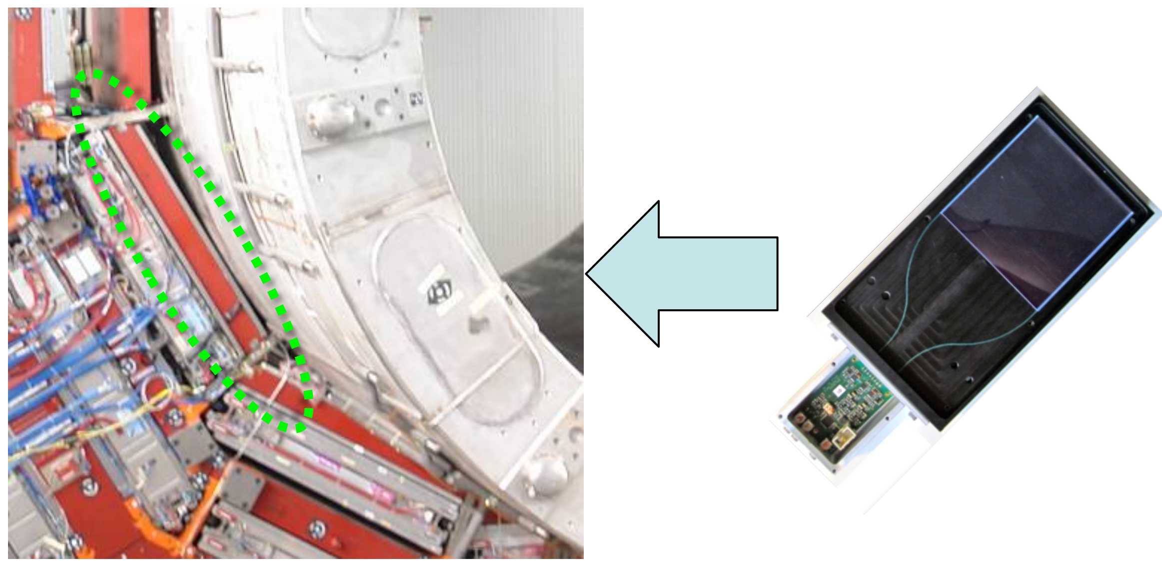
Simulation studies for the proposed MTT system at CMS



EDM student's seminar

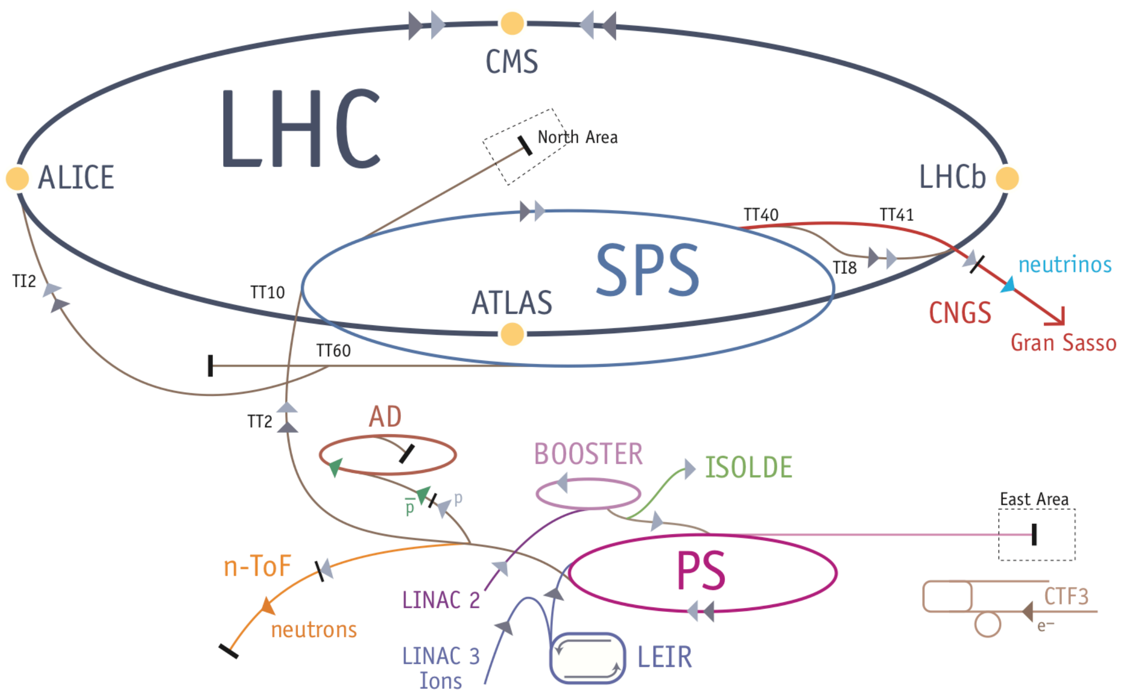
Paul Maanen

3. Physikalisches Institut B
30.11.2012

Outline

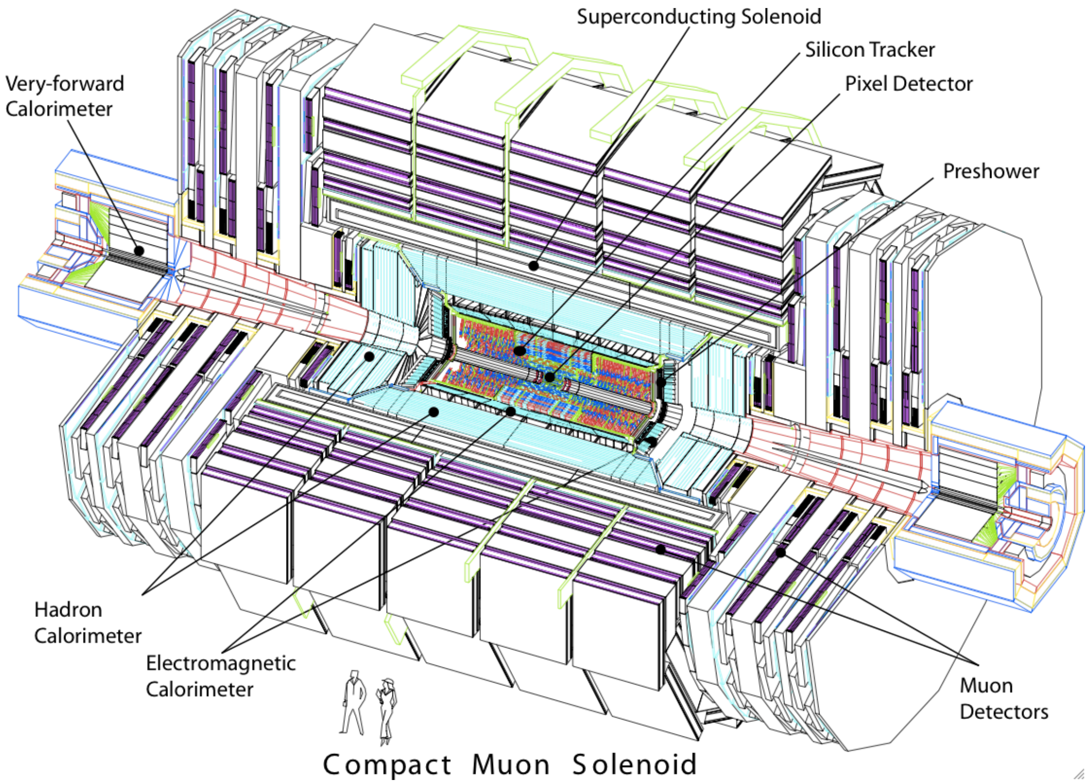
- LHC & CMS
- Motivation for MTT
- Concept & Design
- Implementation into CMSSW
- Studies with the new detector
- Conclusion & Outlook

Large Hadron Collider



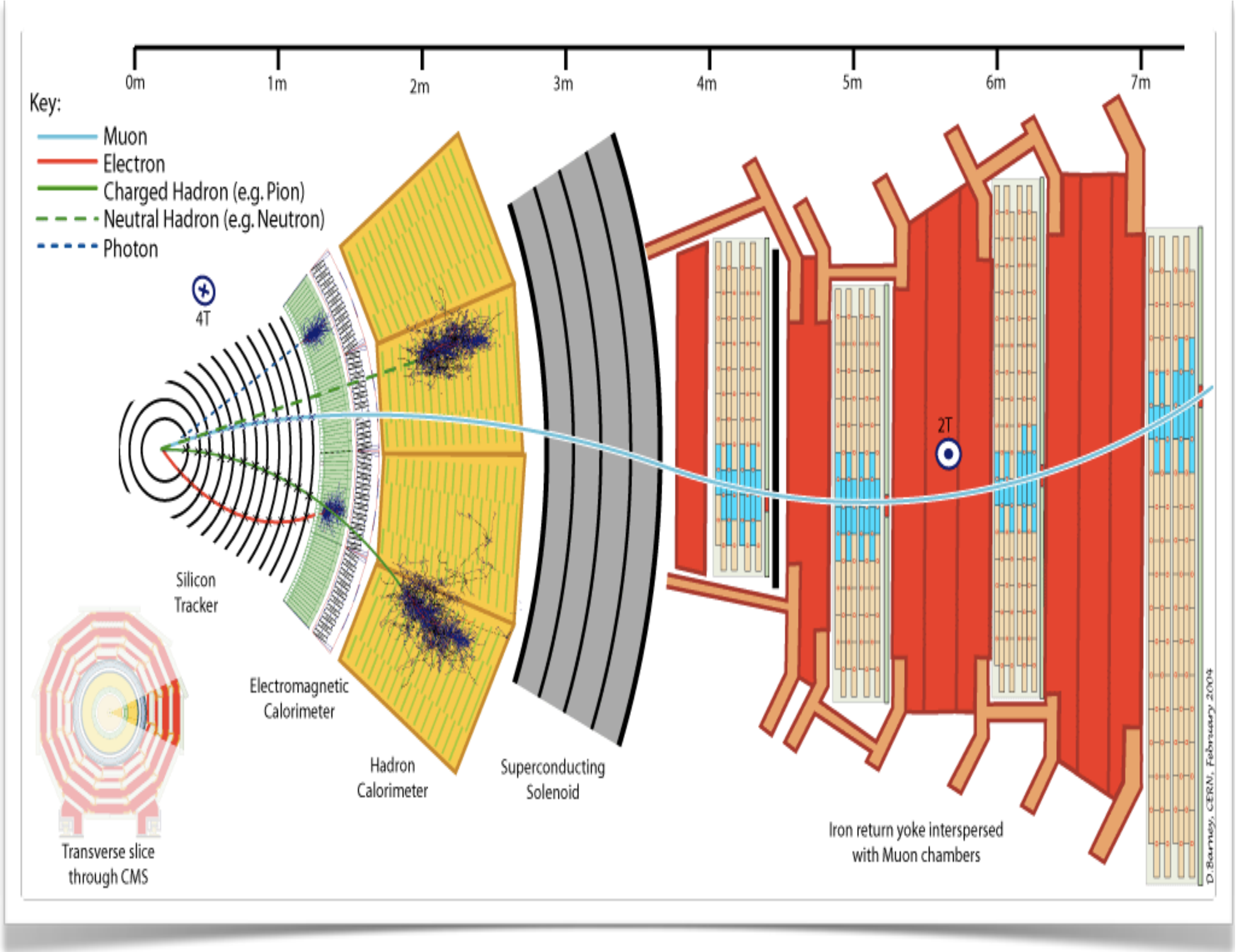
- Design cms energy: 14 TeV
- Design luminosity: $L=10^{34}\ cm^{-2}s^{-1}$
- Circumference: 26.7 km

Compact Muon Solenoid



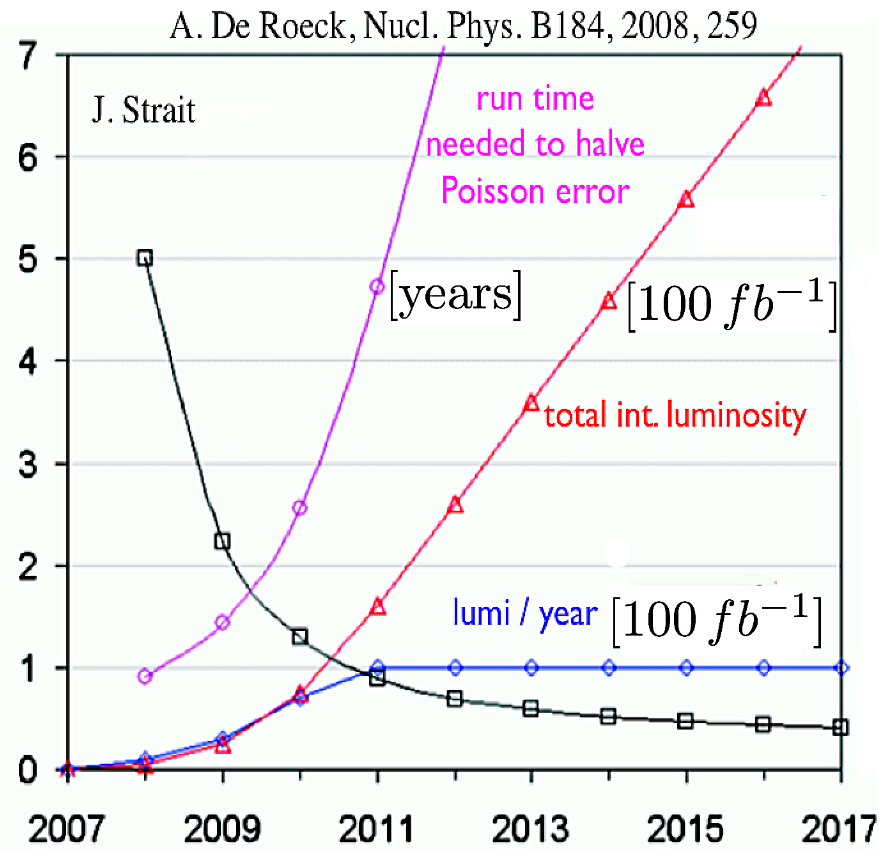
- Multi purpose Detector
- Cylindrical Design
- Diameter: 15 m
- Length: 21 m
- Weight: 12.5 kt

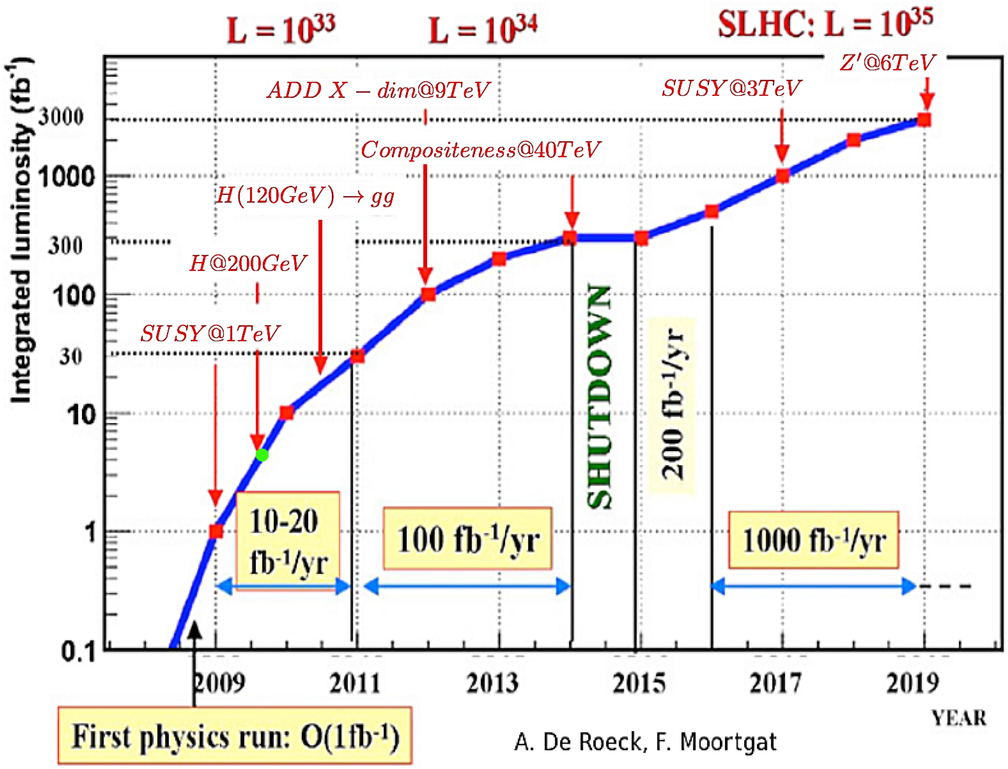
Compact Muon Solenoid



- Multi purpose Detector
- Cylindrical Design
- Diameter: 15 m
- Length: 21 m
- Weight: 12.5 kt

Upgrade plans



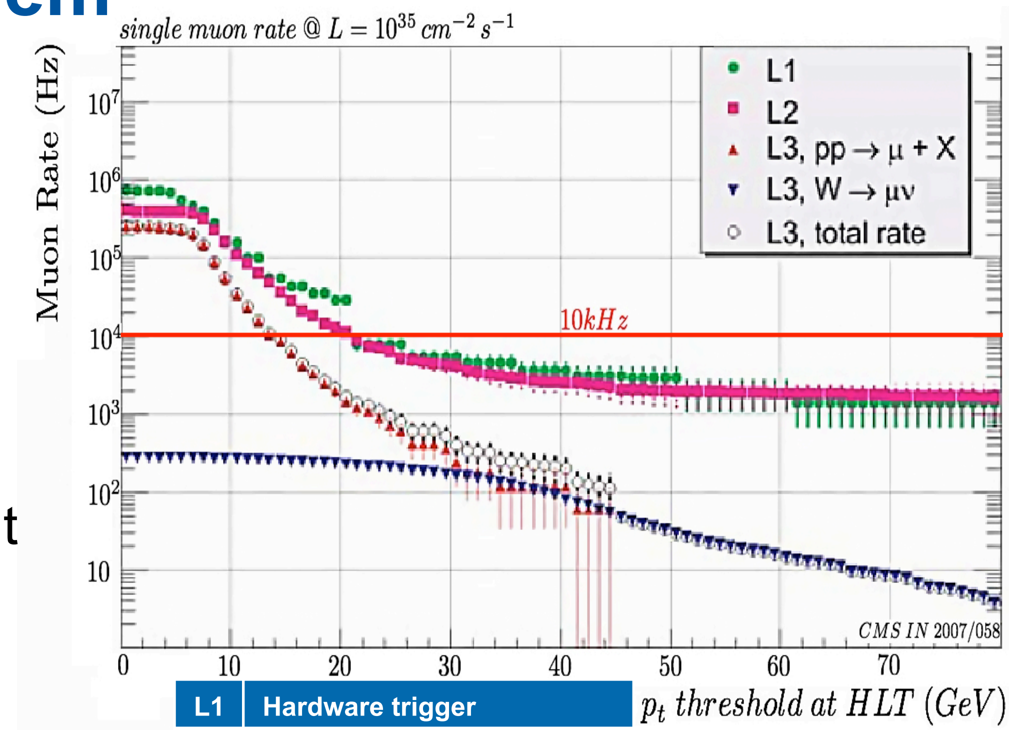


- Only luminosity upgrade extends physics reach significantly
- High Luminosity HL-LHC era after LS3, from 2020 onwards

CMS Germany
BMBF FSP-CMS

The trigger rate problem

- Current CMS L1 trigger:
  - → 100 kHz maximum rate
  - → 3.2 µs latency
  - → 10 kHz single-µ-Rate
- Goal for HL-LHC :
  - → keep µ-triggerrate about constant
- Problem:
  - → p_t cut has insufficient rejection power
  - → increase p_t resolution

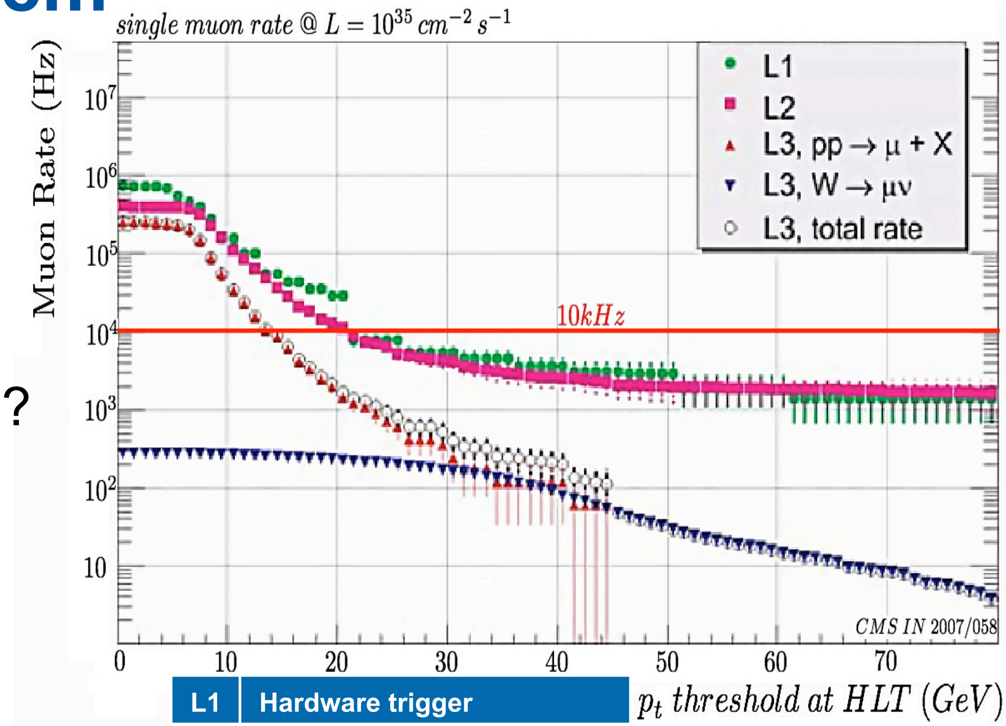


L1	**Hardware trigger**
L2	**L1+full TDC information from DT**
L3	**L2+tracker data**

CMS Germany
BMBF FSP-CMS

The trigger rate problem

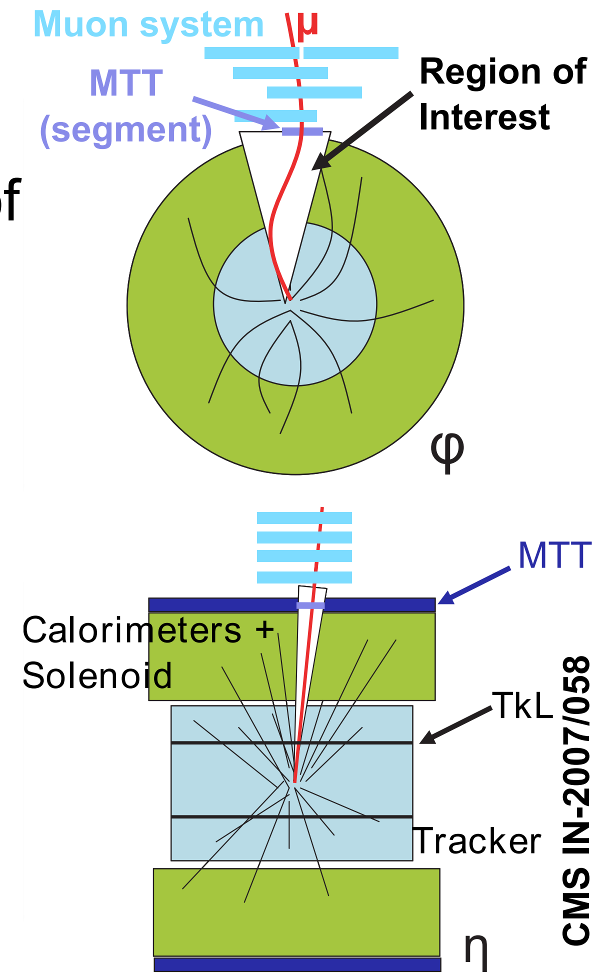
- The solution:
  - → Use tracker info in L1
    - » Bandwidth?
    - » Latency?
  - → Partial readout possible? (but how?)



L1	Hardware trigger
L2	L1+full TDC information from DT
L3	L2+tracker data

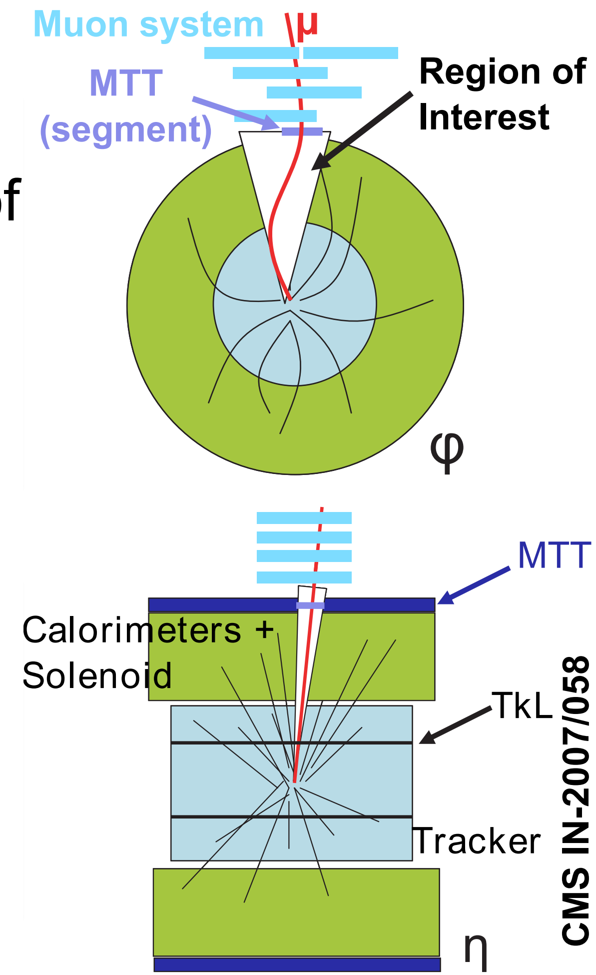
Concept

- New detector layer just before innermost muon chamber
- Fast muon tag defines region of interest
- Tracker is readout in ROI



Concept

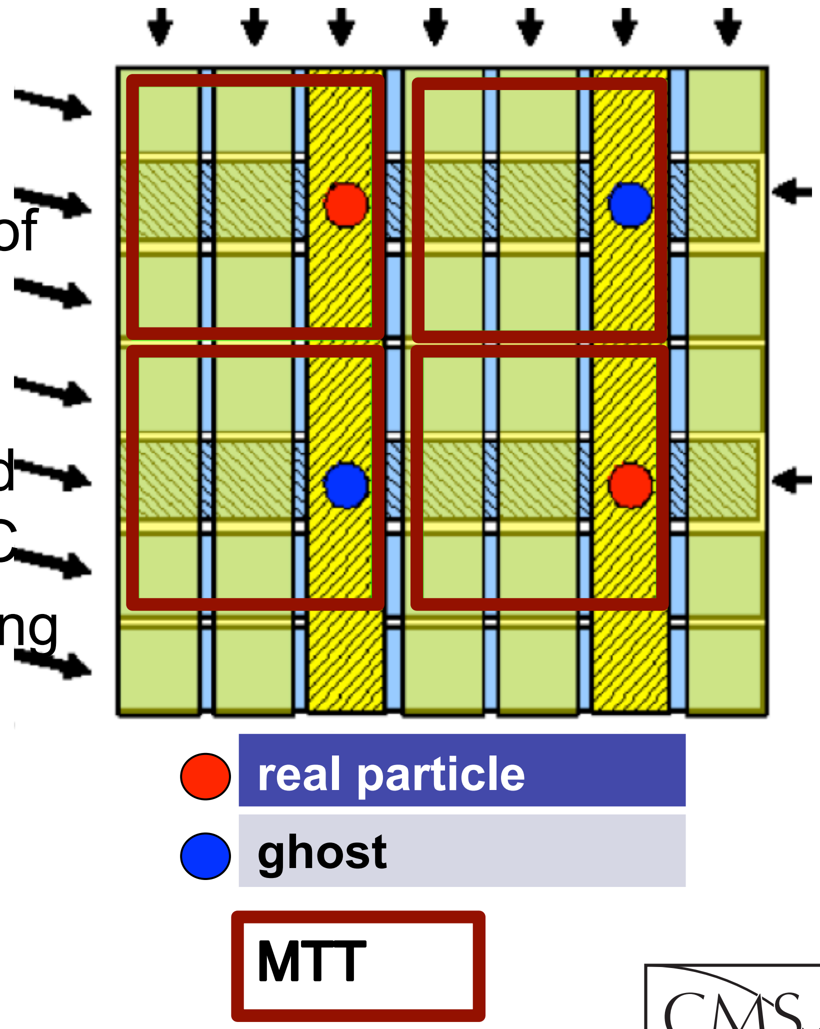
- New detector layer just before innermost muon chamber
- Fast muon tag defines region of interest
- Tracker is readout in ROI
- Tracker information is matched to muon candidates in DT/RPC



III. Physikalisches Institut B
RWTHAACHEN

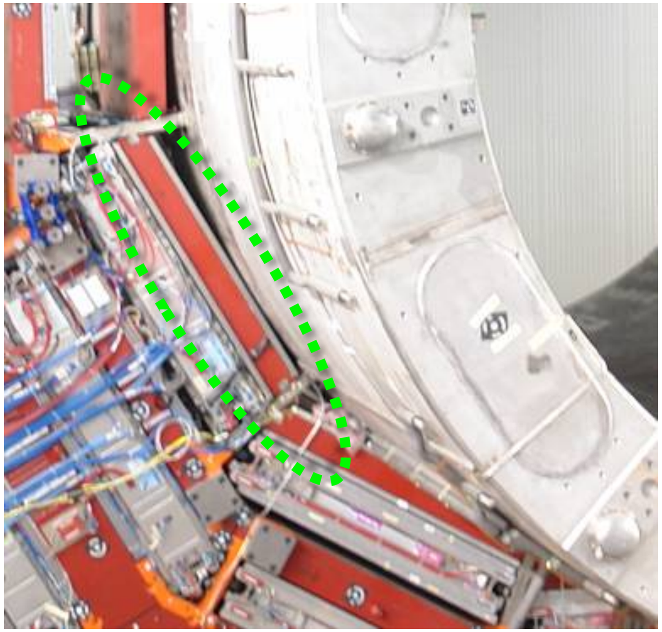
Concept

- New detector layer just before innermost muon chamber
- Fast muon tag defines region of interest
- Tracker is readout in ROI
- Tracker information is matched to muon candidates in DT/RPC
- Additional benefit: Ghost-busting capabilites



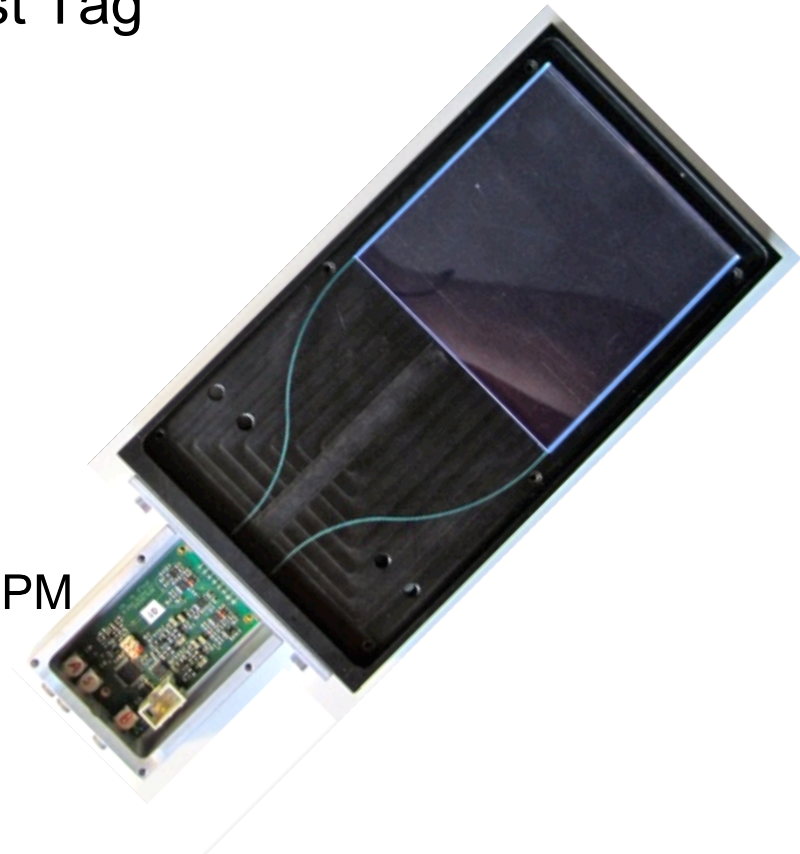
Concept

- Requirements for Muon Track fast Tag
  - → **fast** (25ns bunchspacing)
  - → **thin** (< 1cm space)
  - → **affordable** (300 m^2 to cover)
  - → **insensitive** to magnetic fields



Concept

- Requirements for Muon Track fast Tag
  - → fast (25ns bunchspacing)
  - → thin (< 1cm space)
  - → affordable (300 m^2 to cover)
  - → insensitive to magnetic fields



- Possible realization:
  - → Scintillating tiles read out by Silicon PM

Open Questions

- What is the **optimal granularity** of MTT?
- How good is the **stability against noise**?
- How can MTT interact with a tracker trigger?
- ???

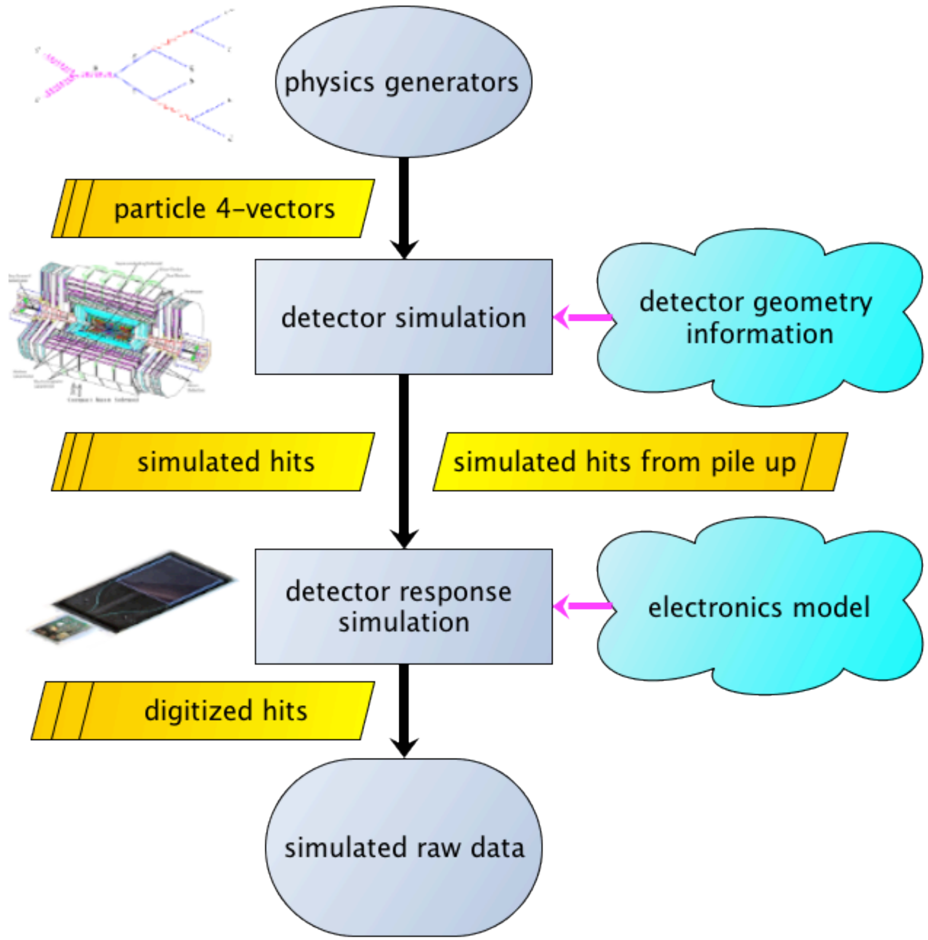
III. Physikalisches Institut B
RWTH AACHEN

Open Questions

- What is the **optimal granularity** of MTT?
- How good is the **stability against noise**?
- How can MTT interact with a tracker trigger?

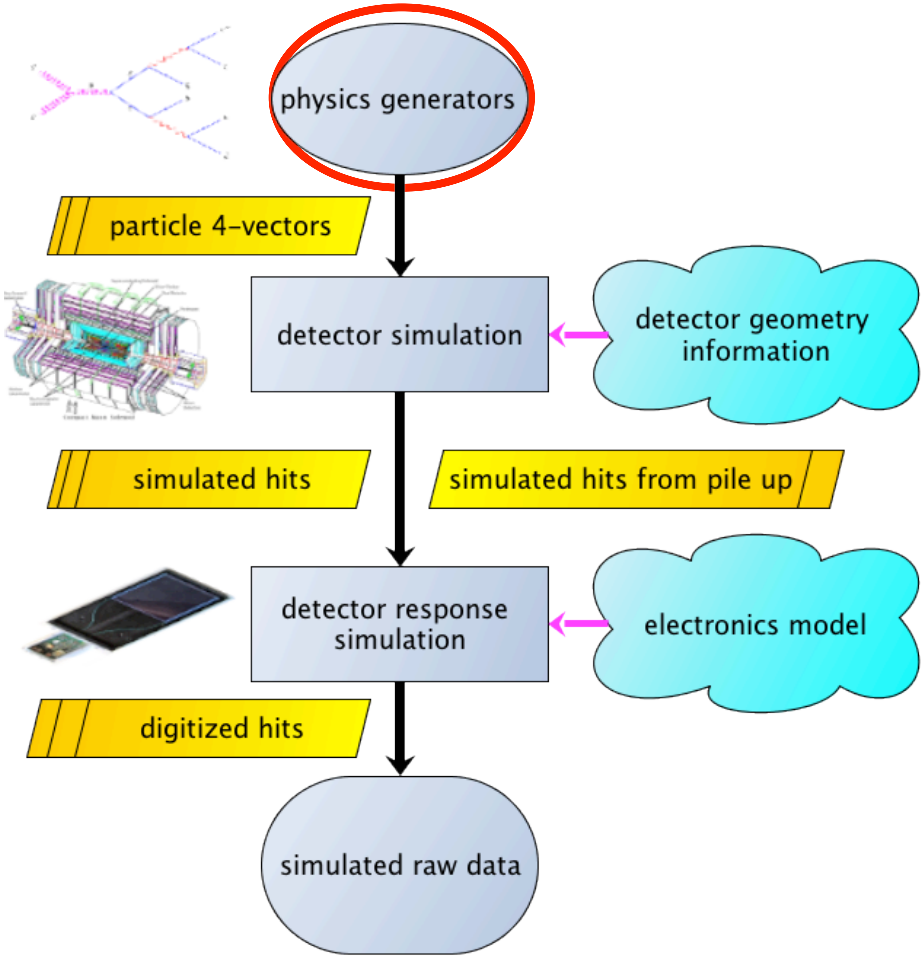
- We can not answer these questions from prototyping alone, so we need **detailled Simulations**.
- To answer the **„big picture“** questions, **MTT** has to be implemented in the official framework called **CMSSW**.
- Challenge: Far more complicated than Geant4 standalone....

CMSSW simulation in a nutshell



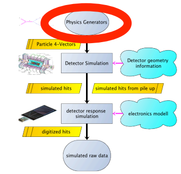
III. Physikalisches Institut B RWTH AACHEN

Physics generation



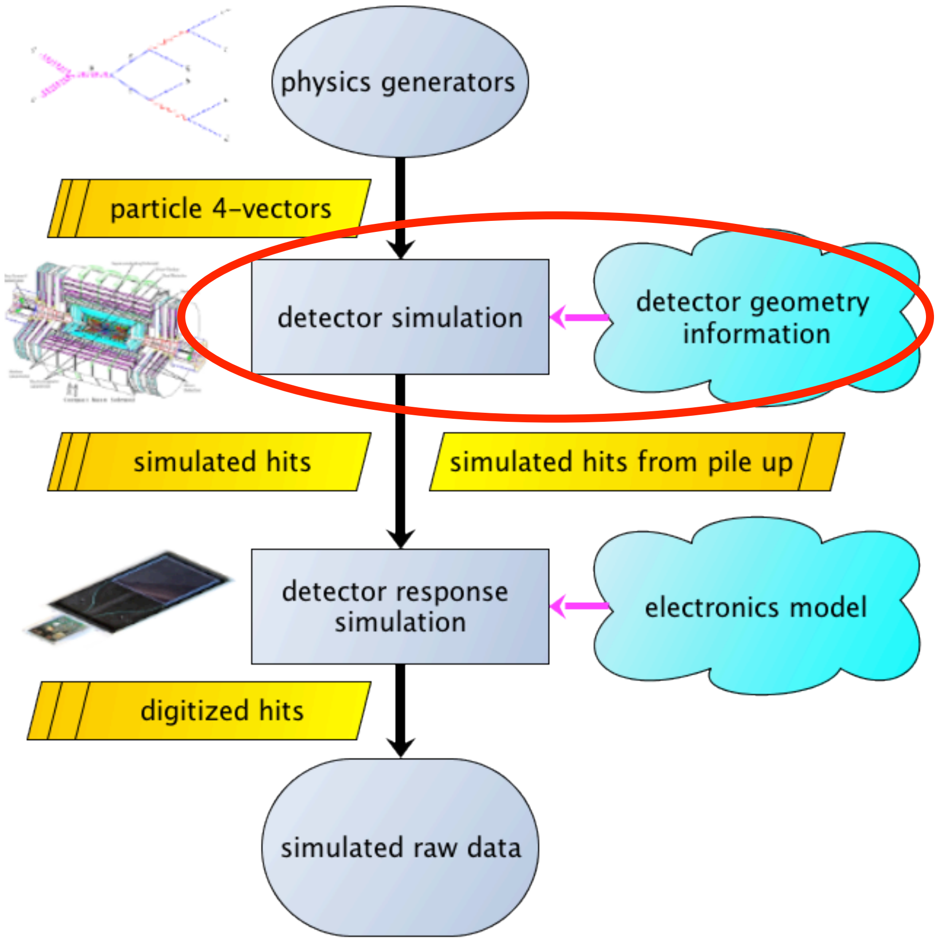
CMS Germany
BMBF FSP-CMS

Event generation



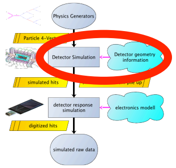
- Variety of physics generators (pythia, herwig, whizard, etc.) available
- Generator information stored in HepMC format and send to detector simulation
- Ready to use out-of-the-box

Detector simulation



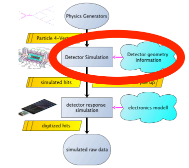
CMS Germany
BMBF FSP-CMS

Detector simulation



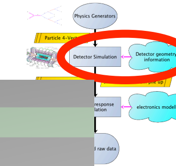
- Detector simulation is done via Geant4 interface
  - → allows access to Geant4 objects at any stage
  - → uses XML-based Detector Description machinery, configurable at run time via a hierarchy of XML files
- converts DD solids and materials to Geant4 counterparts

Detector simulation

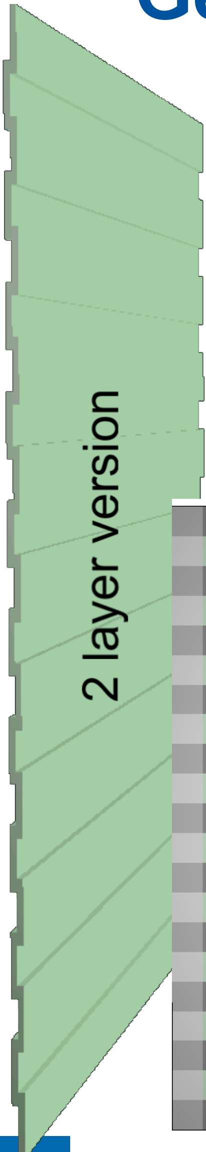


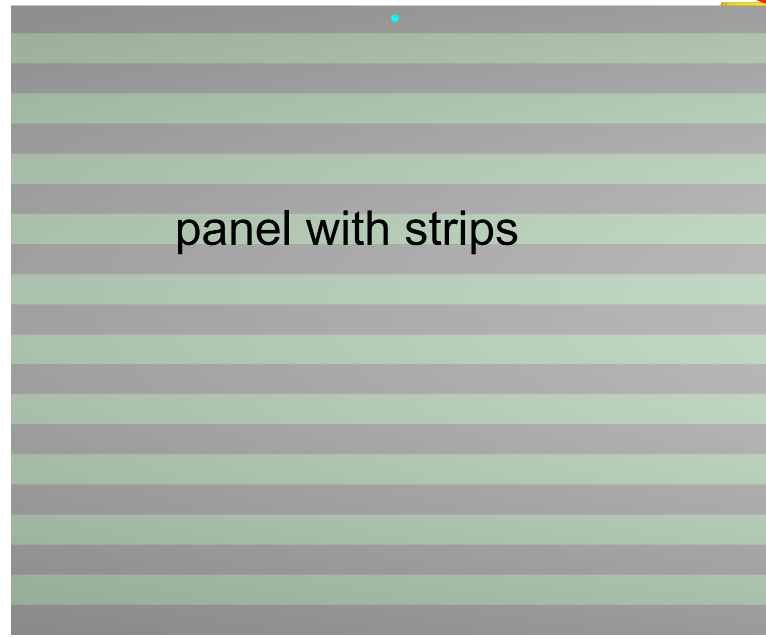
- Need to:
  - → Transform the **concept into** a concrete **design**
  - → Implement materials, shapes and positions in XML code
  - → Define active materials
  - → Write custom XML parser to provide the user with an **easy to use** geometry model at runtime (access to detector dimensions, coordinate transformations, etc.)
- Crosschecks of the Geometry are also needed...

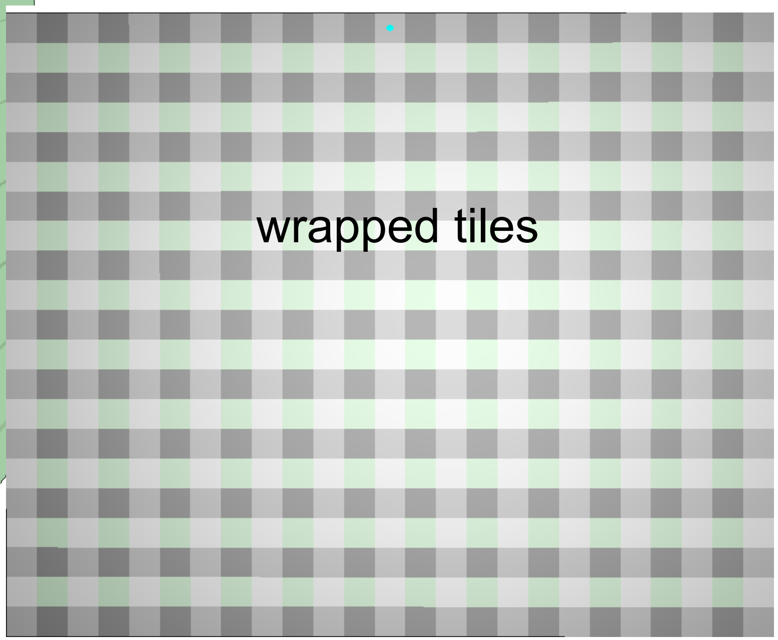
Geometry implementation

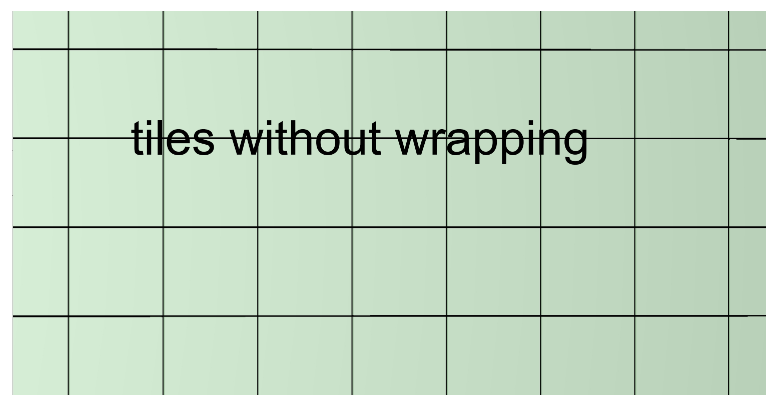


Hierarchy:
1 panel made of
1 or 2 layers consisting of
strips of
wrapped tiles

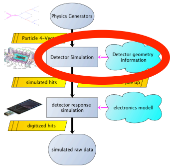


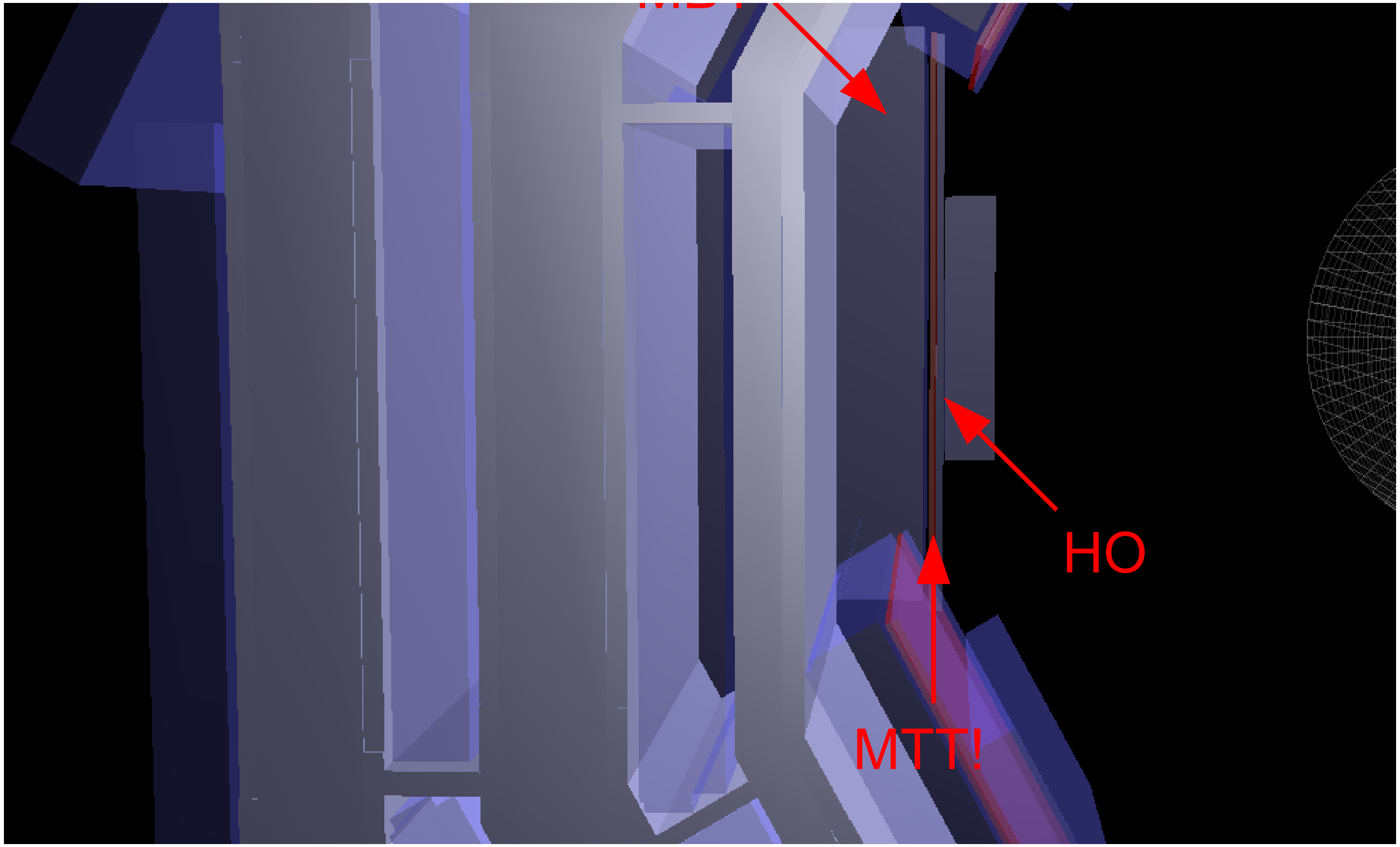






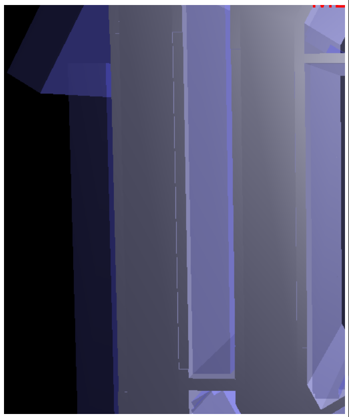
Geometry implementation

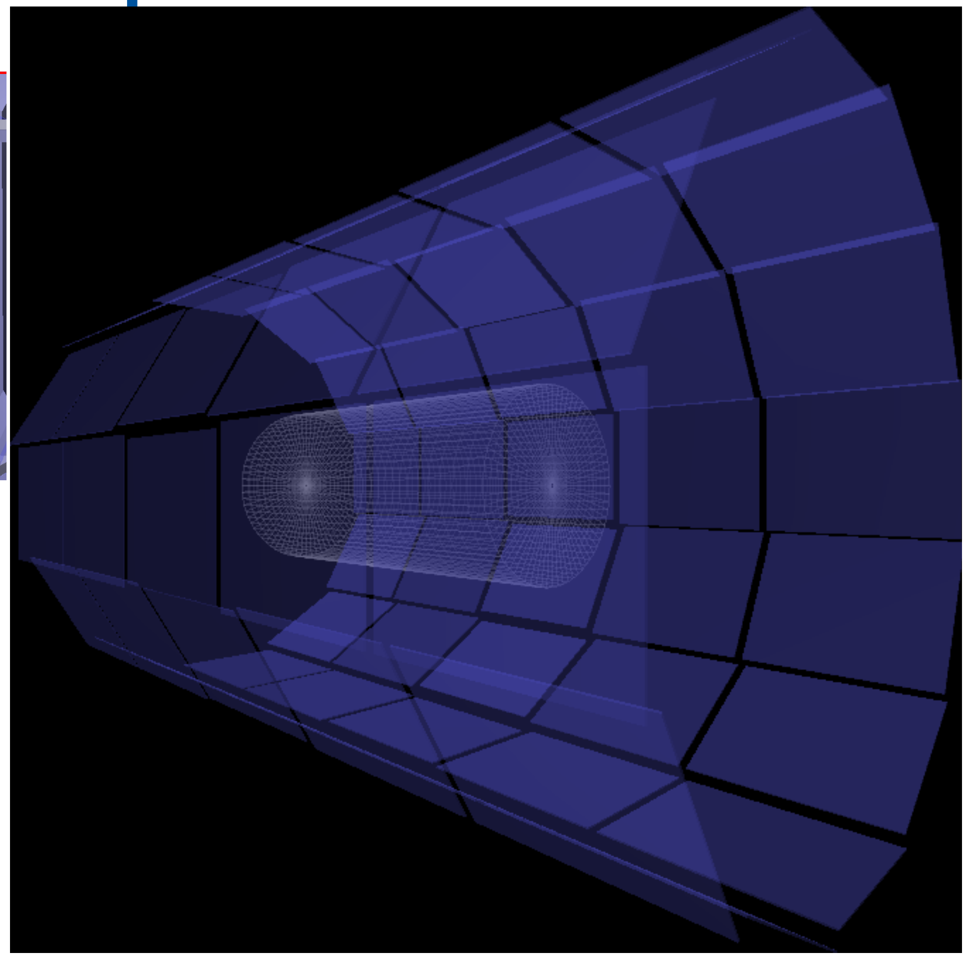


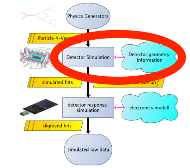


- Some visual crosschecks....

Geometry implementation

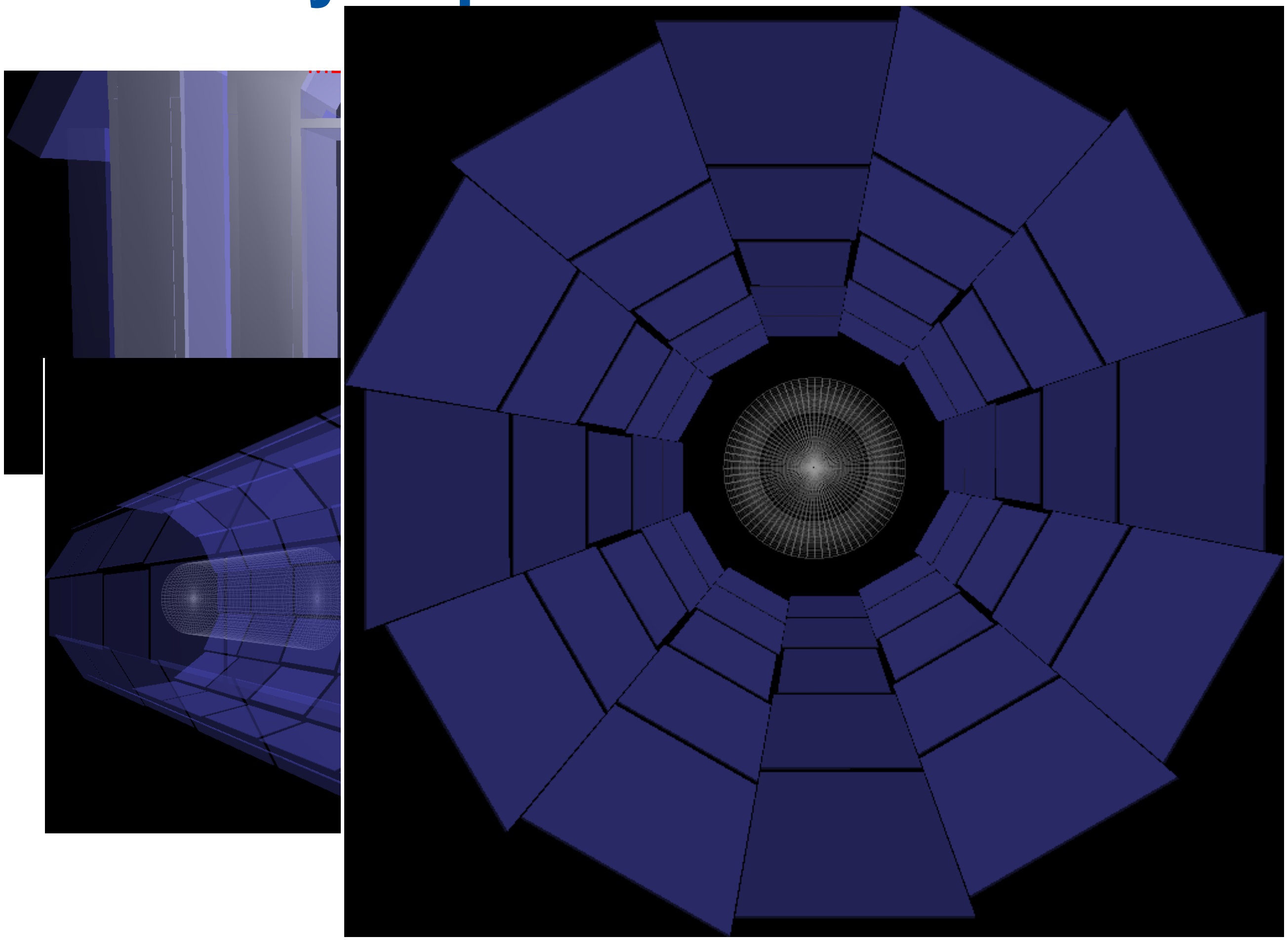


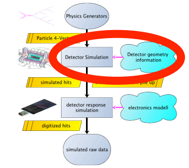




- Some visual crosschecks....

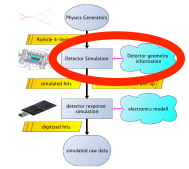
Geometry implementation

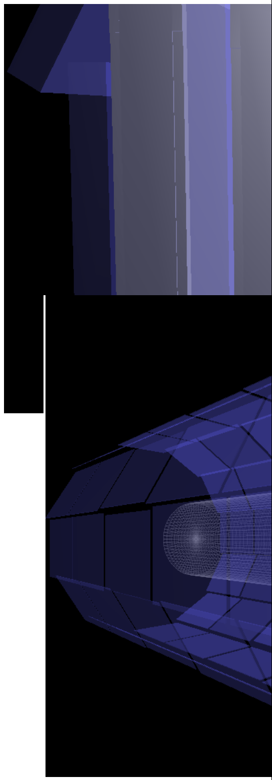


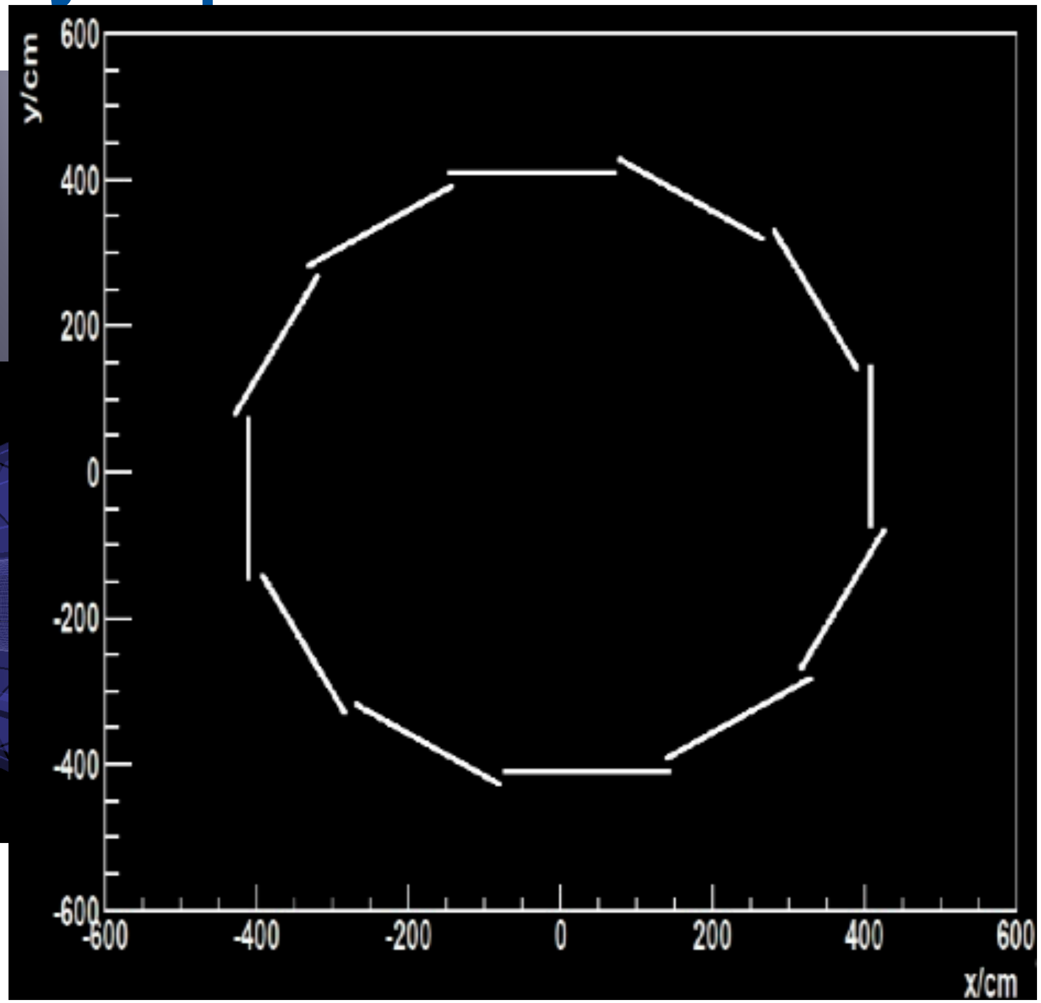


- Some visual crosschecks....

Geometry implementation



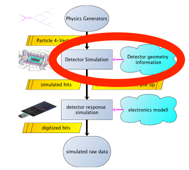


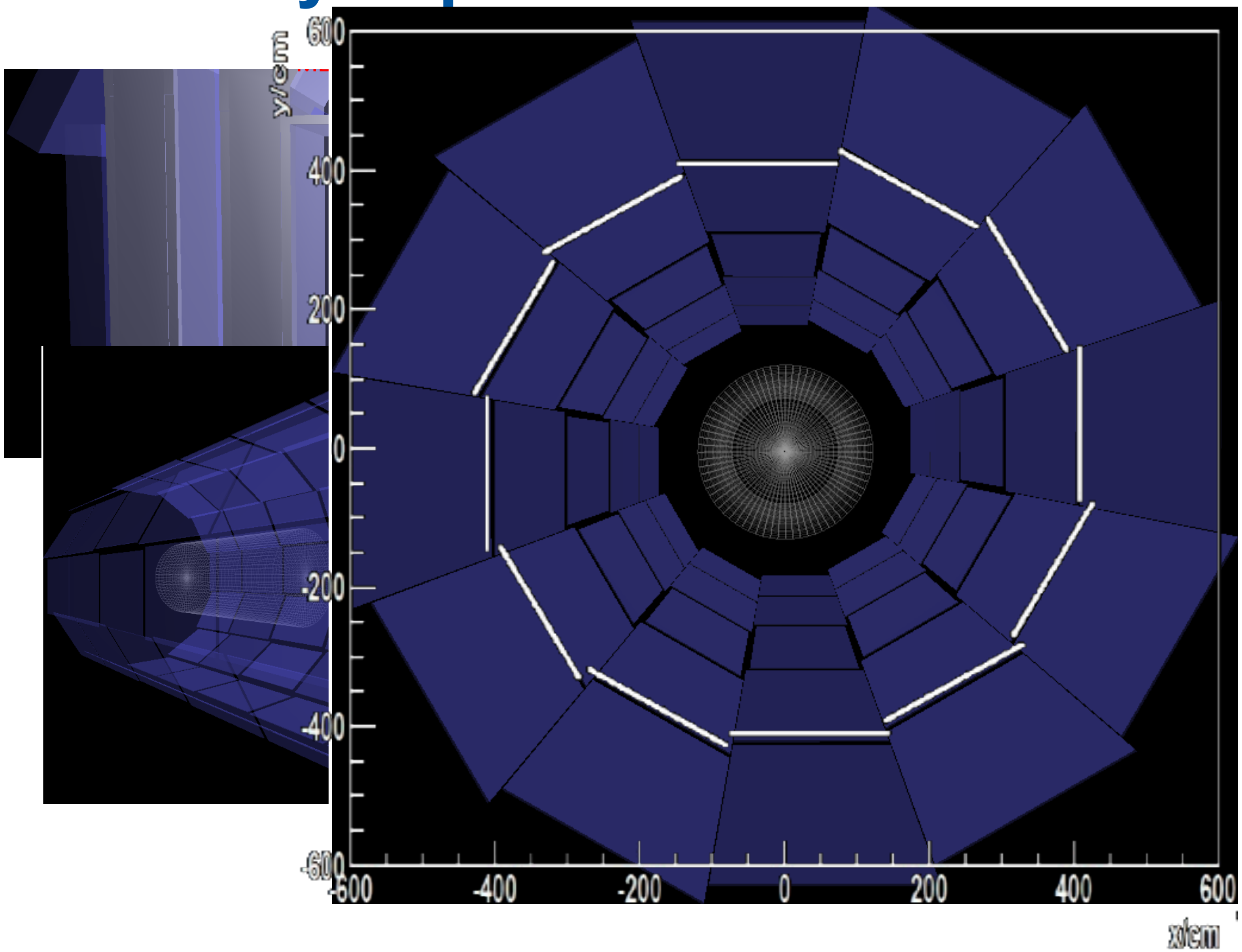


- Have a look at the position of the sim. hits.....

III. Physikalisches Institut B
RWTH AACHEN

Geometry implementation

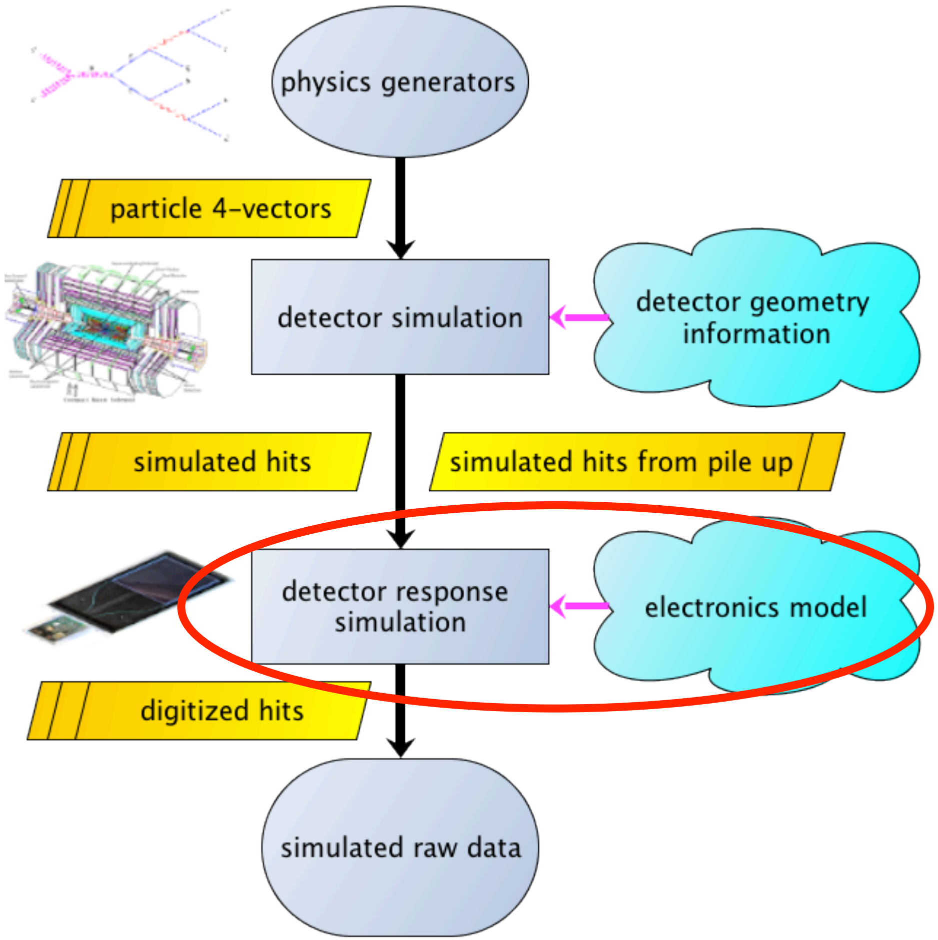




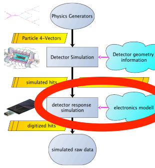
- Looks good!

CMS Germany
BMBF FSP-CMS

Detector response simulation



Detector response simulation



- Detector response in CMSSW is **only parametrized**
  - → Need dedicated **simulation and hardware** studies

- Implemented trivial model & data format
  - → List of hit tiles
  - → 100% efficiency, no timing, no energy information

III. Physikalisches Institut B
RWTH AACHEN

Studies with simulated hits

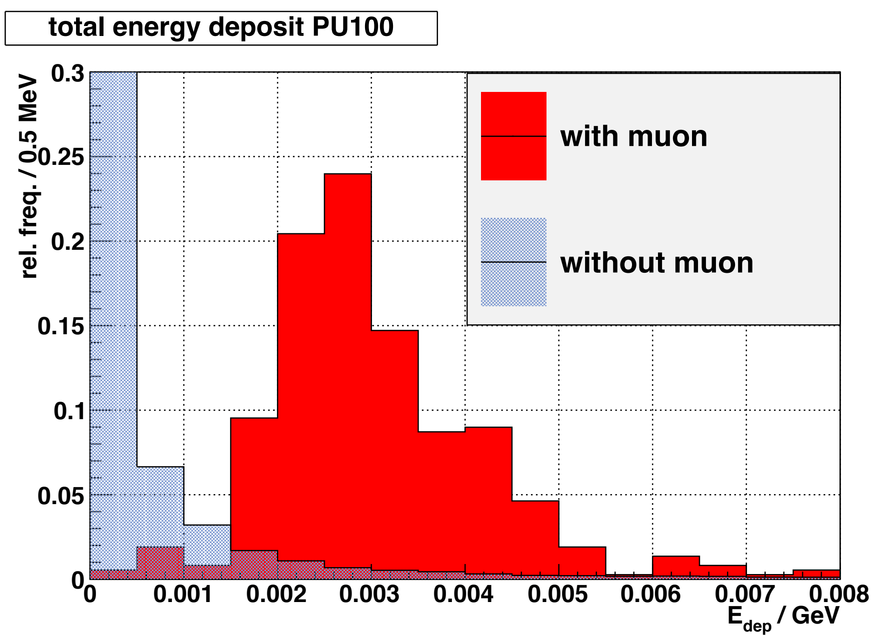
- Is **discrimination** between muons and backgrounds possible?

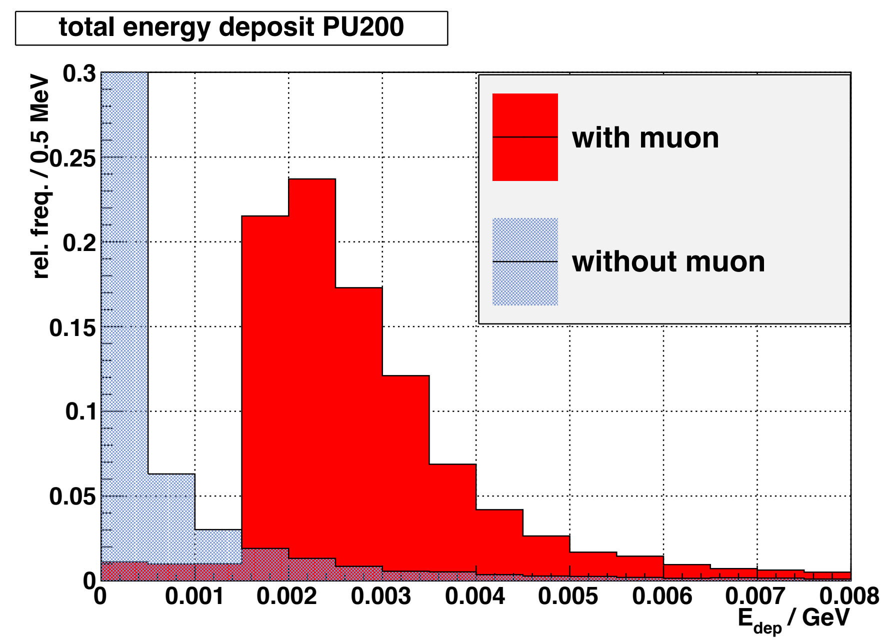
- Set up Simulation:
  - → Choose geometry with 2 strips, 10 tiles as first approach
  - → Signal: Muon gun plus pile up

- Look at **deposited energy** as discriminating observable..

Studies with simulated hits

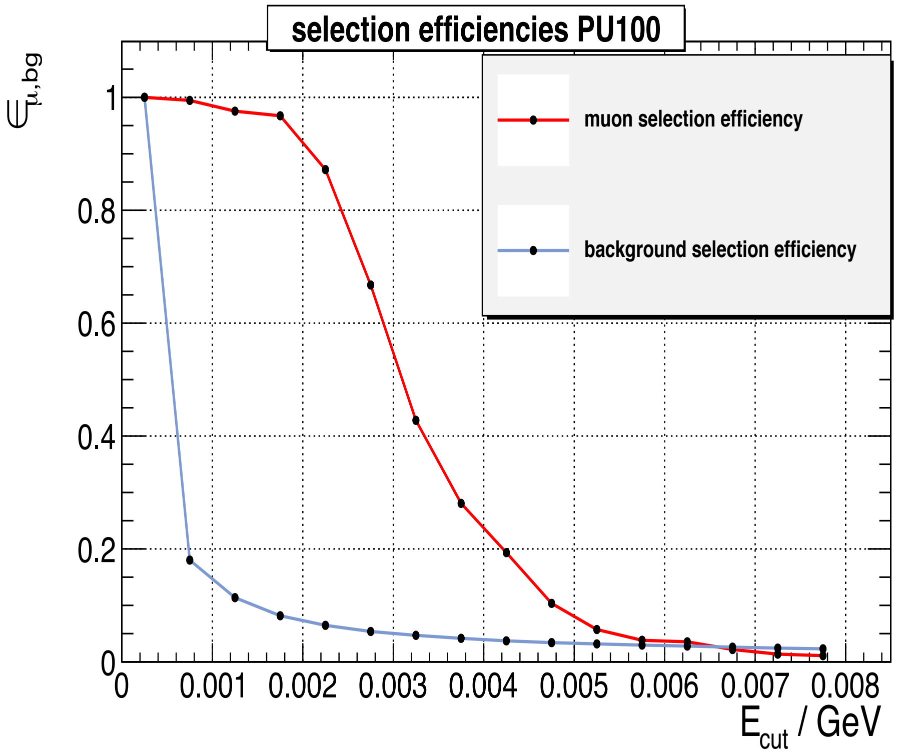
- Energy distributions are **nicely separated**.
- Cut should be possible.

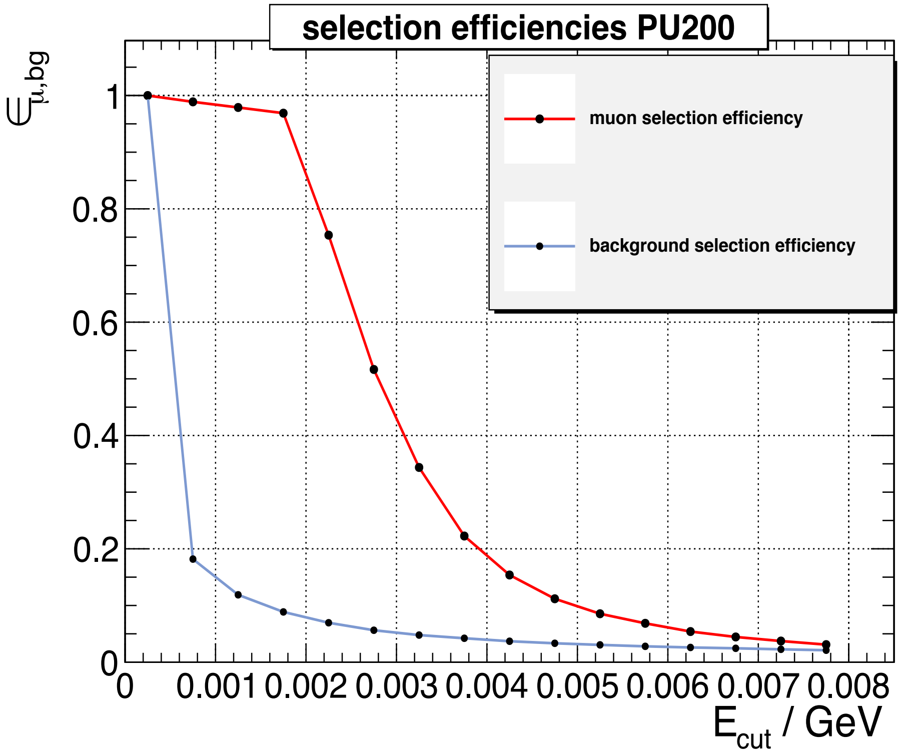




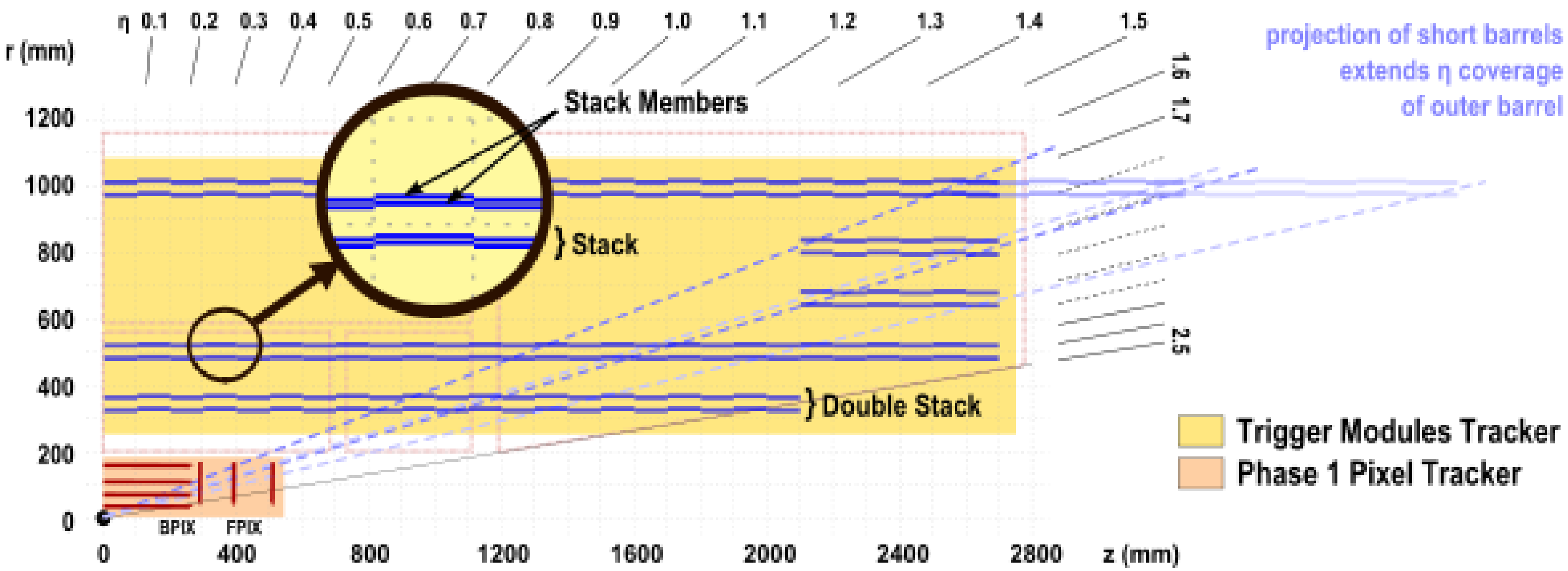
Studies with simulated hits

- Optimal cut value ca. 2 MeV
- May achieve >90% muon selection efficiency at 90% background reduction.





Studies with L1Tracks



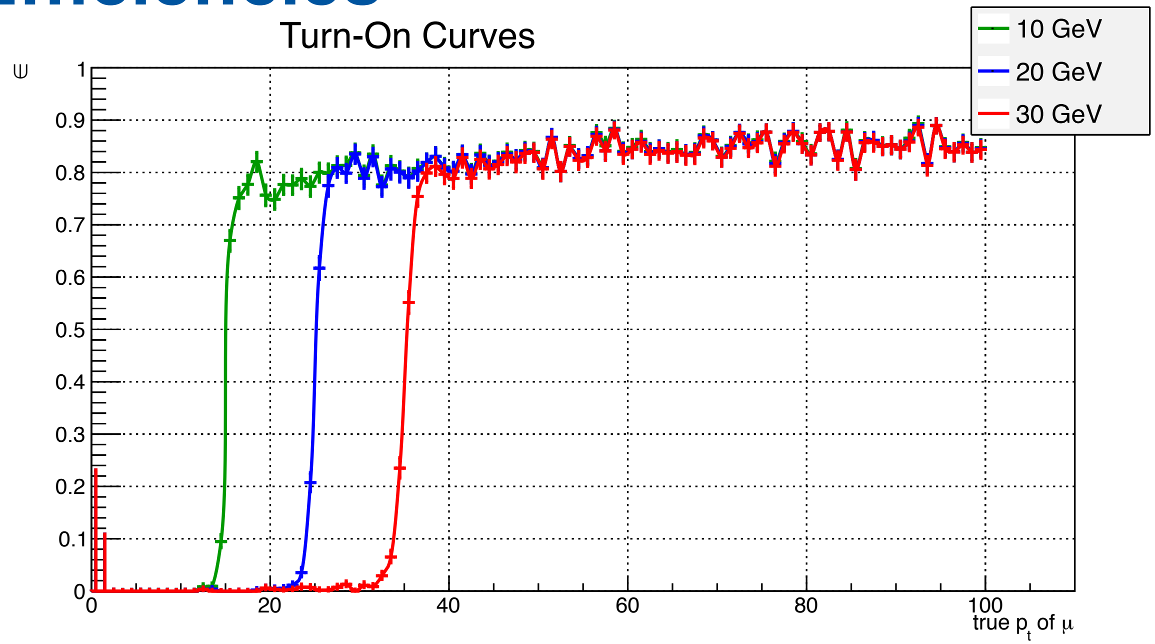
- Long Barrel design: Completely pixelated tracker (cf. CMS DN2012/003)
- Capable of self-triggering
- Produces L1 tracks with rough estimate of vertex, momentum

Studies with L1Tracks

- **Extrapolate** L1Tracks fullfilling p_t and acceptance requirements linearly to MTT
- Search for digitized hit in matched tile and its neighbours
- If hit is found and satisfies energy cut, we have found a muon candidate

Studies with L1Tracks-Efficiencies

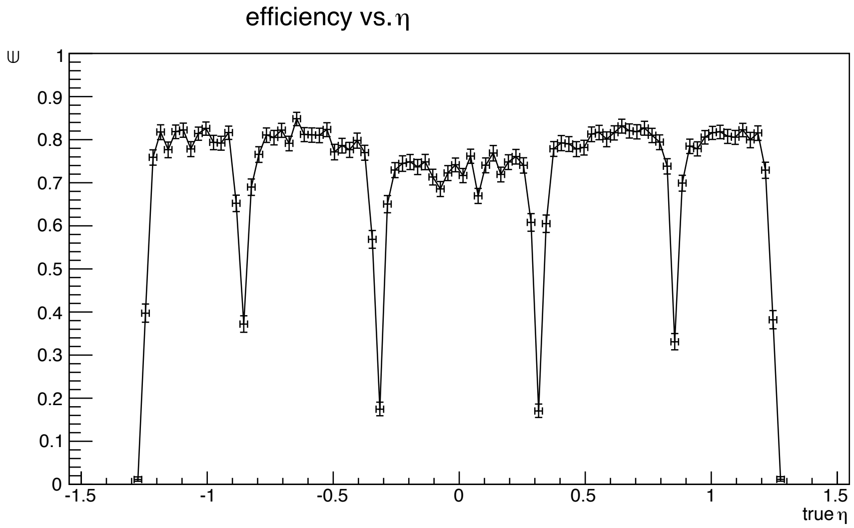
III. Physikalisches Institut B
RWTHAACHEN

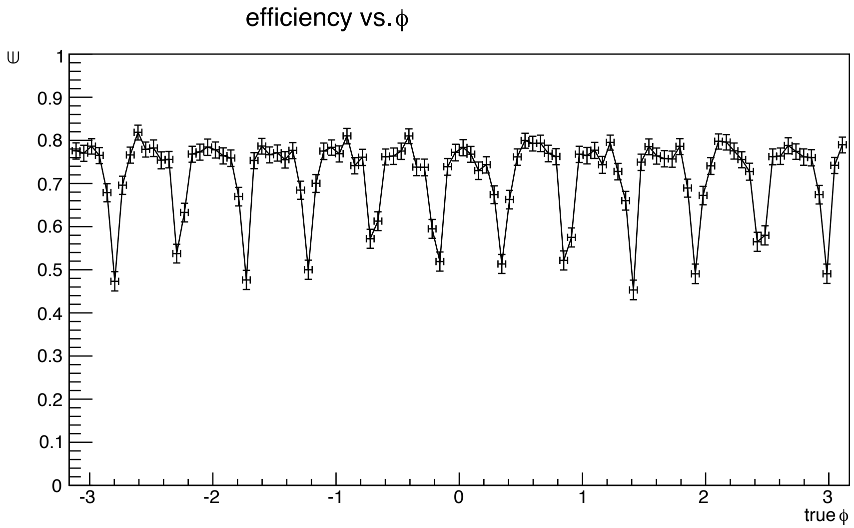


- Same Geometry as before
- Muon gun without pileup
- **Steep** turn on curves
- Efficiency **rather low**

CMS Germany BMBF FSP-CMS

Studies with L1Tracks-Efficiencies





- Cracks in Φ and η lower eff. Significantly
- Better coverage preferable

III. Physikalisches Institut B
RWTH AACHEN

Conclusions & Outlook

- MTT has been implemented into CMSSW **as new detector.**
  - → Design of a new subdetector hierarchy
  - → Geometry description & materials implemented
  - → Detector numbering scheme defined
  - → Trivial response simulation implemented
- A flexible simulation framework has been created for design & performance studies.
  - → Can now start optimising...
- Done some **preliminary studies**.
  - → Discrimination of signal and background is in principle possible
  - → Matching with L1Tracks possible, but needs optimisation

CMS Germany
BMBF FSP-CMS

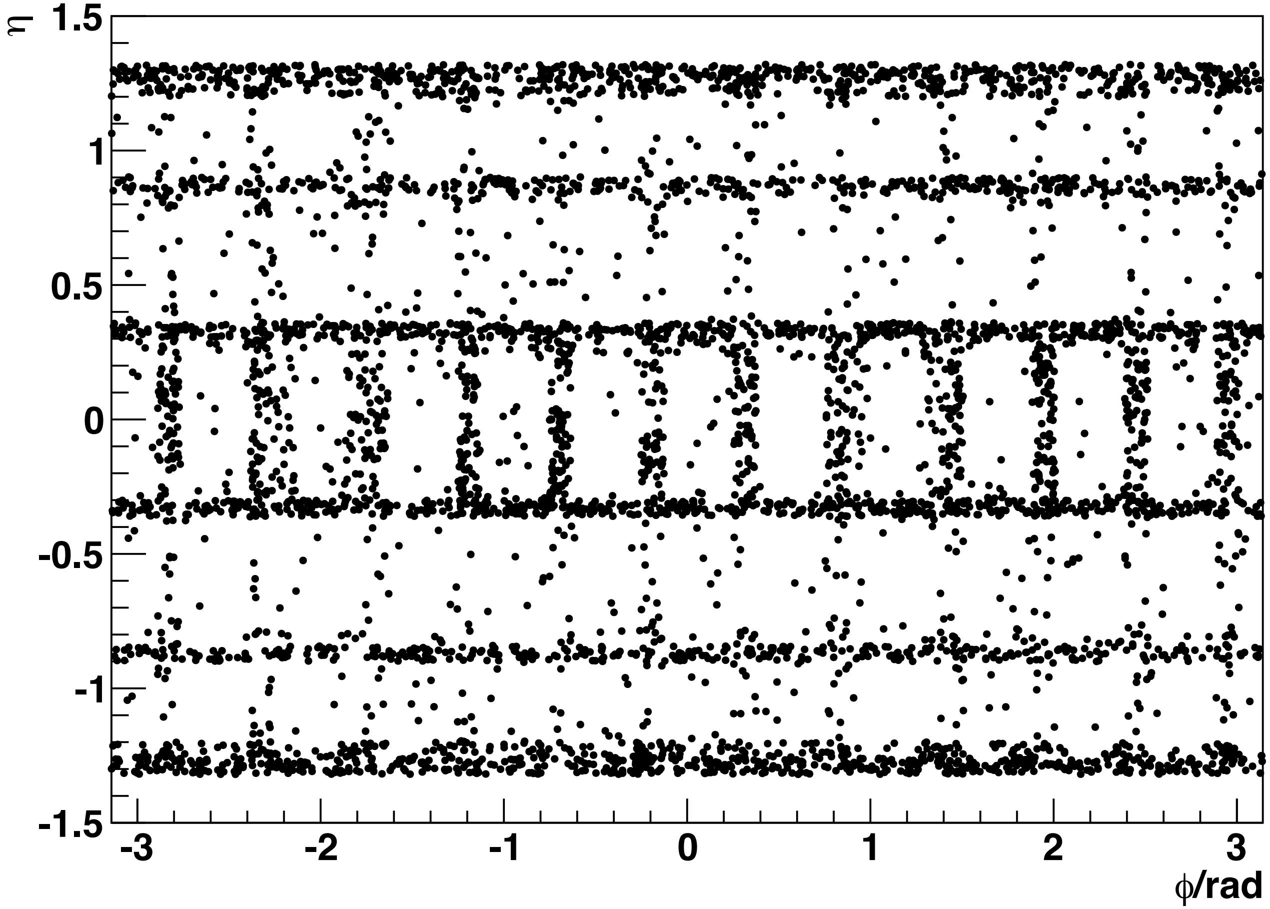
Conclusions & Outlook

- Next Steps:
  - → parametrize response of tiles with Geant4 simulations or hardware studies
  - → implement a model for neutron background & electronics noise
  - → consider additional geometries
  - → further explore the interaction of MTT with other proposed upgrades

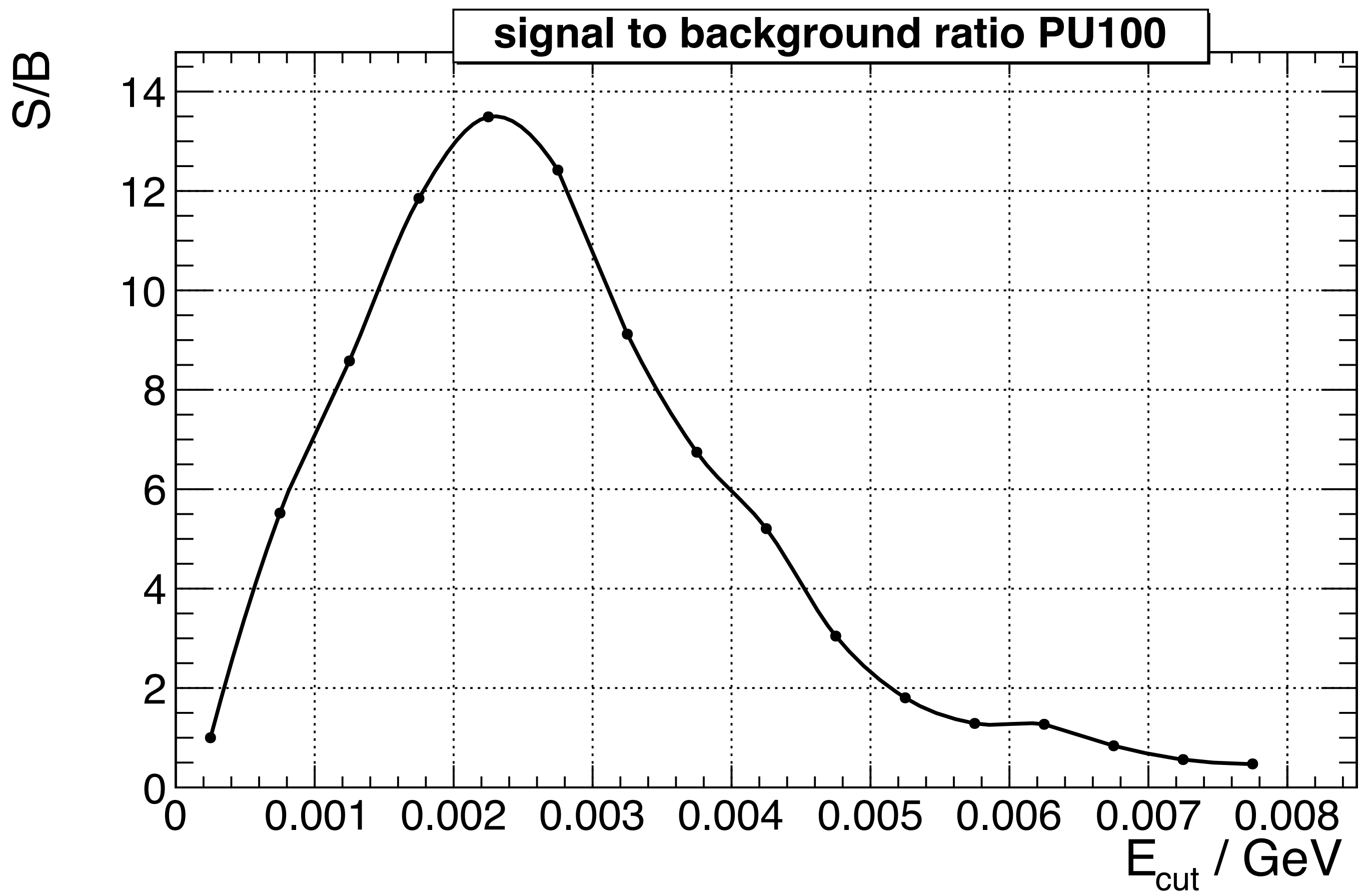
Thanks for your Attention!

Backup

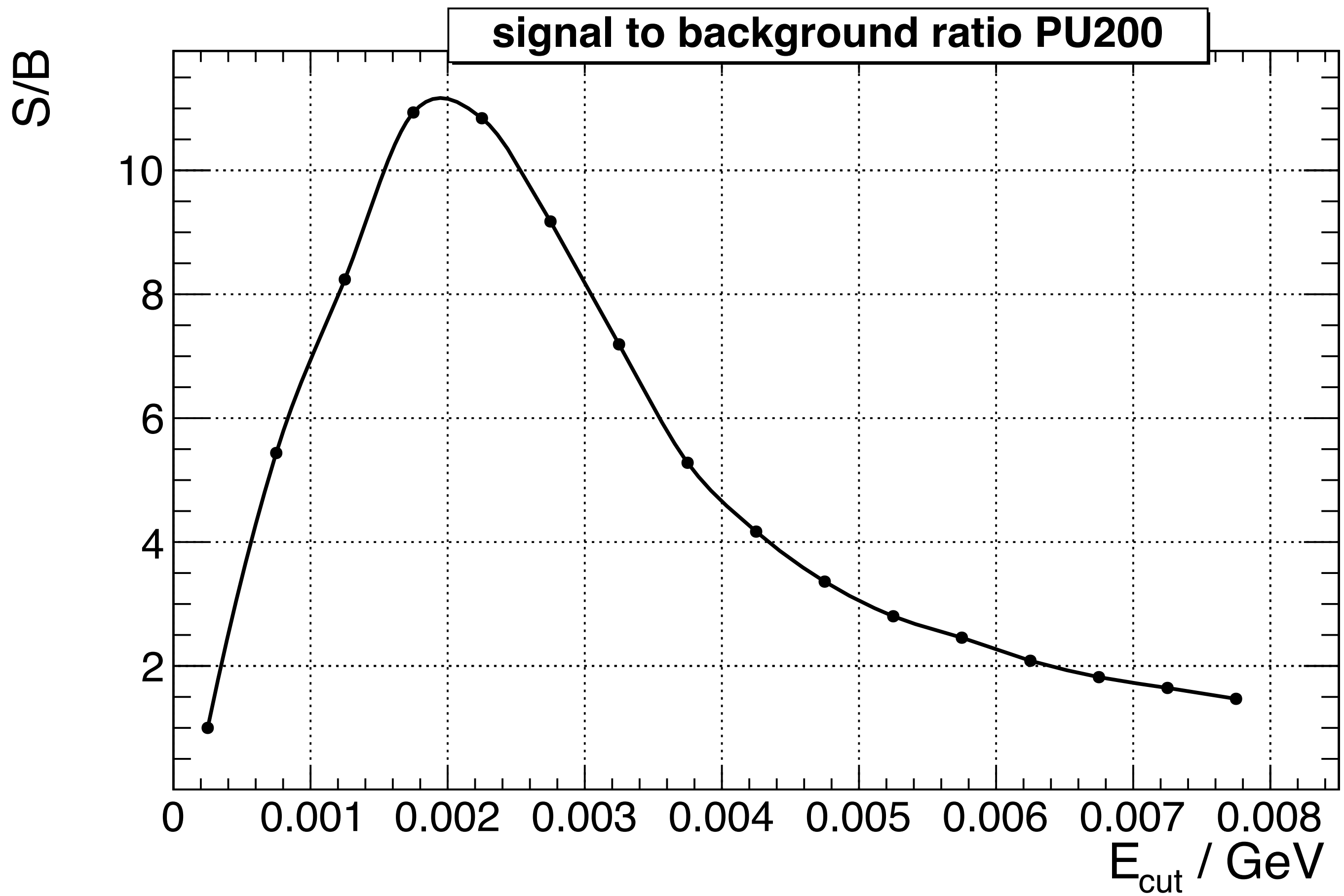
Backup



Backup

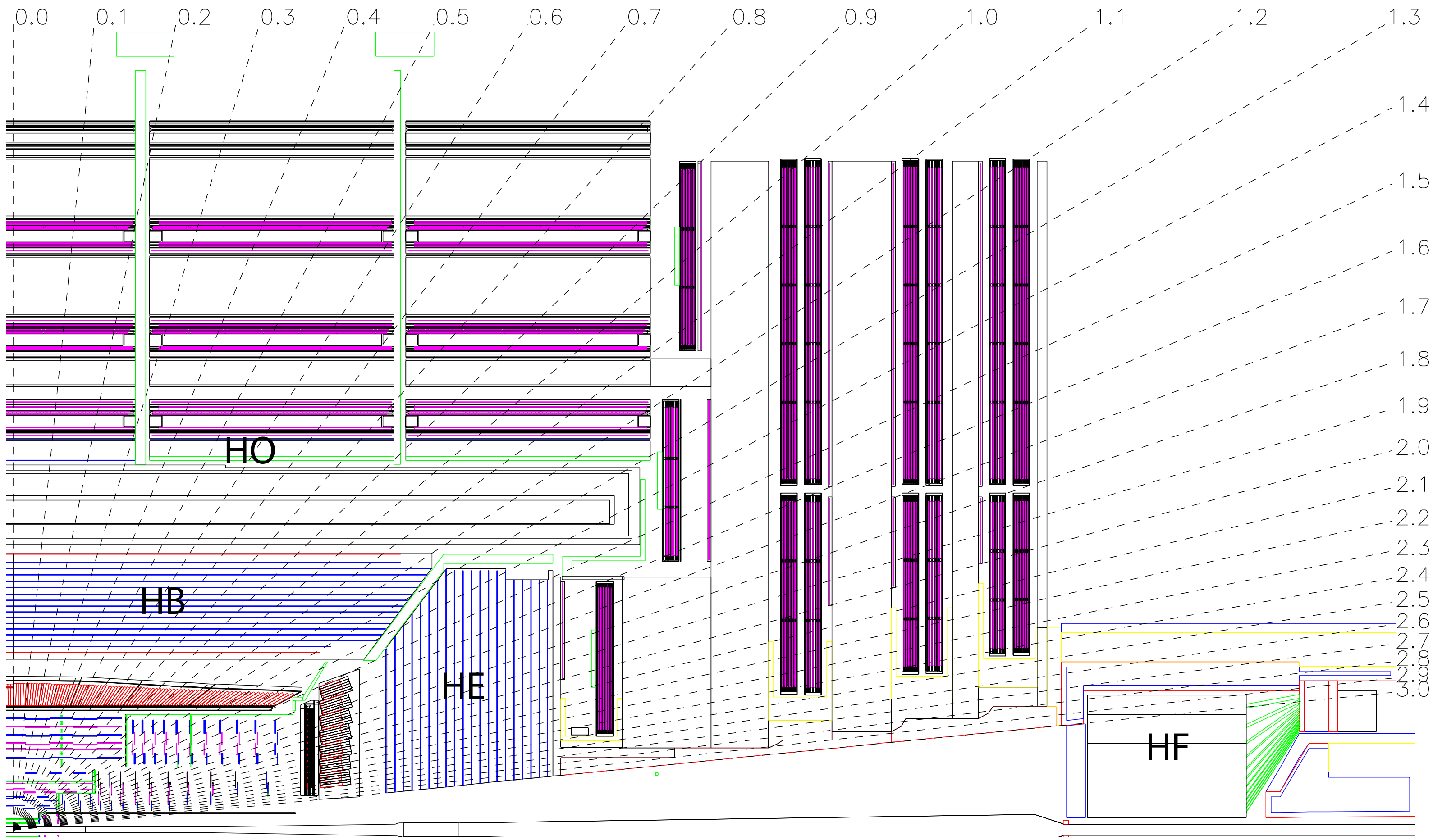

signal to background ratio PU100
S/B
14
12
10
8
6
4
2
0
0
0.001
0.002
0.003
0.004
0.005
0.006
0.007
0.008
E_{cut} / GeV

Backup


signal to background ratio PU200
S/B
10
8
6
4
2
0
0.001
0.002
0.003
0.004
0.005
0.006
0.007
0.008
E_{cut} / GeV

III. Physikalisches Institut B
RWTH AACHEN

Backup



CMS Germany
BMBF FSP-CMS