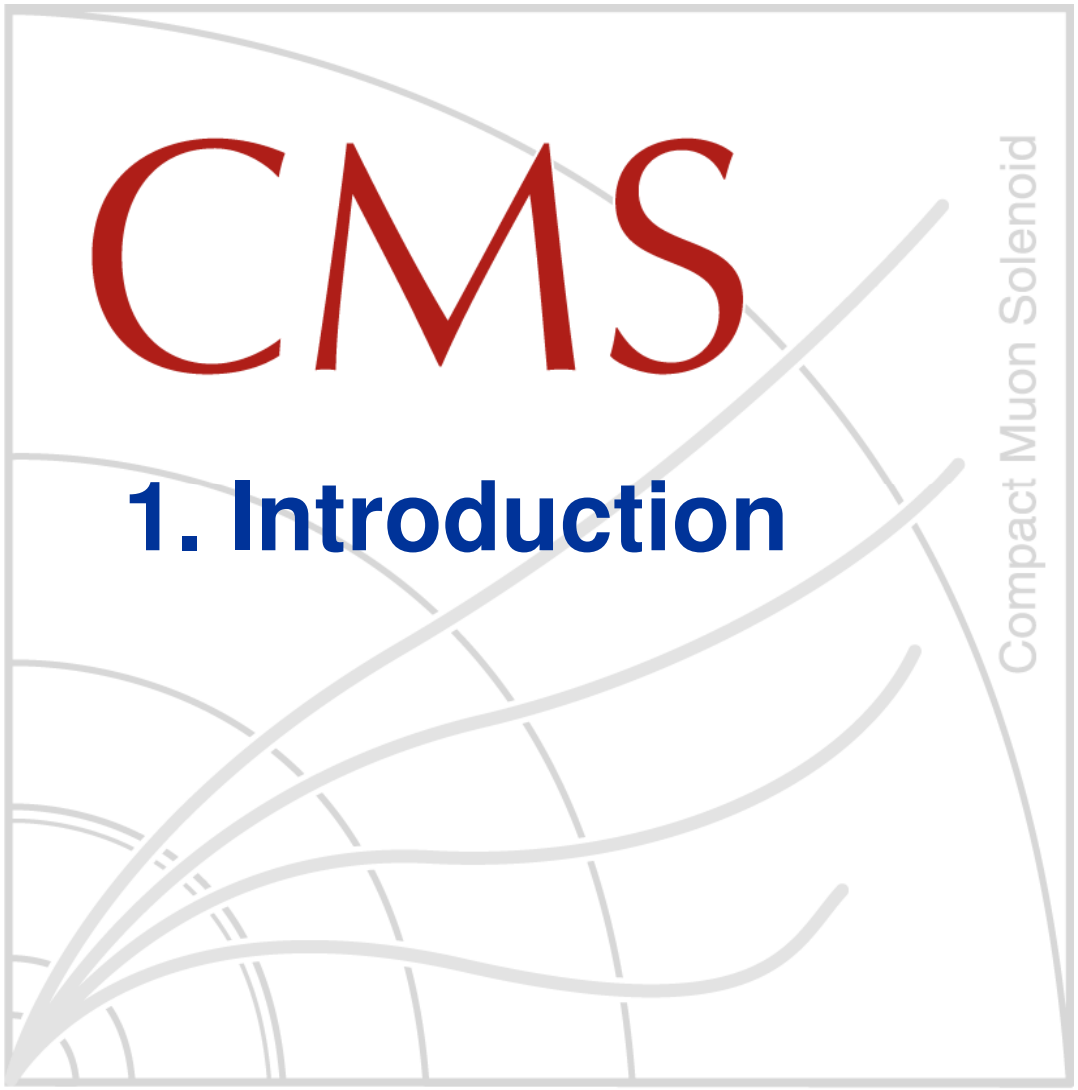
CMS

Compact Muon Solenoid

RPC Upgrade for Phase I
L1 Trigger Simulation

Introduction
L1 RPC Trigger
Trigger Efficiency vs. Trigger Rate
Robustness of Station 2
GMT & Conclusions

Piet Verwilligen
2009-10-28

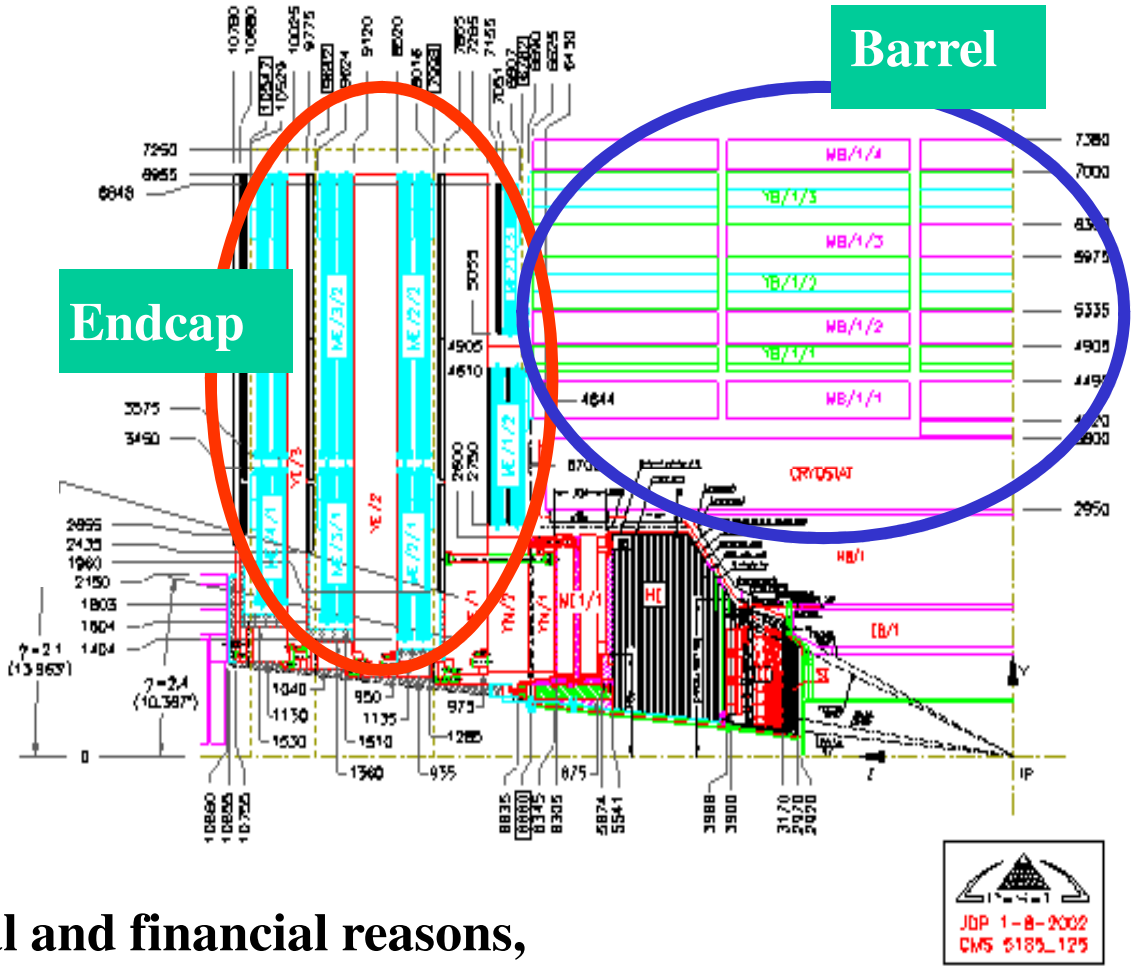


1. Introduction

Introduction: RPC System

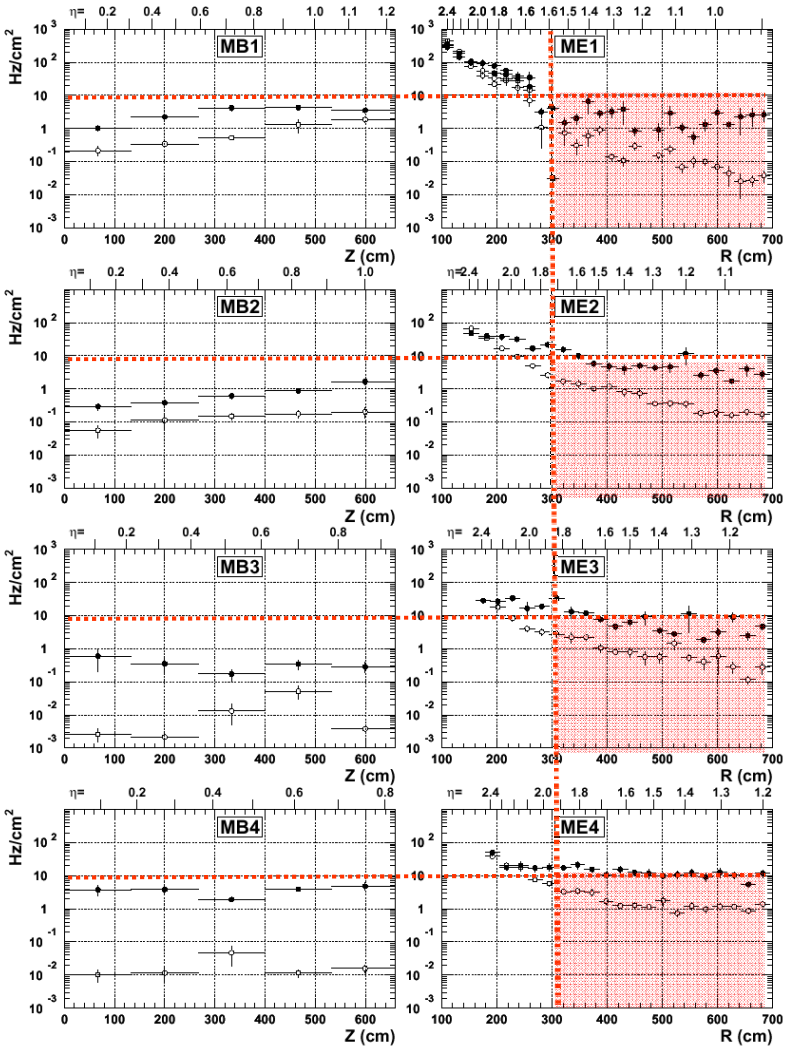
Baseline:

- Six stations in the Barrel
- Four stations in the Endcap up to $\eta = 2.1$



However, due to technical and financial reasons, only three layers up to $\eta = 1.6$ in the endcap region are in place.

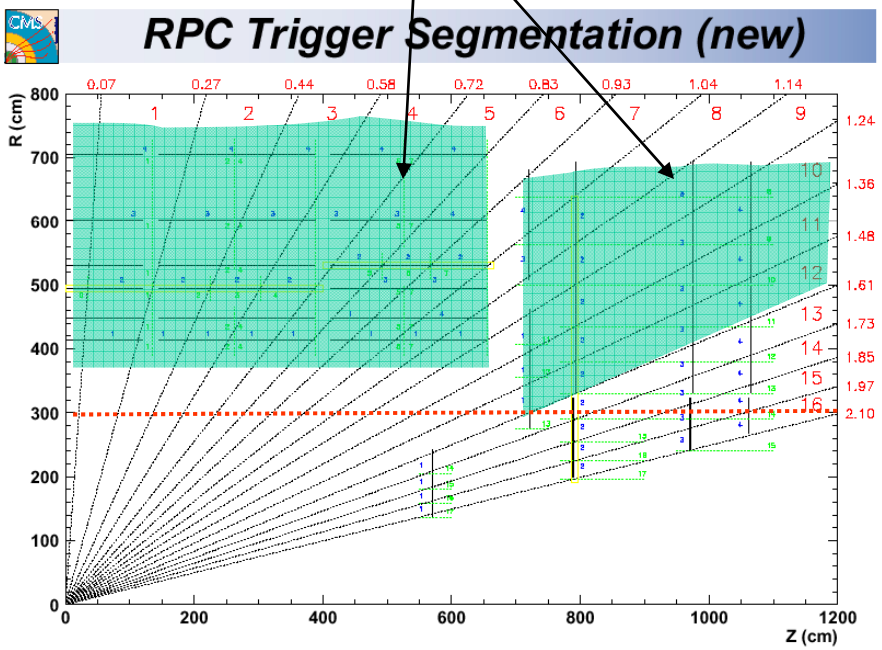
Introduction: Background



Hits due to neutrons (full circles) and charged particles (open circles).

[L1 Trigger TDR -- §8.4.2 p202 – 206]

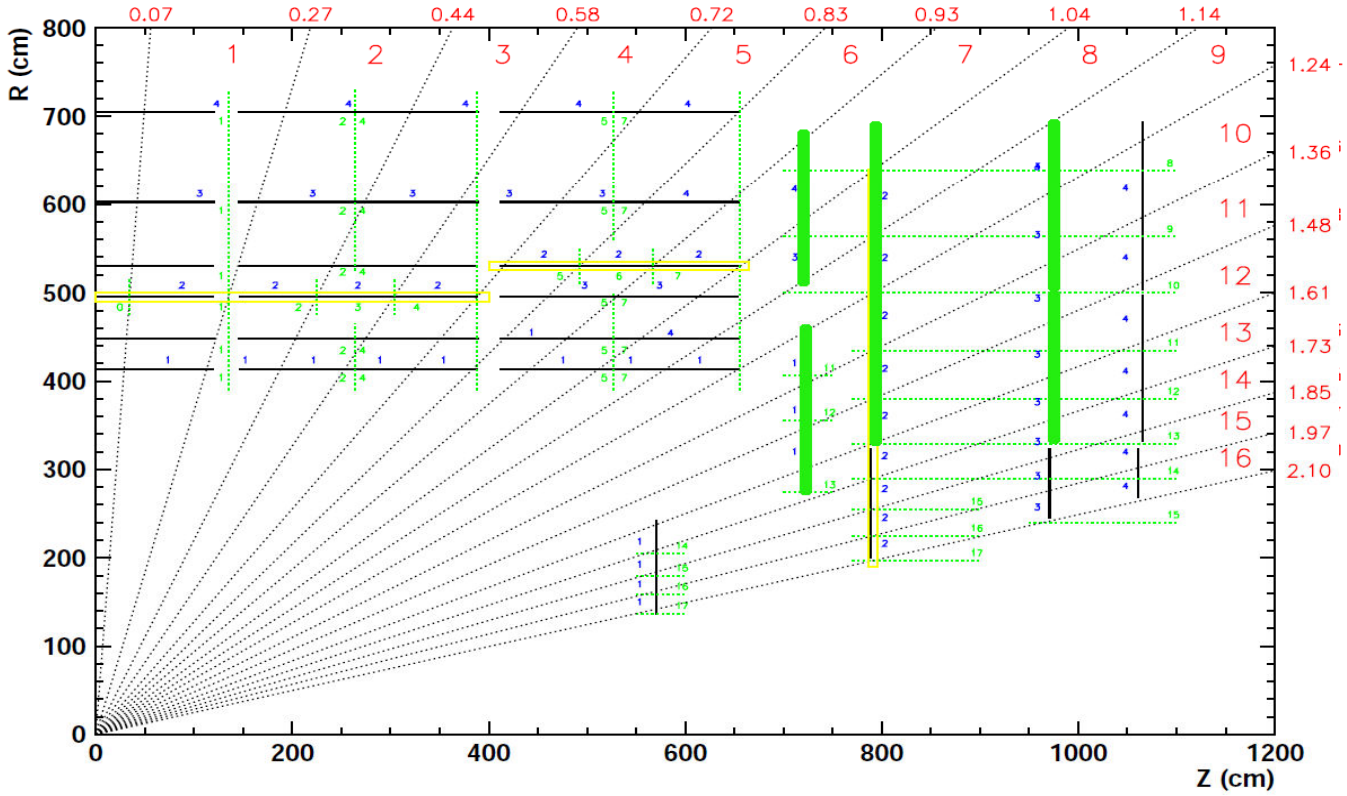
Rate in the shadow region ($\eta \leq 1.6$) is ≤ 10 Hz cm^{-2}

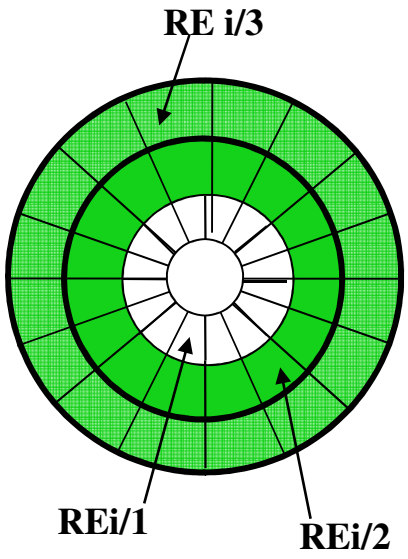


Red dashed line at 10 Hz/cm^2
Estimated at luminosity 10^{34}

Endcap System at Start Up

	RE 1/1	RE 1/2	RE 1/3	RE 2/1	RE 2/2	RE 2/3	RE 3/1	RE 3/2	RE 3/3	RE 4/1	RE 4/2	RE 4/3
No. of chambers	36*2	36*2	36*2	18*2	36*2	36*2	18*2	36*2	36*2	18*2	36*2	36*2





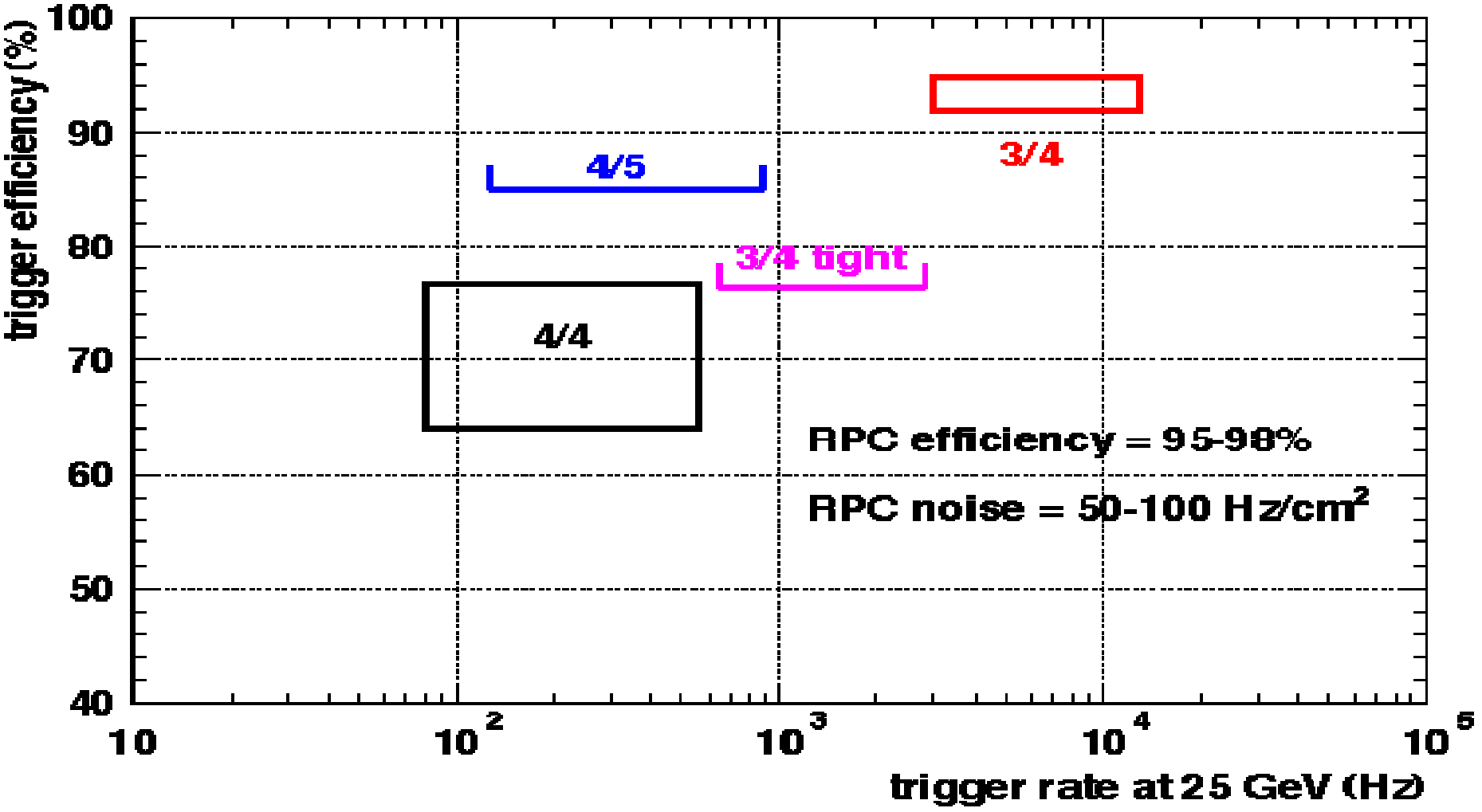
Trigger Study

- The decision of the Trigger Threshold (p_T^{cut}) is a trade-off between high trigger efficiency and low (fake) trigger rate.
  - L1 GMT has limited output rate (< 12.5 kHz)
  - Therefore expected threshold to keep trigger rate below 10.0 kHz at L = 10^{33} cm^{-2} s^{-1} is 25 GeV/c
  - [L1 Trigger TDR – §2.3 Muon Trigger Requirements p26 - 27]

- A study on additional RPC Planes (CMS IN 2001/003), was performed which showed a much better trigger performance (relative high trigger efficiency with relative low trigger rate) with an independent 5th plane in the Endcap.

Results Earlier Trigger Study

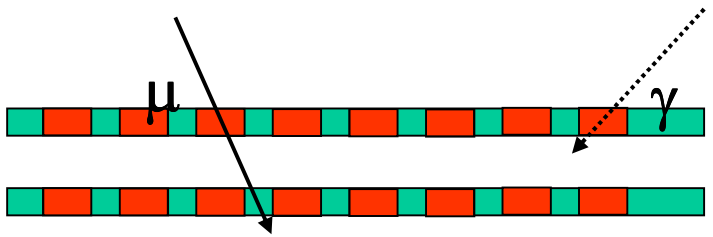
- **CMS IN 2001/003: Study on Additional RPC Planes for the Muon Trigger**



Low η upscope

- A “real” 5th plane was ruled out because too expensive:
  - need additional services: HV, LV, gas, cooling, readout, trigger electronics, …
  - Need more space (open endcaps by few cm), new B field map, …
- Because of the 2nd station is the Trigger Reference Plane
  - hit strips are not copied to other Trigger Segments
  - useful to clean the fake hits in 2nd station → reduce the fake rate

- A “double” station was considered instead: RE2bis
- A double station with OR/AND capability could reduce the noise

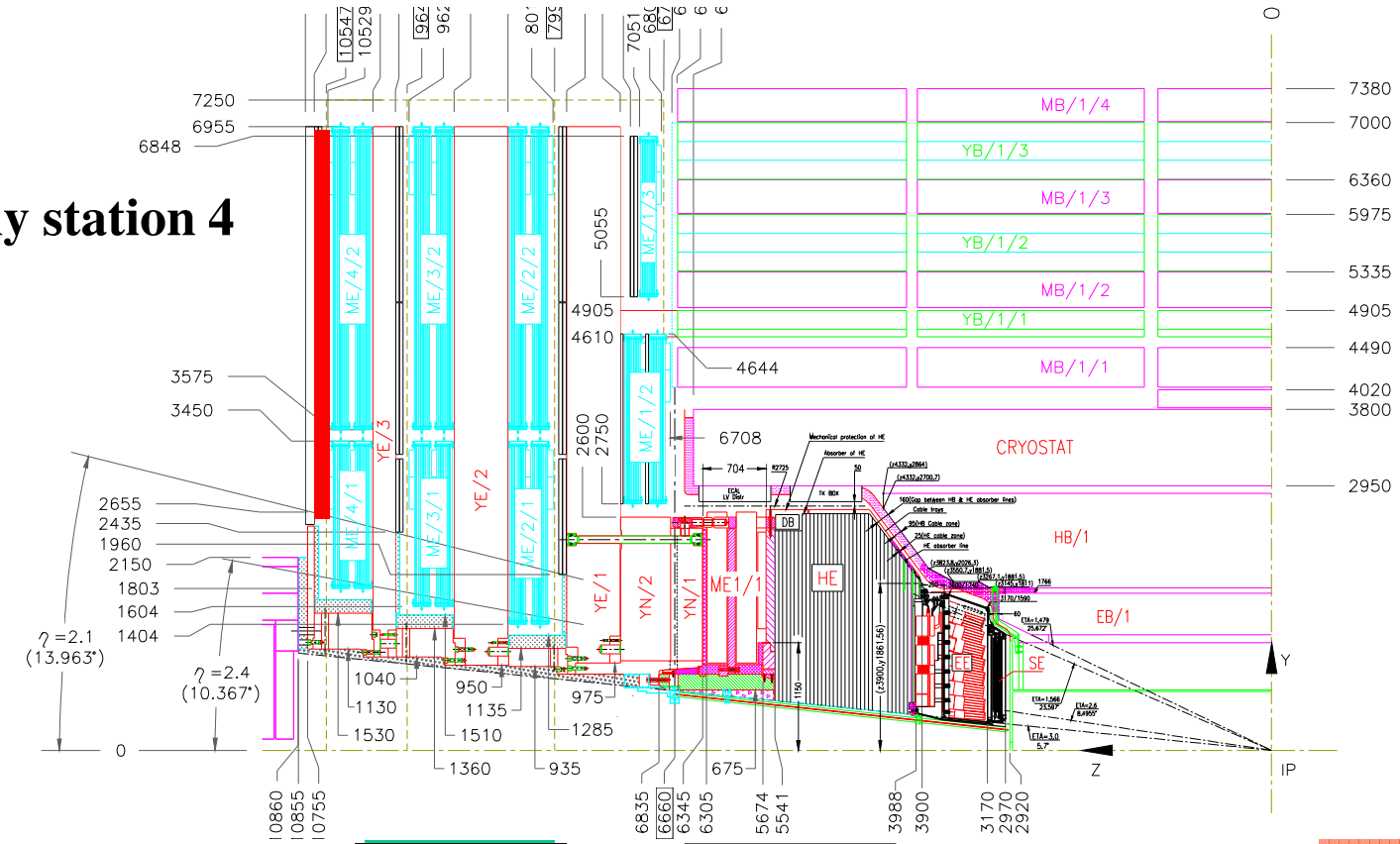


Two options:

- Restore the TDR scheme by adding a 4th station: **RE4**
- Move the actual station RE2 to RE4 & add a double station: **RE2bis**

TDR Approach

Build only station 4



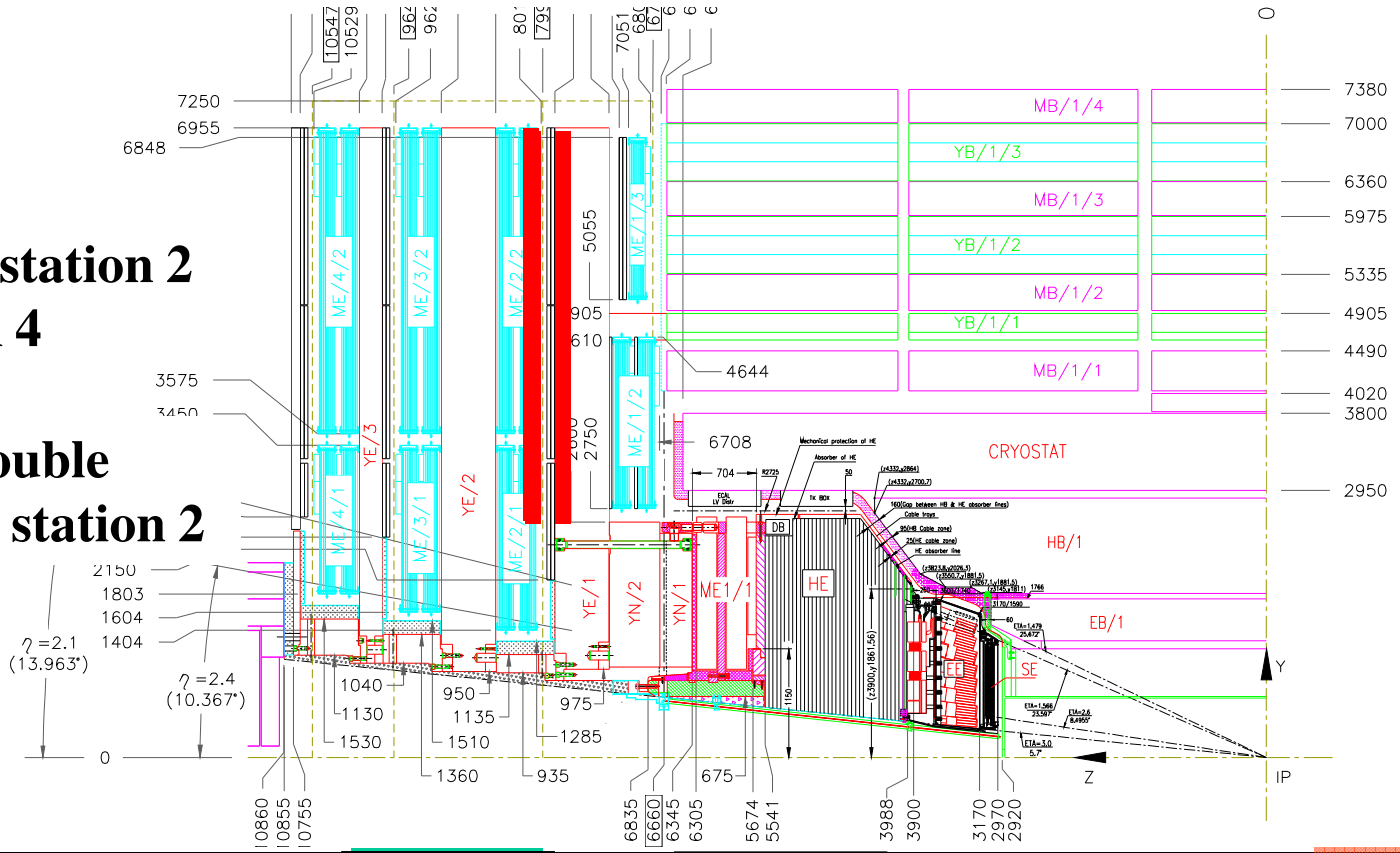
	RE 1/1	RE 1/2	RE 1/3	RE 2/1	RE 2/2	RE 2/3	RE 3/1	RE 3/2	RE 3/3	RE 4/1	RE 4/2	RE 4/3
No. of chambers	36*2	36*2	36*2	18*2	36*2	36*2	18*2	36*2	36*2	18*2	36*2	36*2

4th station

The Double Chamber Approach

Move act. station 2 to station 4

Build a double station for station 2



	RE 1/1	RE 1/2	RE 1/3	RE 2/1	RE 2/2	RE 2/3	RE 3/1	RE 3/2	RE 3/3	RE 4/1	RE 4/2	RE 4/3
No. of chambers	36*2	36*2	36*2	18*2	36*2	36*2	18*2	36*2	36*2	18*2	36*2	36*2

4th station

TDR vs RE2bis

TDR:

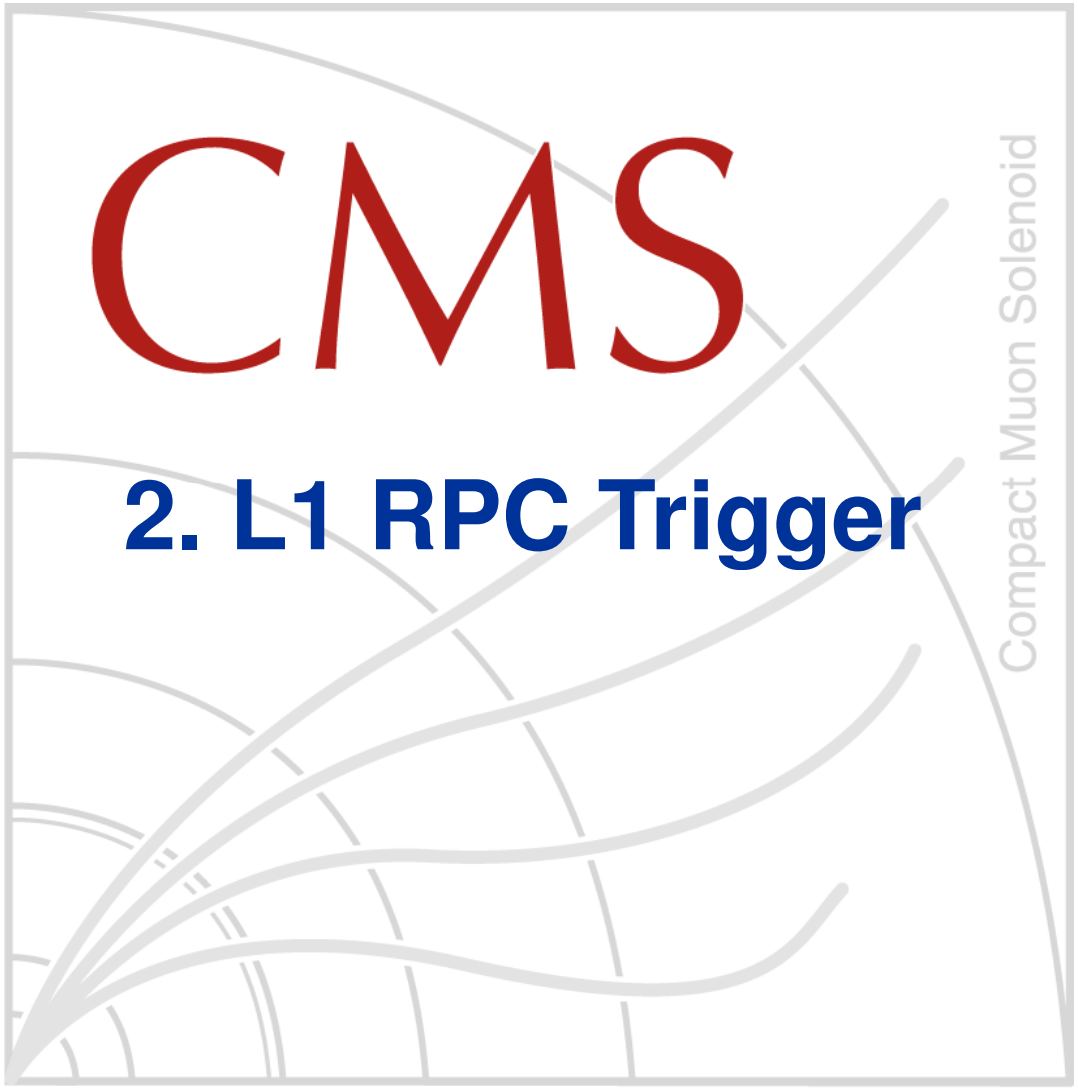
- ± 150 new chambers
- No noise reduction capability in layer RE2
- 3.5 MCHF

Double Station:

- ± 300 new chambers
- Integration issues
- Noise reduction capability
- Add. cost of 900 kCHF

Validation from simulation is needed to take decision:

- Study RPC L1 trade-off between trigger rate and trigger efficiency for different geometries
- Study RE2 robustness
- GMT output rate (future studies)



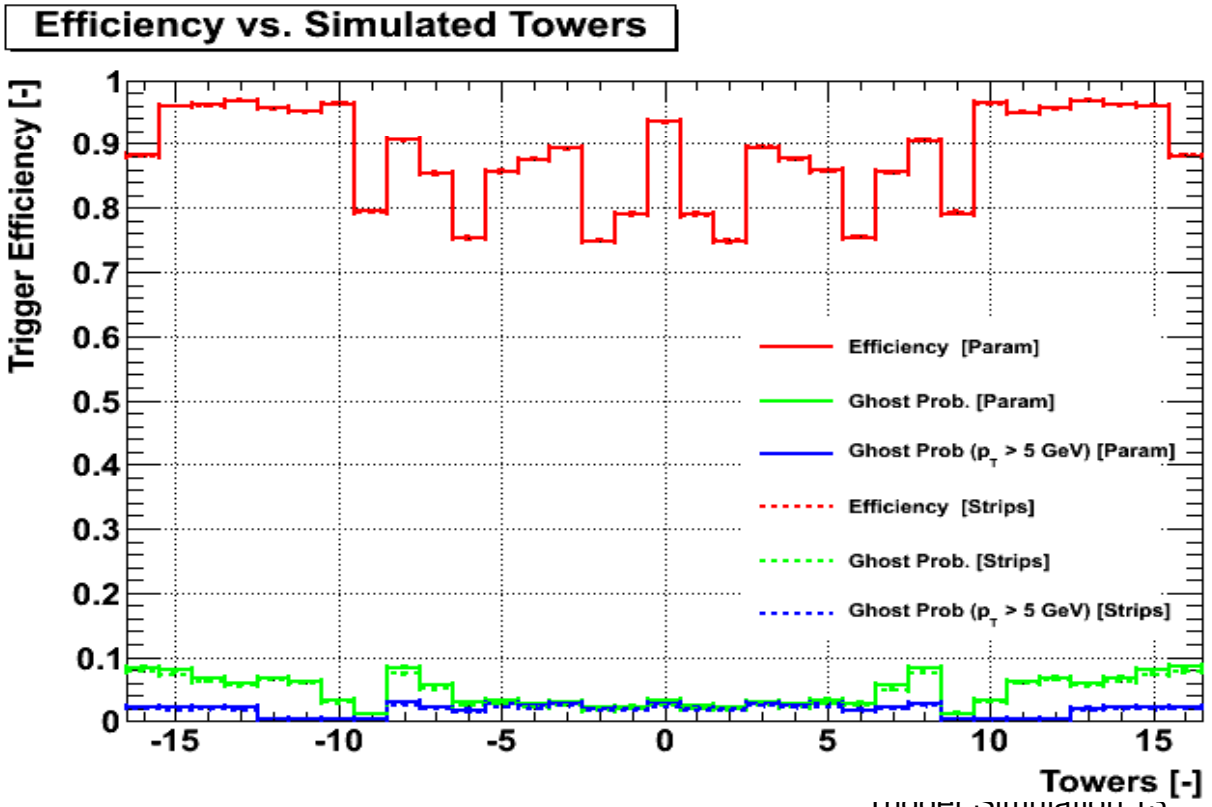
2. L1 RPC Trigger

L1 RPC Trigger Simulation

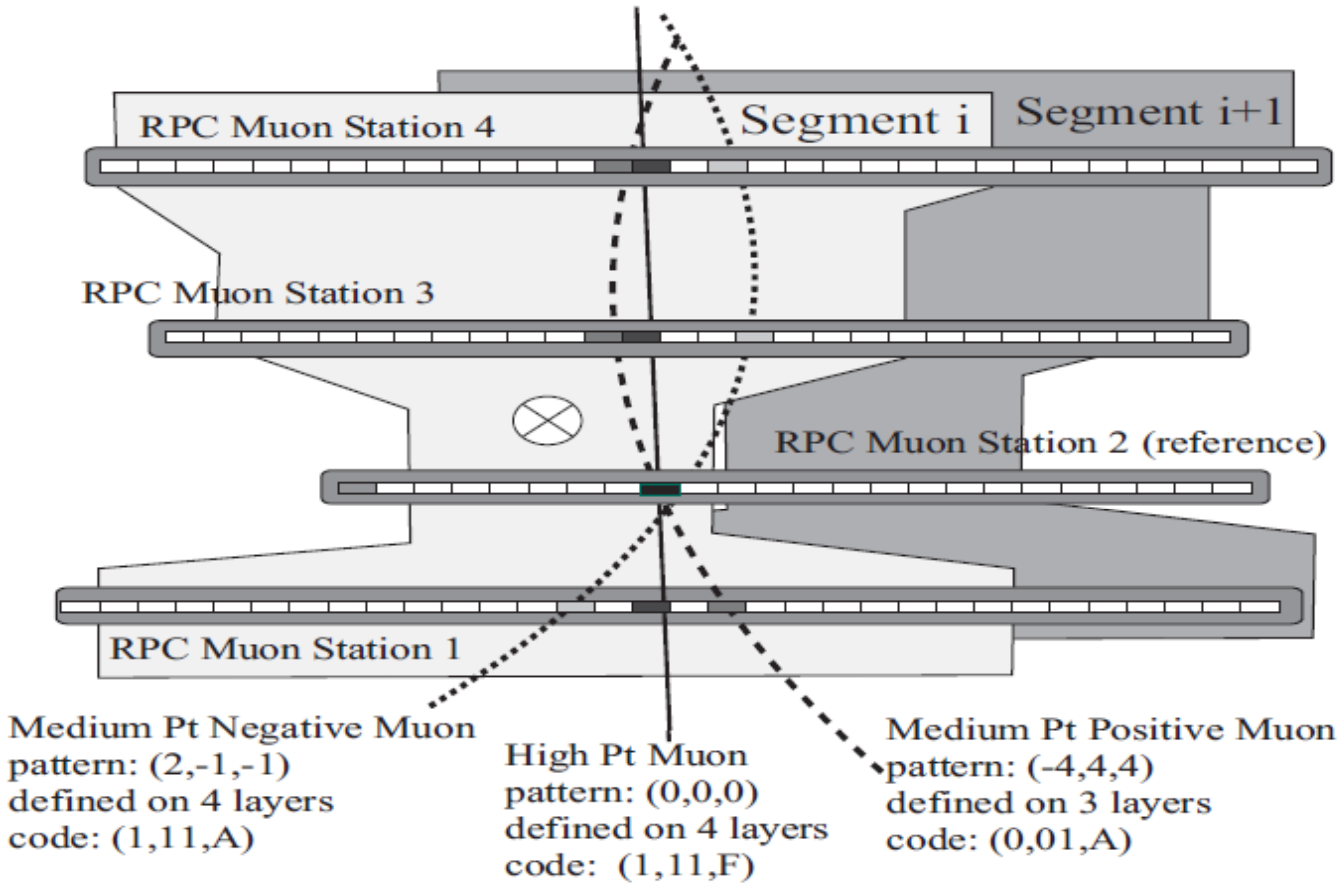
- **Trigger Efficiency:**
  - **If an event is triggered and**
    - **there was a simulated muon in the event**
    - **which meets certain requirements,**

    the trigger is considered "Efficient" for those requirements.

- Trigger Simulation:
  - Single Muons: 10 – 200 GeV/c
  - CMSSW_2_2_10
  - 2 Digitization Models
  - ε = 95 %
  - Rate = 0.05 Hz cm^{-2}
  - Different Geometries
  - Left: TDR Geometry



Trigger Segments (Cones)

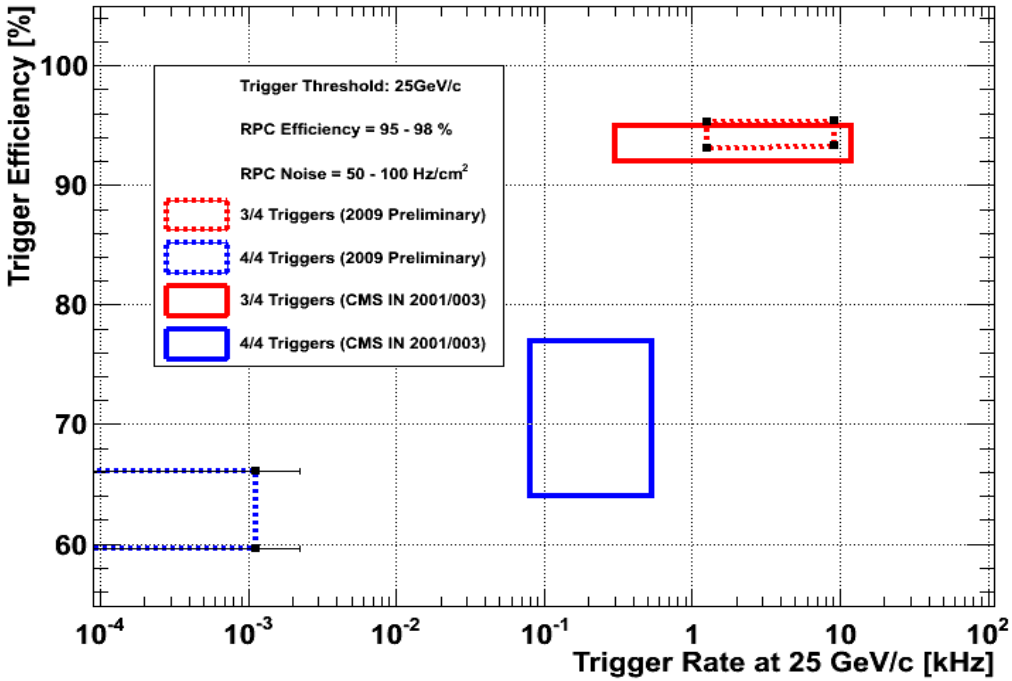


- Trigger Segments (TS) are **uniquely** defined in station 2
- Other stations have their fired **strips copied** to other TS

3. Trigger Efficiency vs. Trigger Rate

Validation

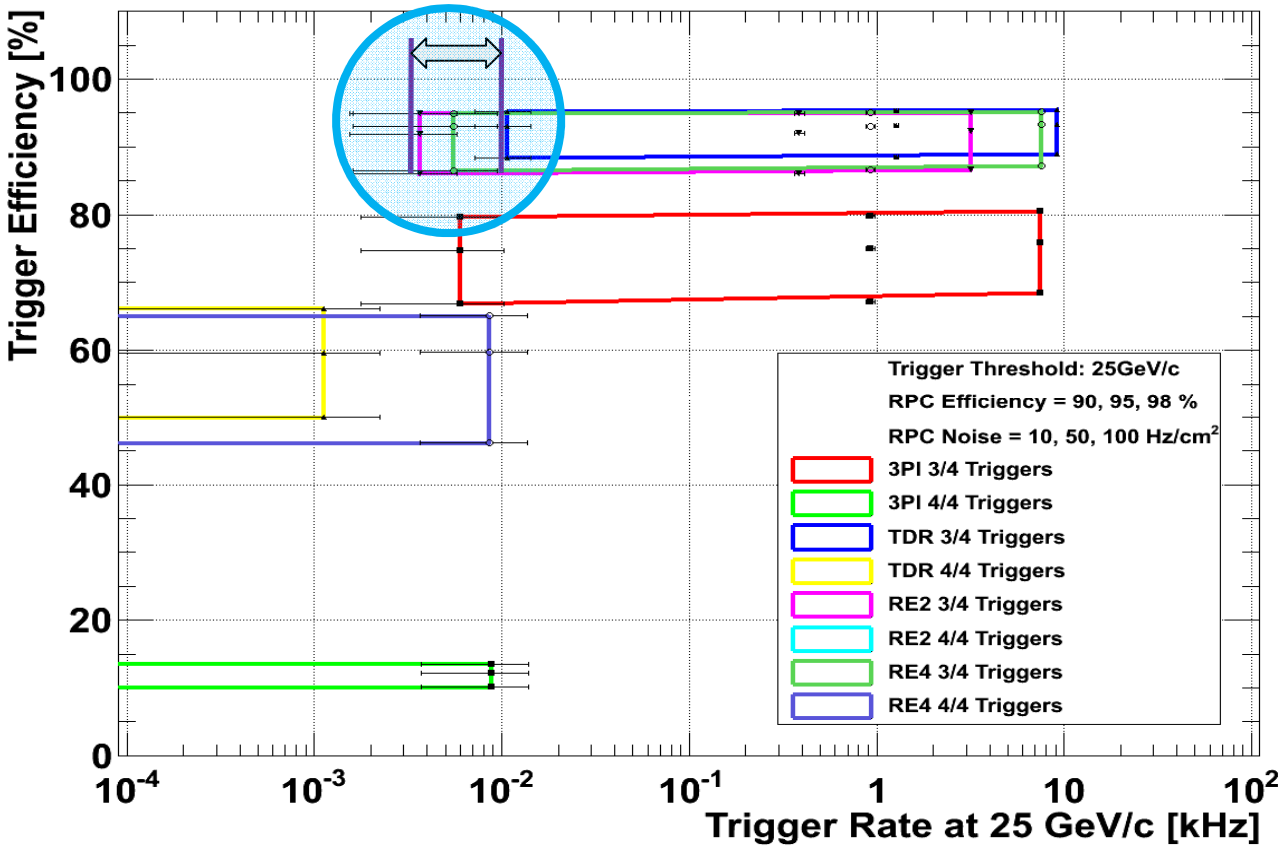
- **RE2bis was implemented as a logical "AND" of 2 RPCs**
  - $\varepsilon = \varepsilon^2$ 90% → 81 %
  - Rate? Turned out to be negligible:
    2 x 100 Hz cm^{-2} → 0.05 Hz cm^{-2}
- **This plot was made in TDR geometry with:**
  - Rate: Neutron hits: Poisson Distribution for random noise
  - Efficiency: Single Muons, 10 - 200 GeV/c , 1.04 < η < 2.1
  - ➔ Pure Fake Rate, no rate due to MinBias and Signal



- **Unable to reproduce exactly the same result as 8 years ago**
- **Major Changes in Software:**
  - Patterns
    - Broad Patterns → Narrow Patterns
  - Algorithm: 3/4 → 4/6
  - Quality:
    - no preferred Layer
    - Q = # Planes hit - 3

Preliminary Results

Full Endcap (Towers 8 – 16 == 1.04 < η <2.10)

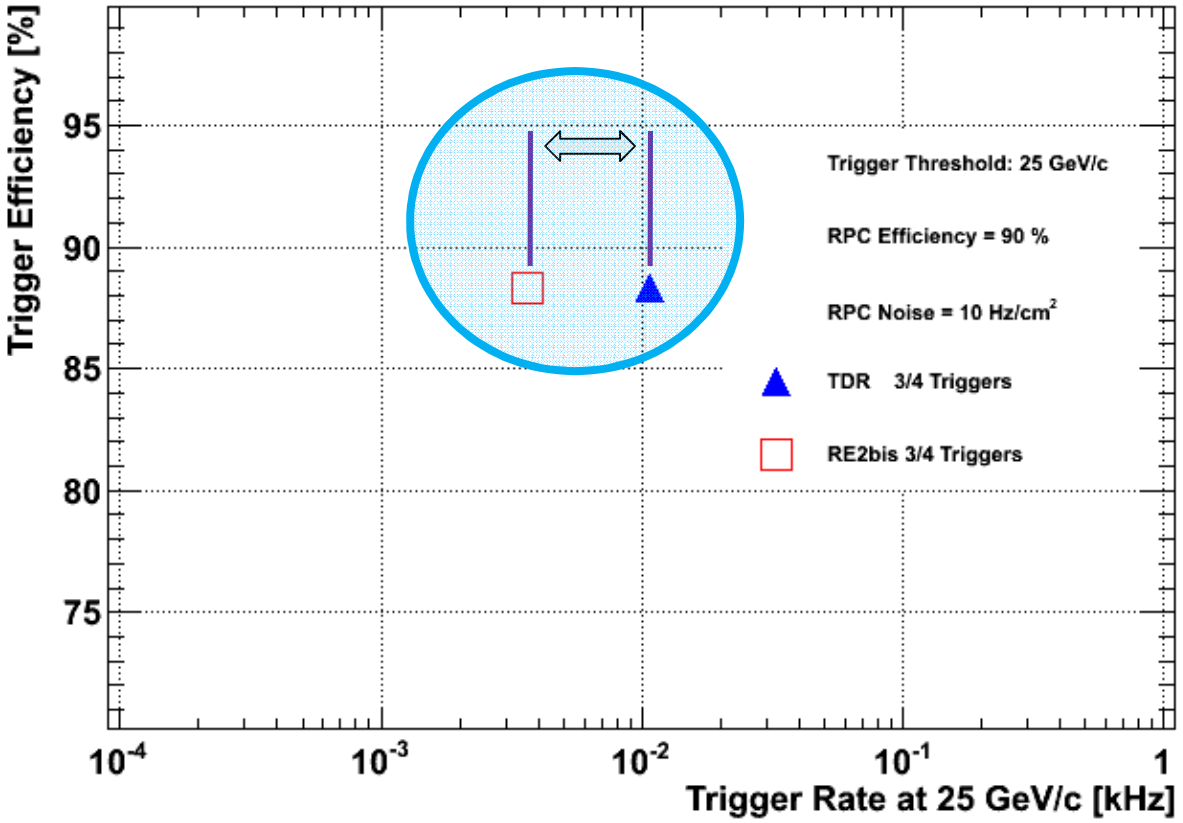


Slightly better (lower) Trigger Rate for RE2bis, but not as high as expected w.r.t. the simulation of a fully independent 5th plane.

Is this worth the effort?

Preliminary Results: Summary

Full Endcap (Towers 8 – 16 == 1.04 < η <2.10)



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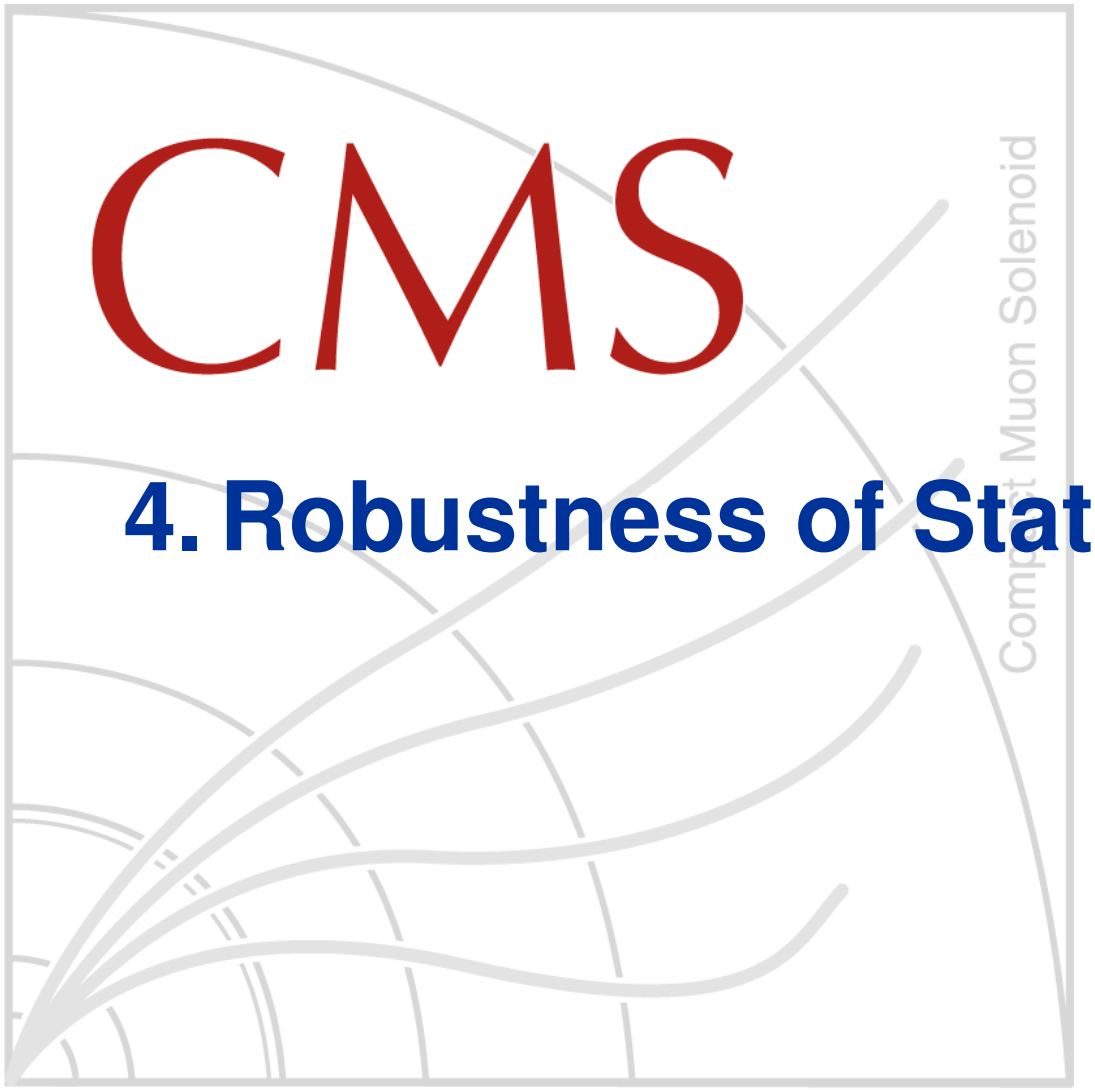
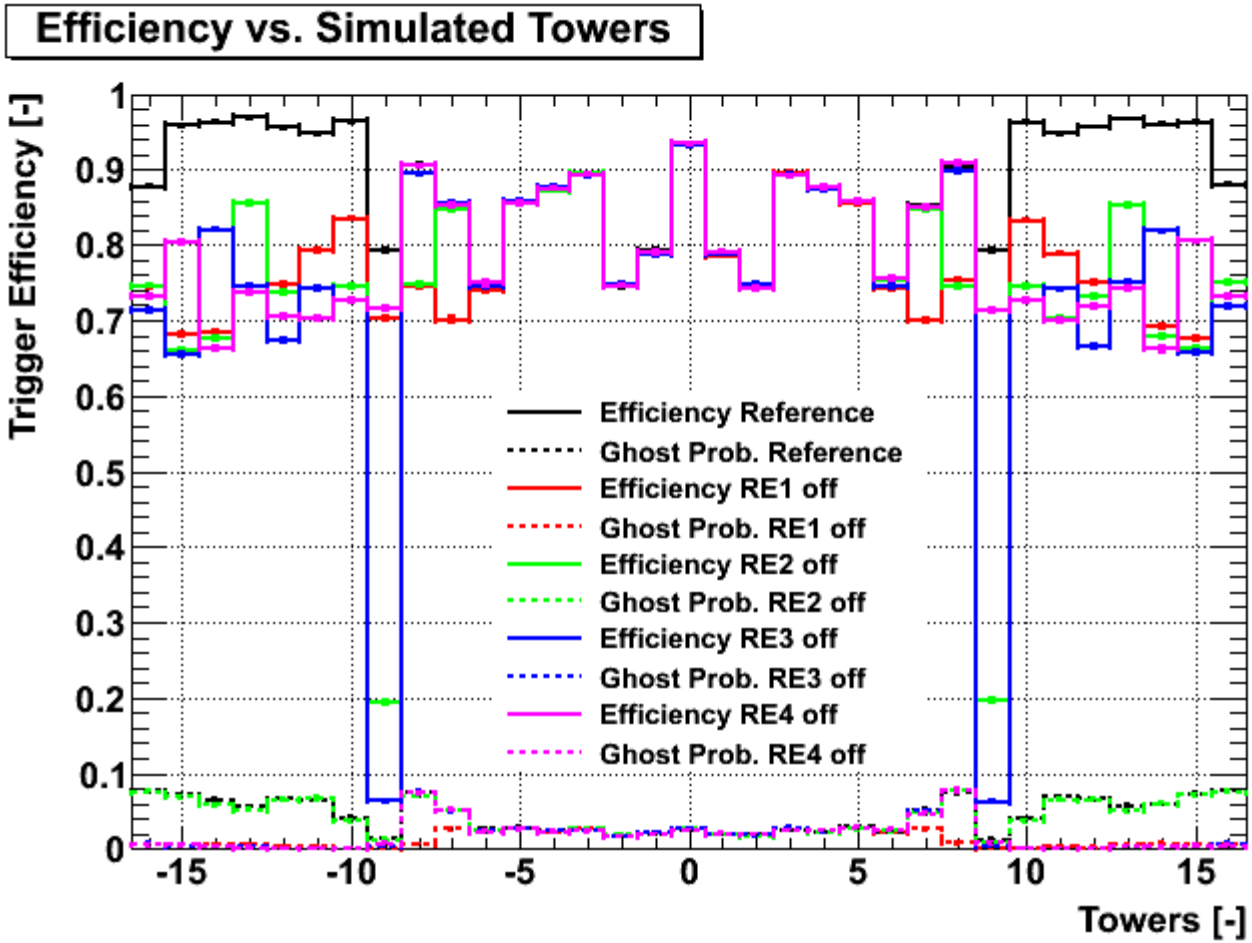


4. Robustness of Station 2

Robustness of Station 2

- What if the second station (RE2) fails?
  - Trigger Efficiency? p_T assignment?
  - What would be the difference with another station failing?

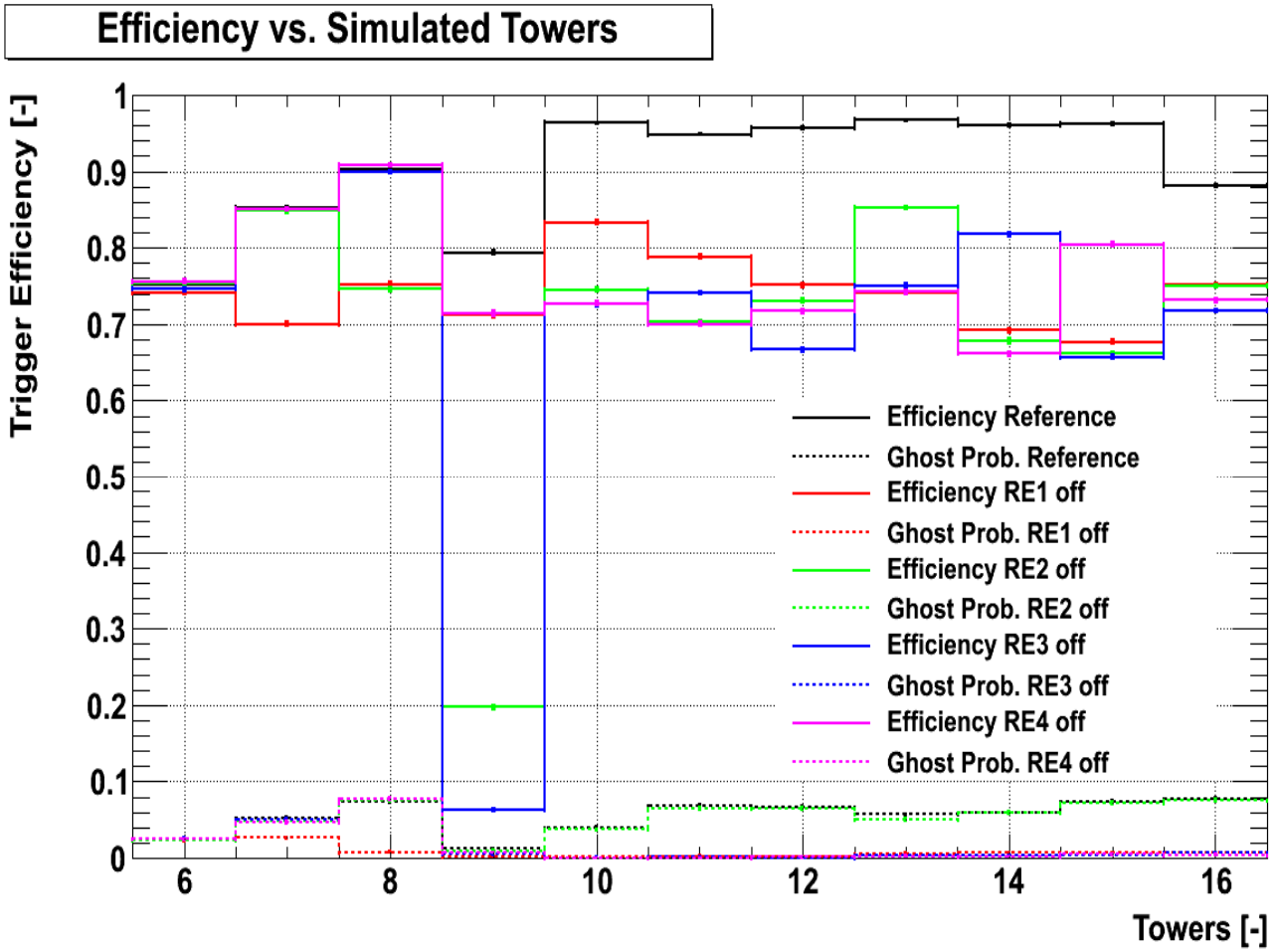


TDR Geometry

ε = 95 %

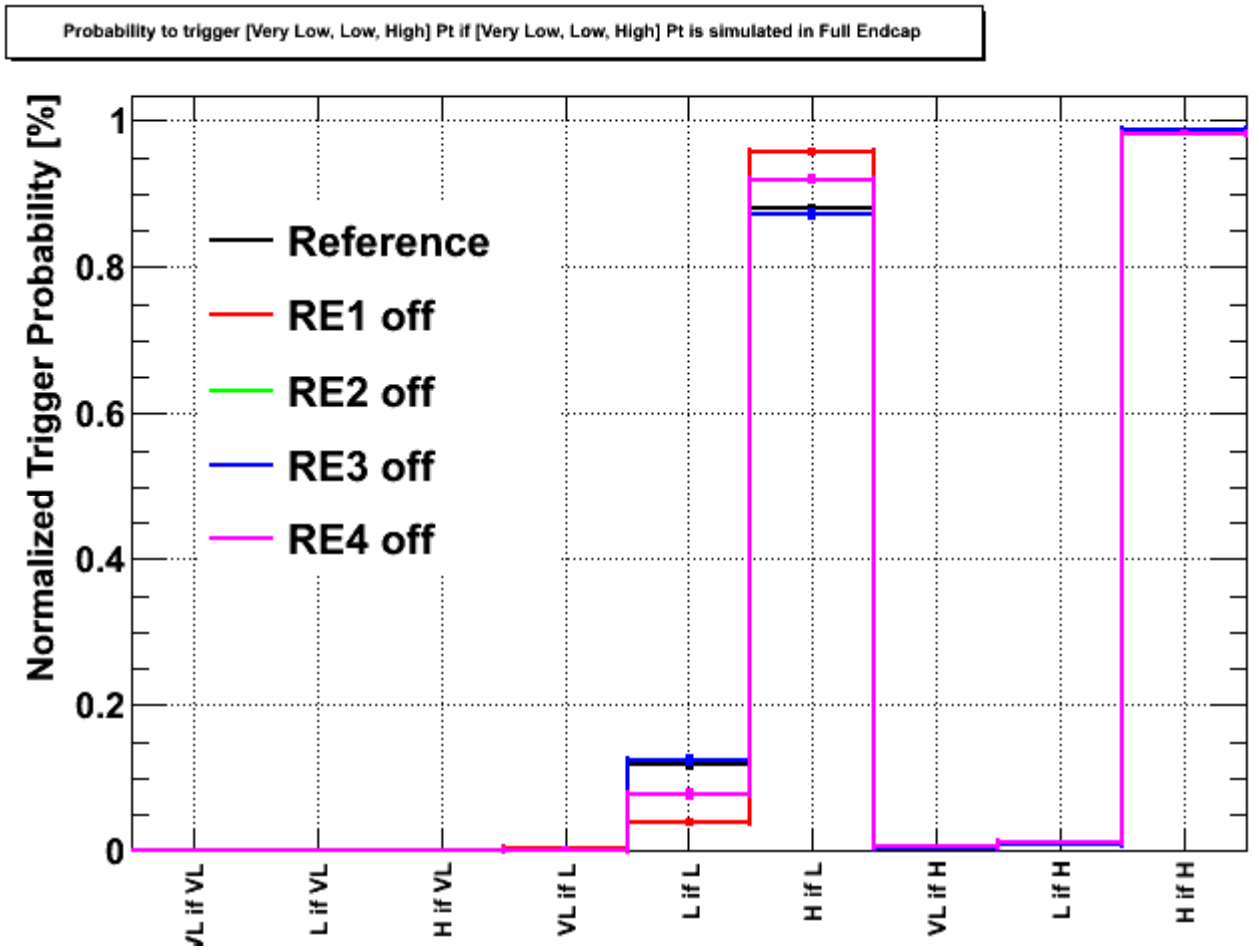
Rate = 0.05 Hz cm^{-2}

Trigger Efficiency Full Endcap



Ghost rate is dominated by RE1 and RE3, switching off RE2 does not affect the ghost rate

P_T Mismatch Probability

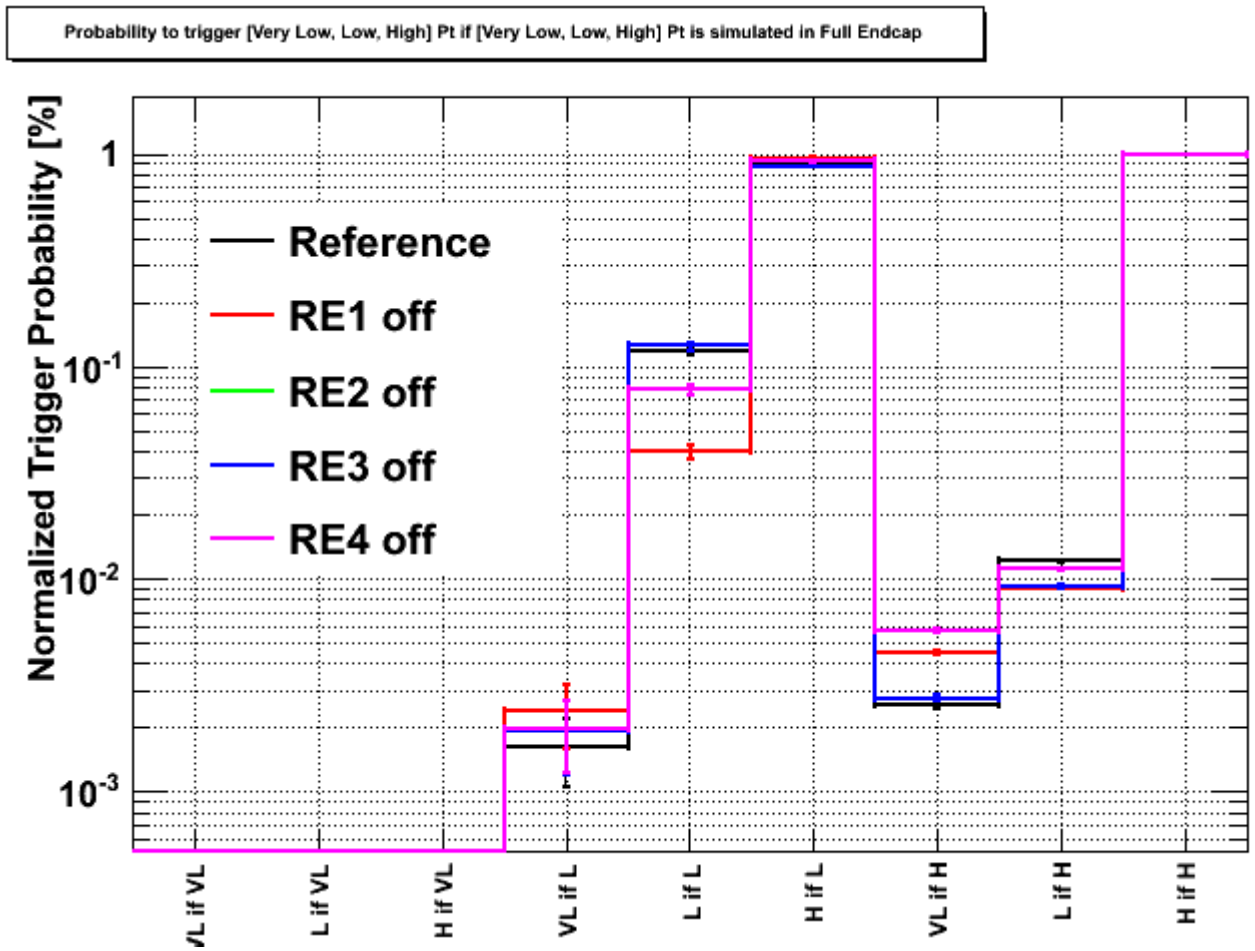


VL < 4.5 GeV/c

L < 14.0 GeV/c

H > 14.0 GeV/c

P_T Mismatch Probability



VL < 4.5 GeV/c

L < 14.0 GeV/c

H > 14.0 GeV/c

The probability to assign High p_T if high p_T is simulated is not affected by taking out one of the stations

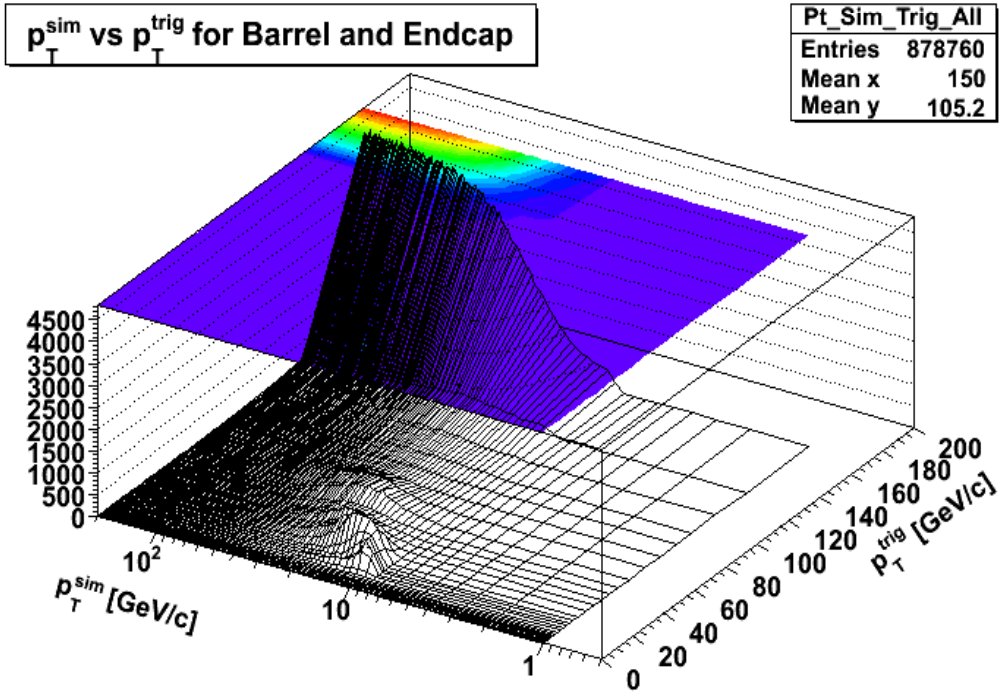
Robustness Remarks

- **RPC Trigger is designed to give a rough and over-estimated guess of the p_T.**
- **This feature is conserved, especially when one of the important stations for measuring the muon bending (RE1, RE2) are off, because the L1MuRegionalCand with highest Quality and highest p_T is transferred to GMT.**

p_T sim vs p_T trig according to TDR simulations (2000).

A lot of not so high p_T muons has high p_T assigned to keep the trigger efficiency for high p_T muons as high as possible.

More important will be the investigation of the probability to assign low p_T to low p_T muons.



5. GMT & Conclusions

Next step: GMT

- **Global Muon Trigger:**
  - Looks for “matchable” L1MuRegionalCands of DT/CSC and RPC
  - Transmits accepted candidates (matched or not matched) to the Global Trigger which performes the final L1 decision (according to L1 muon paths)

- **Next Step: Study GMT outcome with RPC candidates:**
- Need to add CSC calibration, digitization and L1 to produce CSC L1 candidates
- Study physical samples (W → μv, Minimum Bias, …)
- Study Noise Environments (hitrates due to neutron flux)
- For different detector configurations:
  - Current system (3 planes)
  - TDR System (4 planes)
  - RE2bis System (4 planes)

- **→ Real improvement in Muon Triggering by RPC Upgrade**

Conclusions

- **Simulation is ongoing:**
  - First results indicate that TDR approach will be adequate
  - Hopefully decision by beginning of next year
- **Funding & Responsabilities:**
  - Division of responsibilities between Europe and Asia is currently under discussion
  - Total cost of the project is in range 4 – 5 MCHF
  - Large part of the funds already ensured: Belgium, India, Pakistan, China, Korea
  - Involvement of CMS and Italy highly welcome
- **Ready to start:**
  - CMS RPC Collaboration is ready to start production in 2010
  - Milestone for completion could be 2013 - 2014
- **Infrastructure and integration issues to be discussed:**
  - Cooling in RE4
  - Integration with CSC

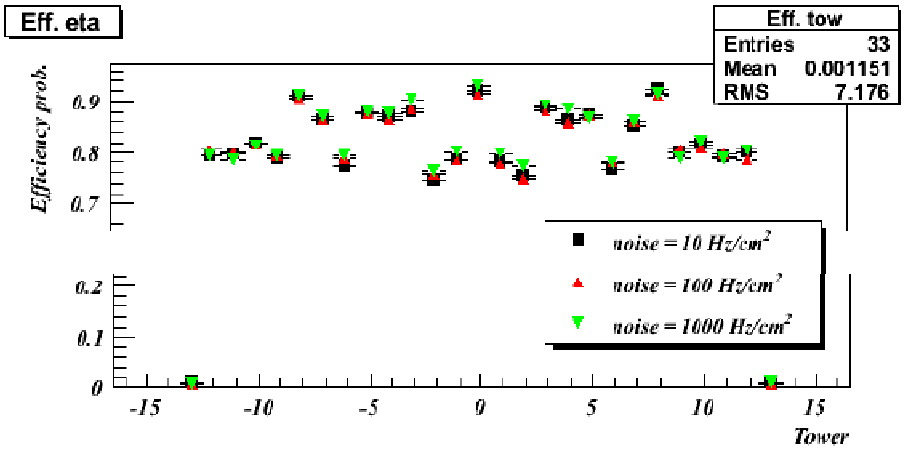
Questions?

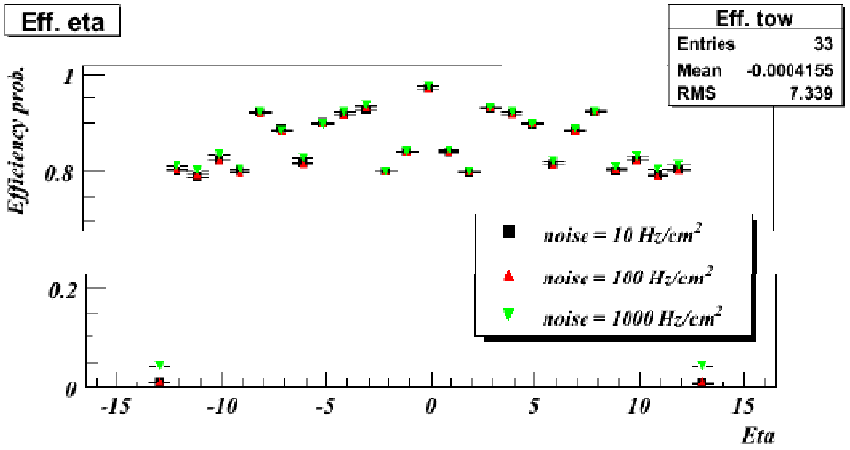
Back Up slides

What I didn't show …

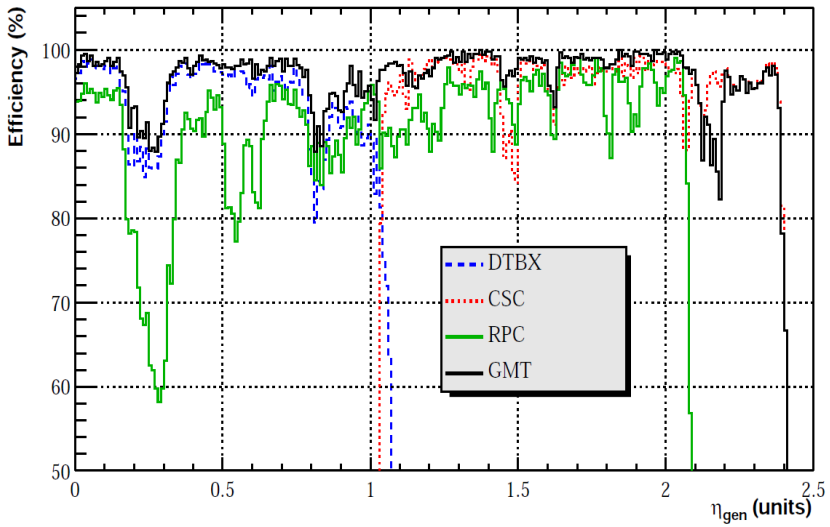
Reproduce Results

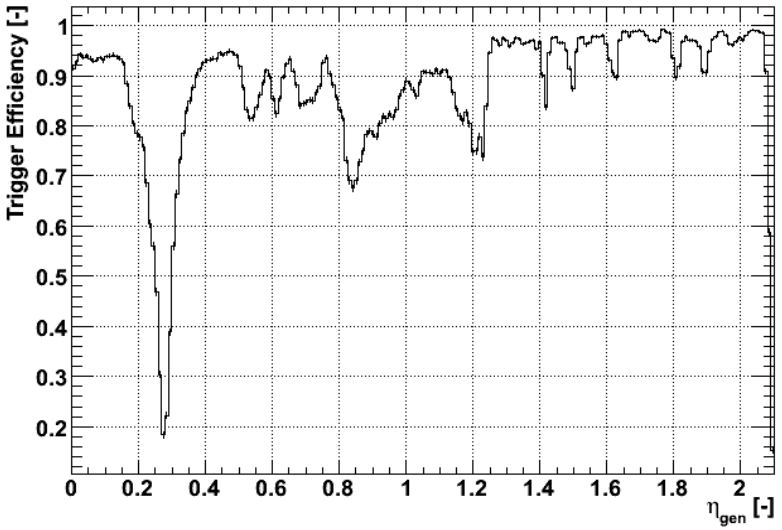
Trigger Simulation 2006 (left) and 2009 (right)



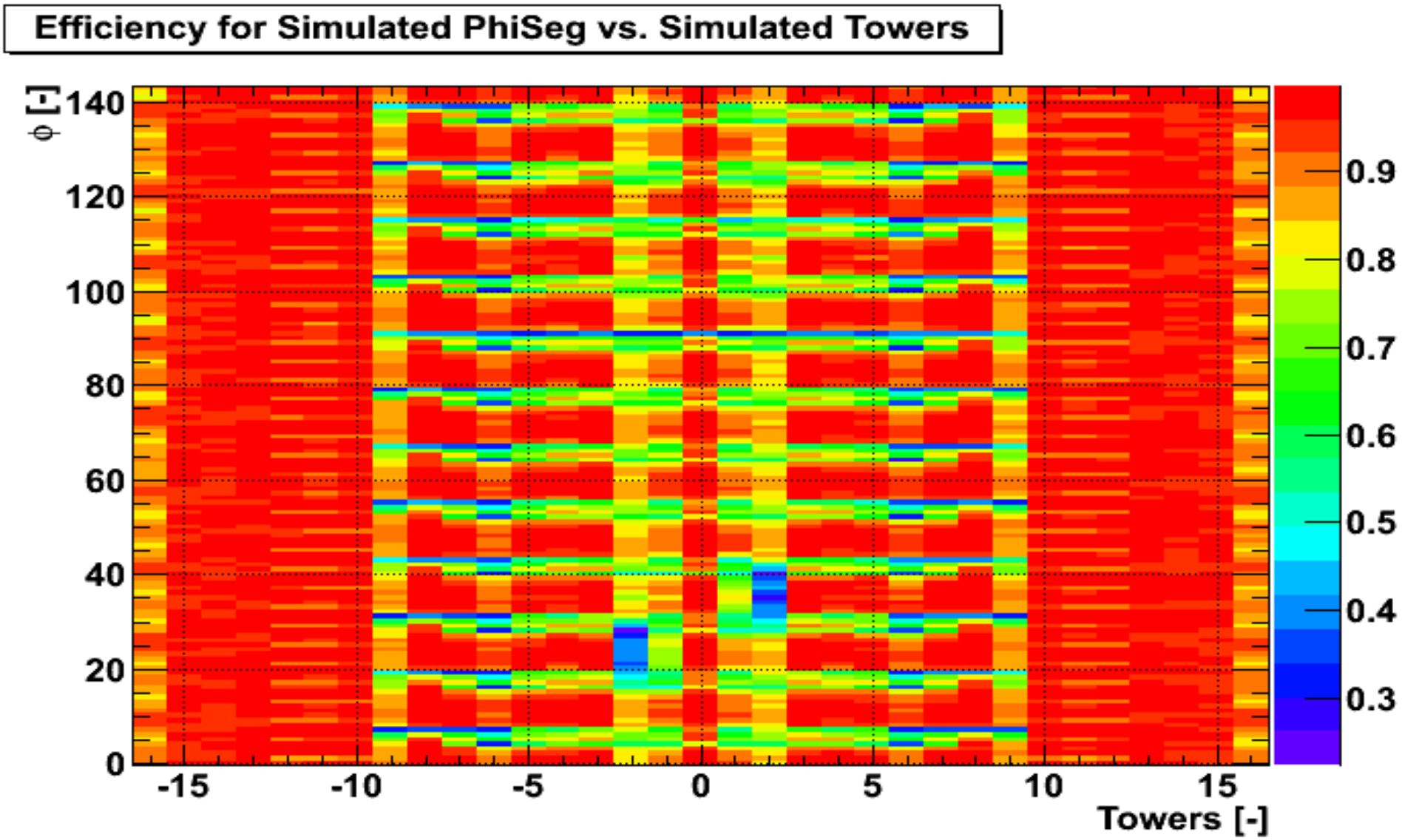


Trigger Simulation 2001 (left) and 2009 (right)





RPC Trigger Performance



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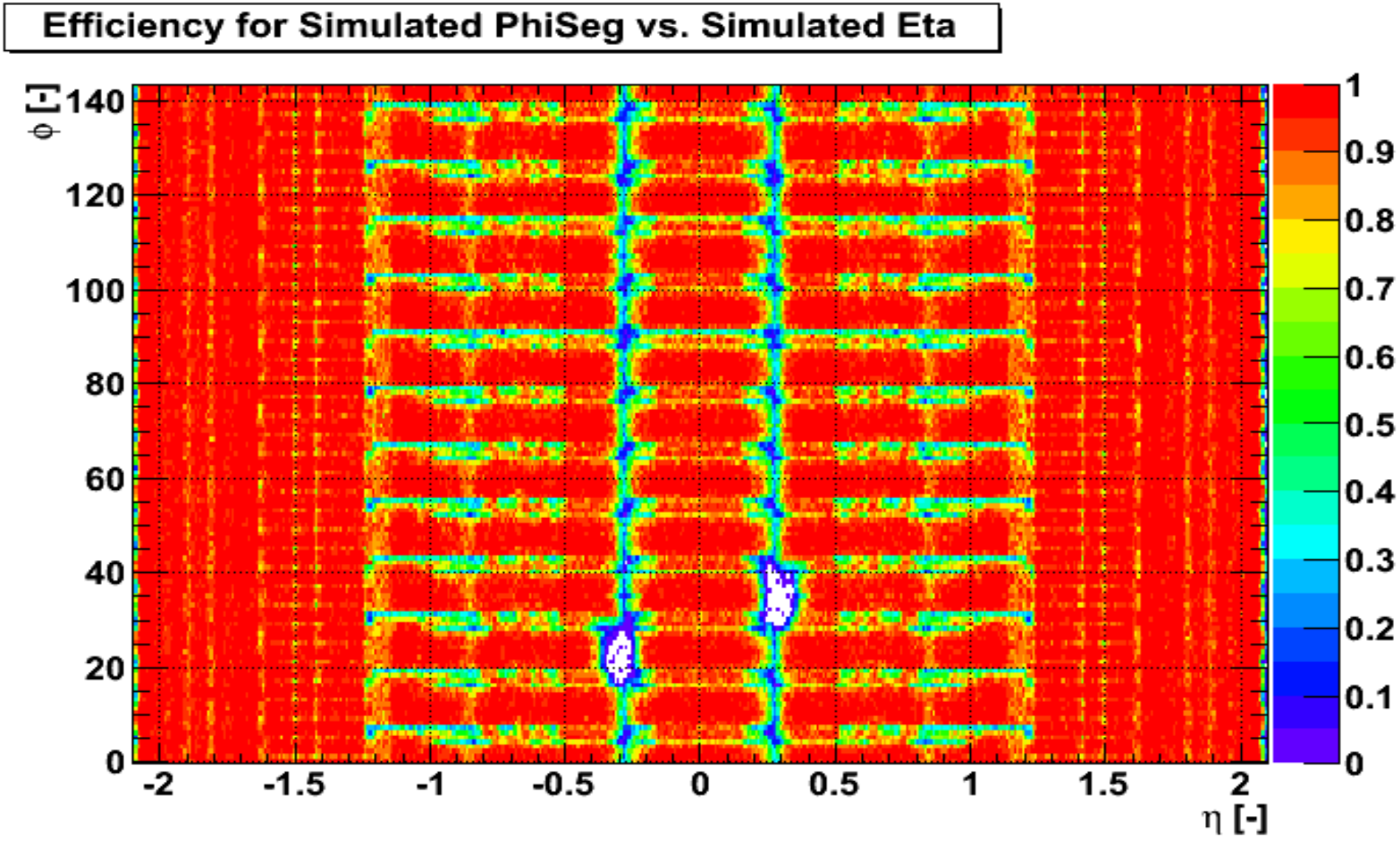
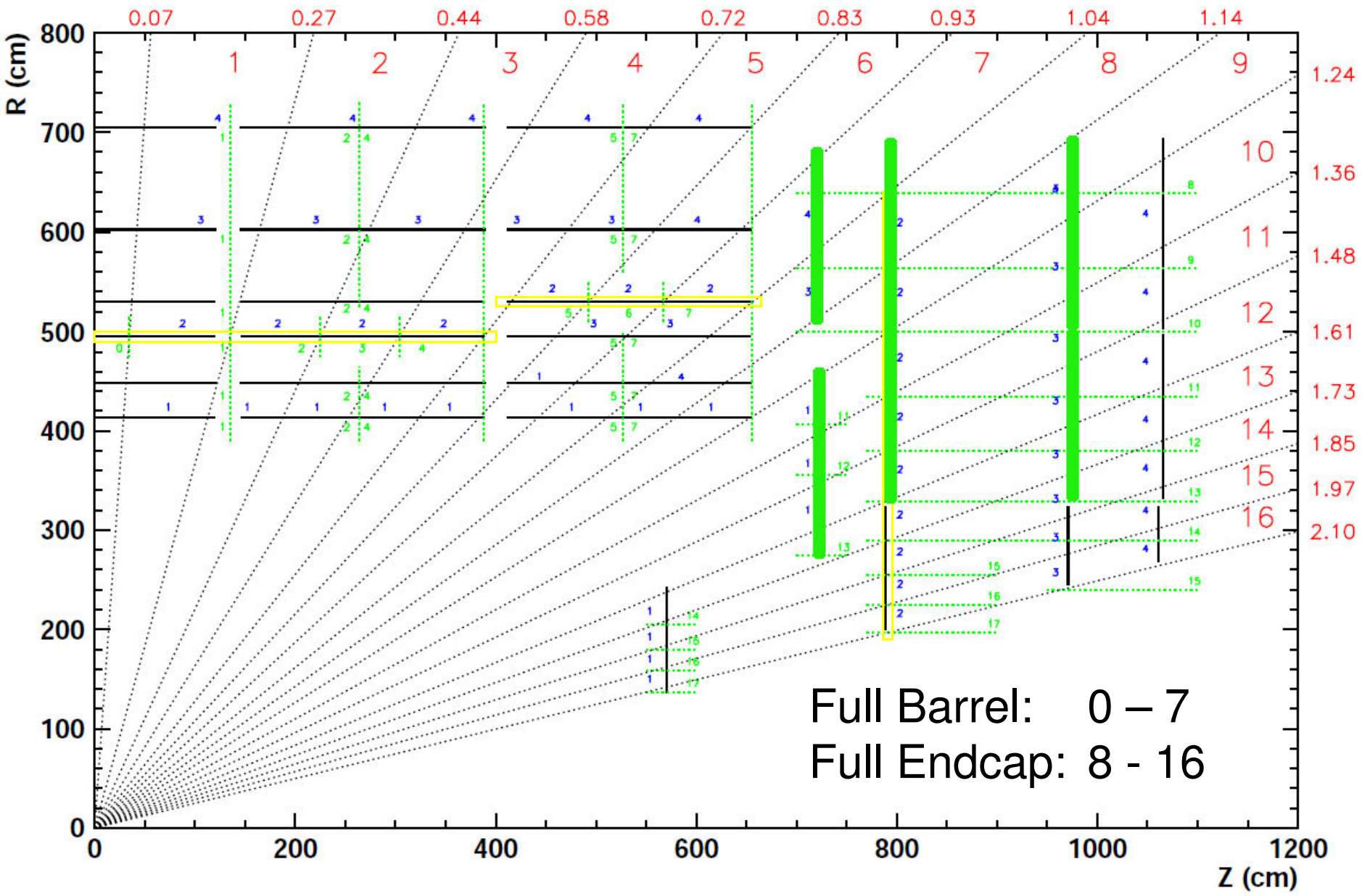


RPC Tower Geometry

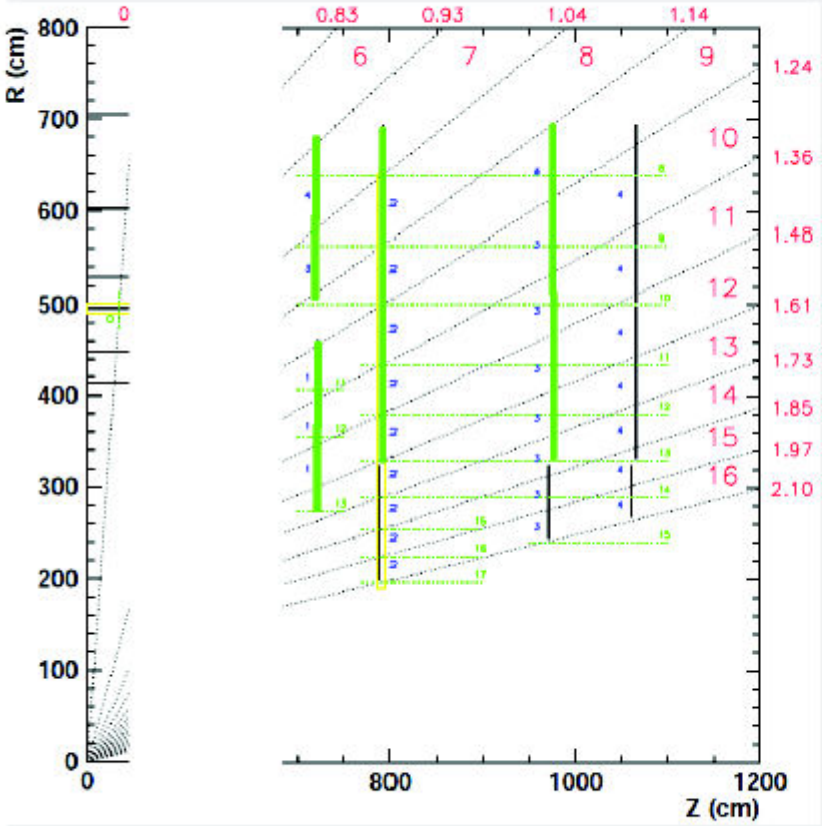


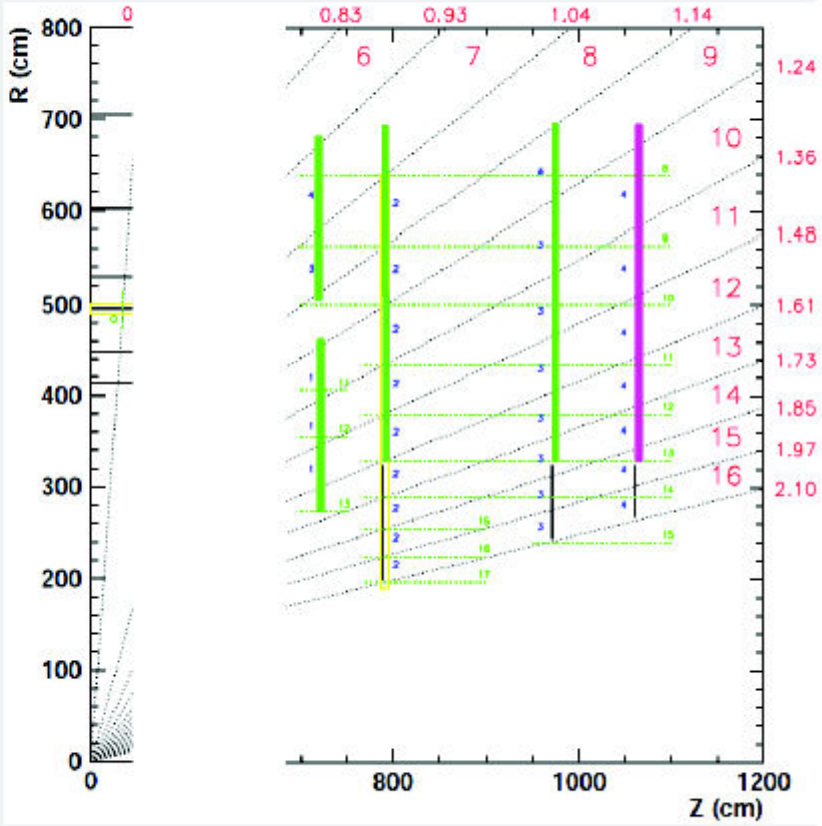
Trigger Simulation

- A “real” 5th plane was ruled out because too expensive (need additional services: HV, LV, gas, cooling, readout)
- Because of the 2nd station is the Trigger Reference Plane (hit strips are not copied to other Trigger Segments),
  - it might be useful to clean the fake hits in this station to reduce the fake rate.
- A “double” station was considered instead: RE2bis
- RE2bis was implemented as a logical “AND” of 2 RPCs
  - $\varepsilon = \varepsilon^2$ 90% → 81 %
  - Rate? Turned out to be negligible: 2 x 100 Hz cm^{-2} → 0.05 Hz cm^{-2}

Different HW Solutions

Current and TDR System for $\eta < 1.6$

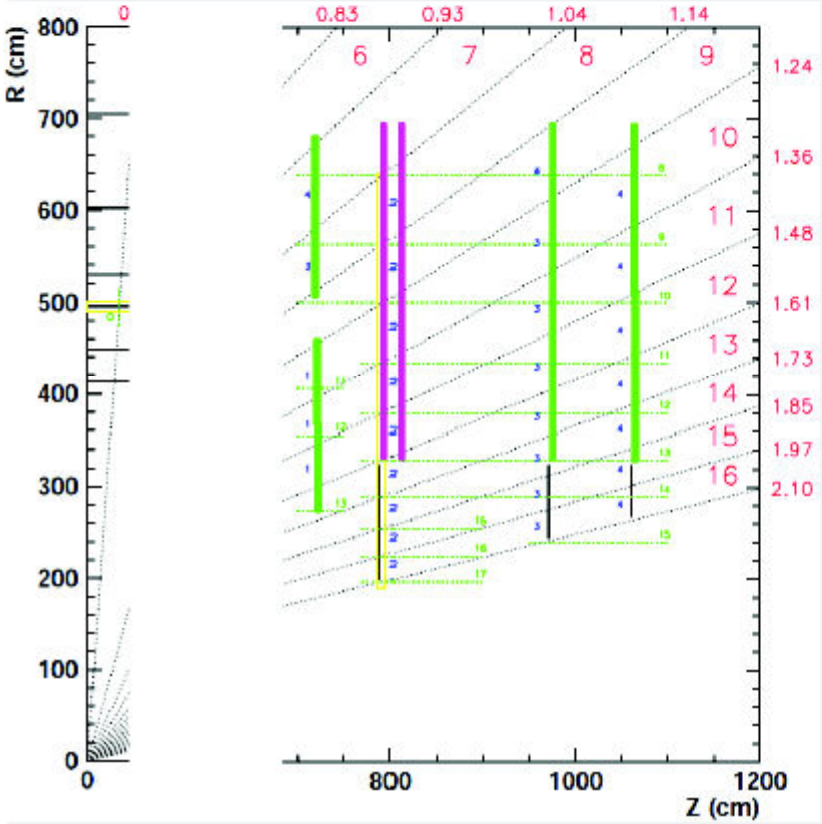


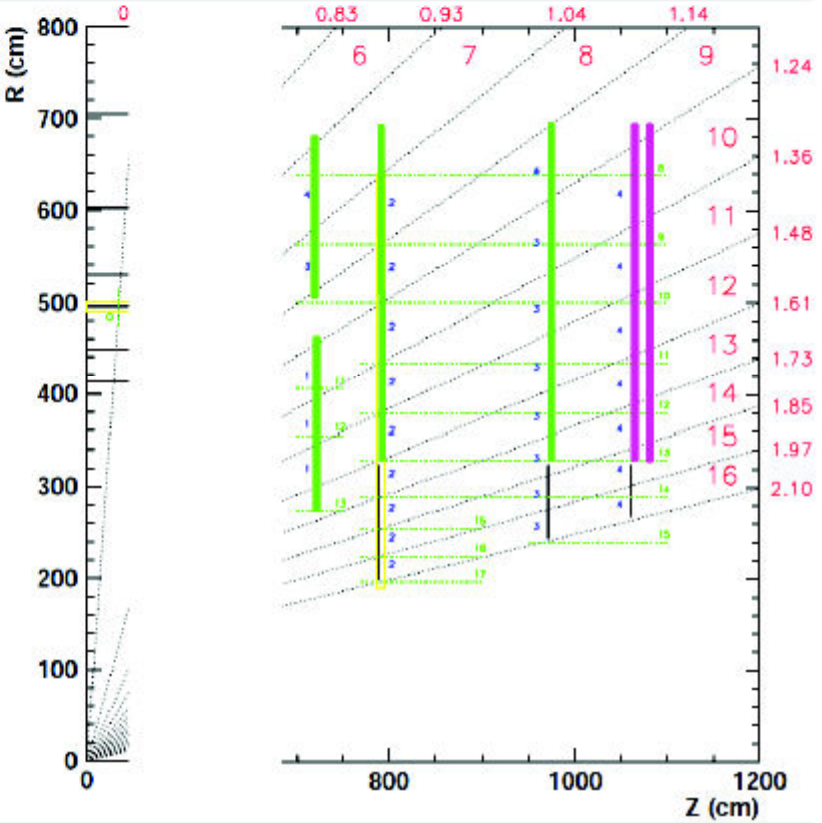


- Current Lay-out
- TDR Lay-out

Different HW Solutions

RE2bis and RE4bis System for $\eta < 1.6$





- RE2bis Lay-out
- RE4bis Lay-out