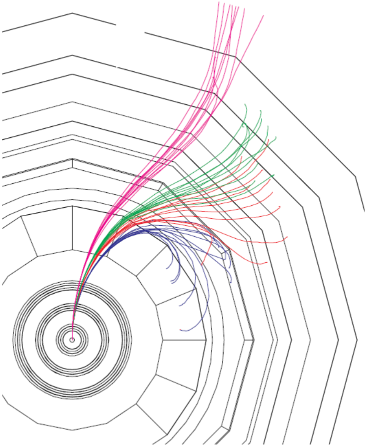


Muon Simulation and Cavern Background

Draft for LPCC Detection Simulation Workshop March 18-19, 2014

Piet Verwilligen

INFN Sezione di Bari

Simulation Meeting
2014-03-14

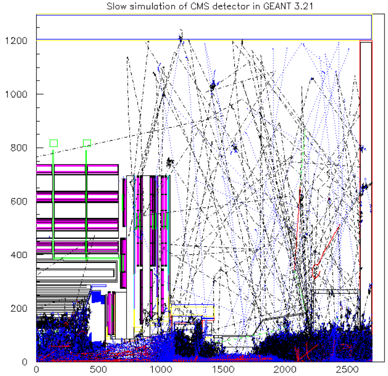
Disclaimers

- I give this presentation not on behalf of the CMS Muon Community.
- This presentation is about the machinery for the simulation of Neutron background in the Muon System and will show it works.
- Simulation results here are only for **illustration**, are not approved by the Muon Community and hence can not be used as CMS result.
- We will start investigating those results soon and interpret them in the context of background rates, compare to data, ...
- This is just the start of the work ...

Introduction :: **Neutron Background**

Illustration

One minimum bias event generated with Pythia 6 and simulated in one quadrant of CMS by GEANT 3.21 in CMSIM. Products tracked to 1 sec after collision. [Tim Cox, UC Davis, 1998]]



The colour and line style corresponds to the track type :

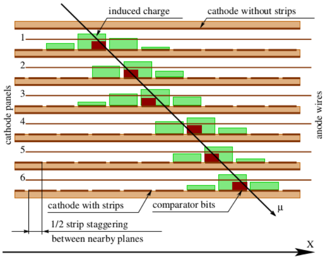
(blue)	dotted line for gammas	....
(red)	solid line for charged particles (except muons)	———
(black)	blank/dotted line for neutral hadrons or neutrinos	. . . . . .
(green)	dashed line for muons	- - - - - -
(yellow)	dotted line for Čerenkov photons	....

Physics Processes

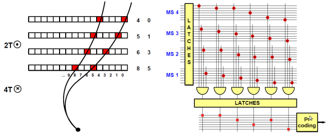
- *pp*-collisions induce hadronic cascades in HCAL, Absorbers
- End product are long-living neutrons of $\mathcal{O}(100\,\text{MeV})$ which are then moderated to $\mathcal{O}(\text{ MeV})$
- ${}^{1}_{0}n$ propagate through steel
- **CMS embedded in a ${}^{1}_{0}n$ gas**
- neutrons are captured in nuclei, emitting a γ of $\mathcal{O}(0.5\text{-}10\,\text{MeV})$
- γ produces $e^{\pm}$ of $\mathcal{O}(\text{ MeV})$ through Compton scattering or Photo-electric effect
- hits in muon chambers due to elastic (n,p) collisions (in gas) or from $\gamma \rightarrow e^{\pm}$ (inside & close to muon chamber) (dominant process)

Introduction :: Impact on Muon Detectors

Cathode Strip Chamber



Pattern Recognition



Impact on Muon Detectors

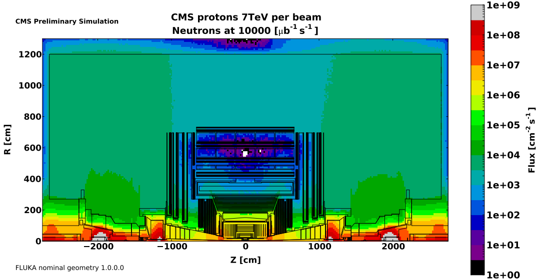
- Precision Chambers (DT,CSC)
  - multiple gas layers (6-12)
  - reconstruct 3D track stubs
  - $e^{\pm}$ do not penetrate all layers
  - bckgnd hits cannot make track stub
  - bkgnd hits can disturb measurement
- Timing Chambers (RPC)
  - double gas, single readout layer
  - reconstruct 2D hits
  - all charged particles make hits
  - hits disturb p_T measurement in Pattern Recognition (PAC)

Implementation in Simulation

- CSC, DT :: no background hits
- RPC :: bkg hits + intrinsic noise

Introduction :: **Simulation Tools**

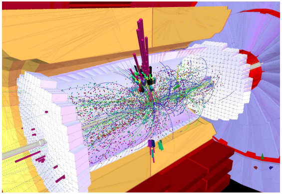
FLUKA — current simulation tool



- Calculation Particle Transport & Interactions w/ matter
- Calculation of Flux & Fluence
  - Beam & *pp*-collisions background
  - Test shielding designs
  - Radiation levels
- Does not provide hit rates
- Hit rates = Sensitivity × Flux
- Sensitivity averaged over Energy spectrum particle
- Sensitivity for each detector

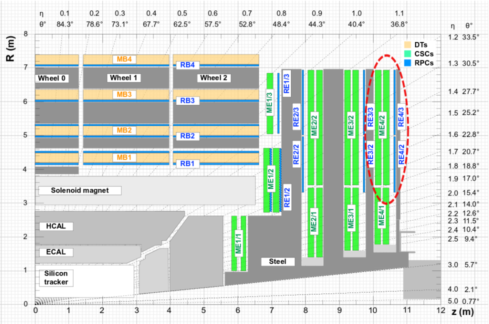
GEANT4 — possible future simulation tool?

- Passage of partices through matter
- Simulation of the detector response of gen. events
- So far used for **Signal** and **Min Bias** (PU) events
- E_{dep} in sensitive volumes (simhits)
- Simhits digitized → electronic signals
- Can be used to predict **Hit Rates**
- Mix **Signal** + **Neutron Background** + **Pile Up**



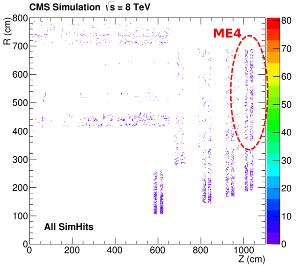
Introduction :: Muon Upgrade

Muon Upgrade during LS1

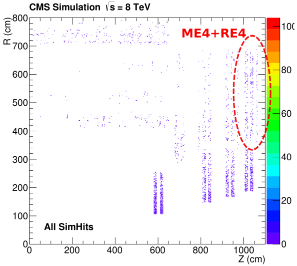


- New CSCs: 67 ME4/2 (5 installed in 2012)
- New RPCs: 72 RE4/2 and 72 RE4/3
- New Yoke: YE4 (Borated Concrete)

pre-LS1 (2012 — Run-I)



post-LS1 (2015 — Run-II)



- Pre-LS1 high rates in ME4/2, lower in Post-LS1 (YE4 Shielding)

Results :: E_{kin} vs tof :: XS & 2015

GEANT Simulation

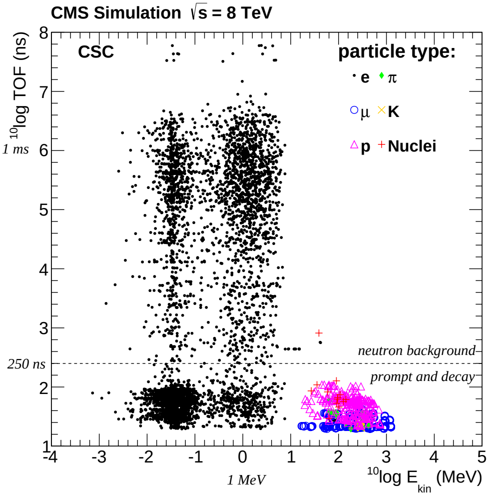
- CMS 2015 Detector Geom
- GEANT 4.9.6
- XS & HP Physics List:
  FTFP_BERT_XS_EML
  FTFP_BERT_HP_EML
- 2500 Minimum Bias Events
  up to 100 ms (>< 500 ns)
- **Time Of Flight vs E_{kin}**

- Limit of 250 ns chosen arbitrarily
- tof $>$ 250 ns neutron hits
- tof $<$ 250 ns prompt & decay

Particle Range (CSC)

```
ProdCutsForGamma = 25.*mm
ProdCutsForElectrons = 1.*mm
ProdCutsForPositrons = 2.5*m
```

E_{kin} vs tof in CSC

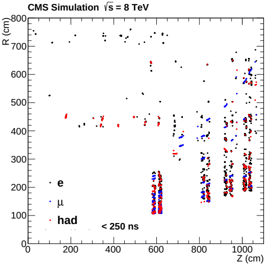


Similar plots available for DT & RPC

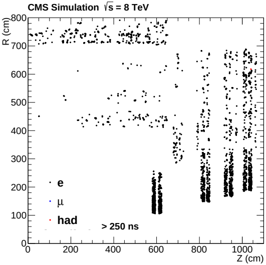
Results :: RZ & E_{dep} vs tof :: XS & 2015

RZ-view

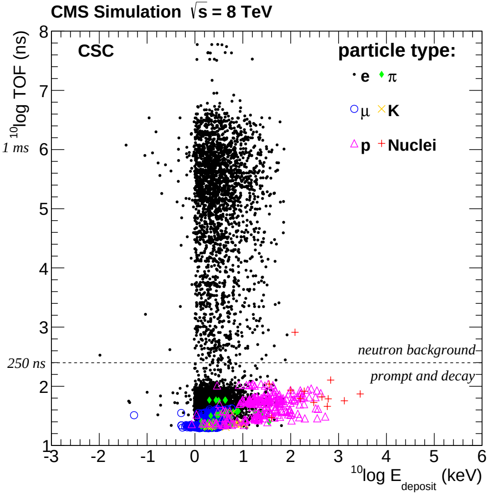
tof < 250 ns



tof > 250 ns

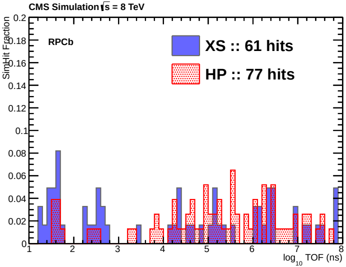


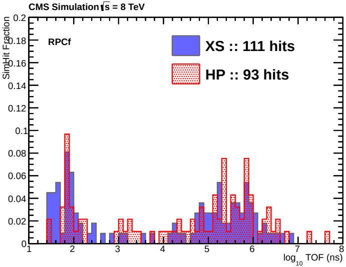
E_{dep} vs tof in CSC

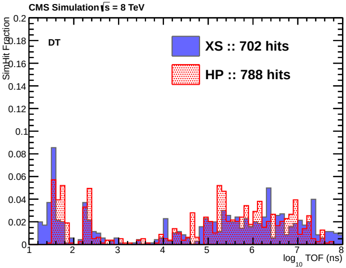


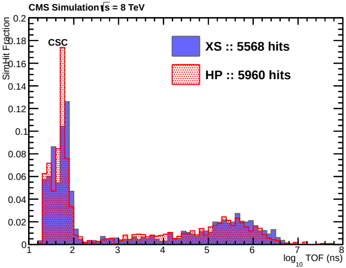
Similar plots available for DT & RPC

Results :: XS vs HP physics list :: 2015



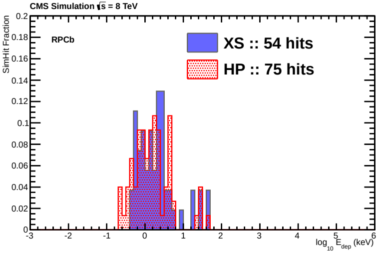


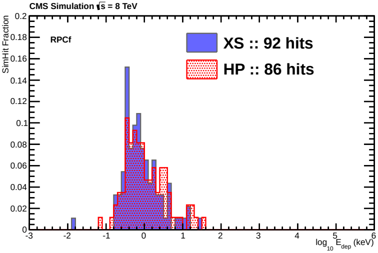


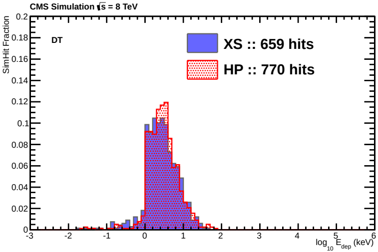


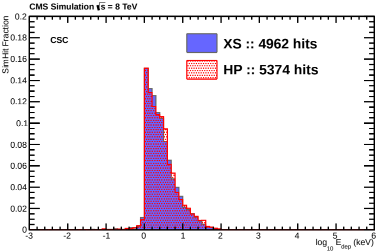
Time of flight of all simhits

Results :: XS vs HP physics list :: 2015





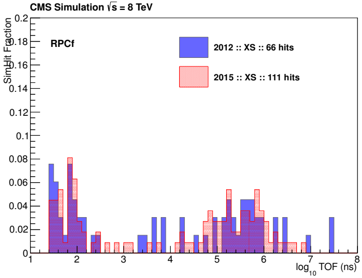


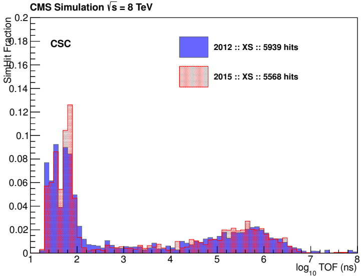


Energy deposit of Electron simhits

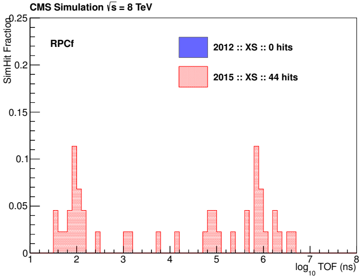
Results :: CMS Geometry for 2012 vs 2015 :: Endcaps

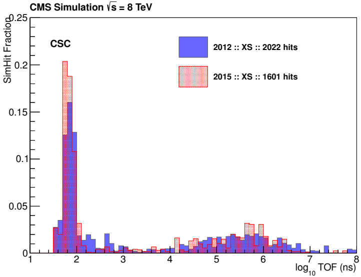
all stations



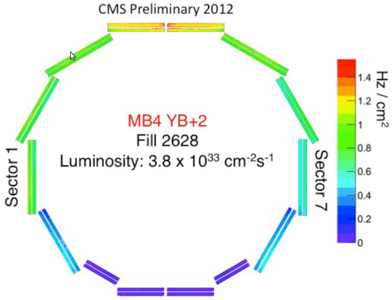


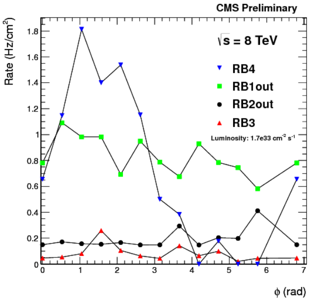
4^{th} station





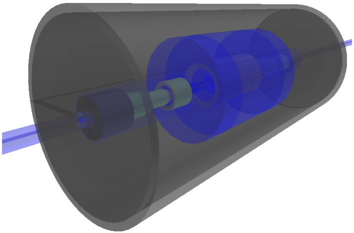
Challenges :: Geometry

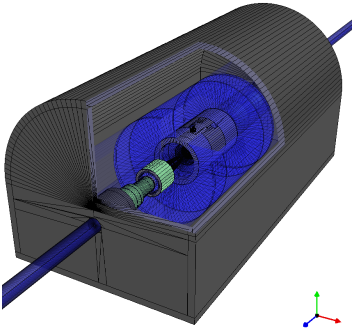




- for CSC and DT the inclusion of neutron hits is straight forward but
  - DT simulation will also benefit from introduction of dead channels (not implemented now)
  - DT are slow . . . signal integration over 16BX (current sim is $\pm$3BX)
- DT, RPC and CSC observe φ-asymmetry due to cavern floor:
  - tests of new geometry ongoing
- RPC Digitization is parametrized:
  - only muon hits are digitized
  - close-by electron hits (δ) are inside **Clustersize** parametrization
  - background electron hits are included in **Noise** parametrization
  - need to be desentangled
- RPC consist of single layer of Bakelite-Gas-Bakelite sandwich:
  - 50 % of gas volume implemented
  - need to be improved in order to have same infrastructure for DT,CSC & RPC

Challenges :: Geometry





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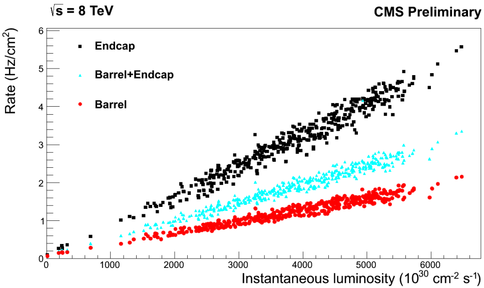
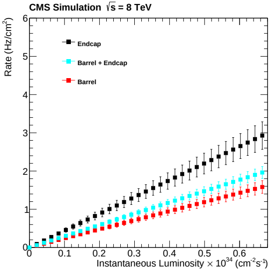
Challenges :: Comparison w.r.t Data

8 TeV Data



- **Hit rate based on digis**
- Results for Barrel and Endcap stations are available at:
- `https://twiki.cern.ch/twiki/bin/view/CMSPublic/RPCPlots`

8 TeV Simulation



- **Hit rate based on simhits**
- Preliminary work — First look
- Improvements: Cls, ProdCuts

At instantaneous luminosity of $\mathcal{L} = 0.6 \times 10^{34}\,\mathrm{cm}^{-2}\mathrm{s}^{-1}$:

- Barrel: 1.4 Hz/cm^2 in Simulation vs 1.8 Hz/cm^2 in Data
- Endcap: 2.6 Hz/cm^2 in Simulation vs 4.8 Hz/cm^2 in Data
- Total: 1.8 Hz/cm^2 in Simulation vs 3.0 Hz/cm^2 in Data

Conclusions & Outlook

- **Neutron background** will be important background at the LHC at higher Energies and higher Instantaneous Luminosities
- **GEANT4** Simulation of neutrons has improved over the years and can be reliable to predict neutron background events in CMS
- First steps towards **unified** integration of **Neutron background** in the 3 muon systems of CMS: DT, CSC & RPC are made:
  - Understand background components
  - Comparison XS physics list with HP physics list
  - Comparison with Data ongoing, discussion in Muon Community about to start
- Will **drive more development** in implementation of the simulation:
  - Double-Gap geometry for RPC detectors
  - Investigate Energy cut-offs
  - Implement realistic Cavern
  - Improve Digitization model
- Understand & predict current backgrounds pave the way for HL-LHC

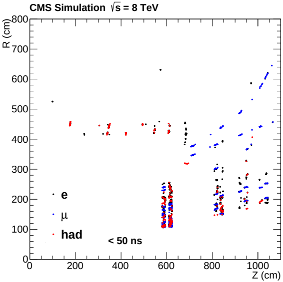
Thanks

I would like to thank:

- **CMS Simulation group:**
  - for support and help with generation of the events: Vladimir Ivantchenco
  - for useful discussions: Vladimir Ivantchenco, David Lange, Mike Hildreth
- **CMS Muon DPG conveners:**
  - Tim Cox, Francesca Cavallo, Alberto Ocampo for useful discussions
- **People working on Neutron backgrounds in CMS in the past:**
  - Tim Cox, Rick Wilkinson, Vadim Khotilovich, Alexei Safanov, . . .
  - **they paved the way and did great progress and without them this was not possible**

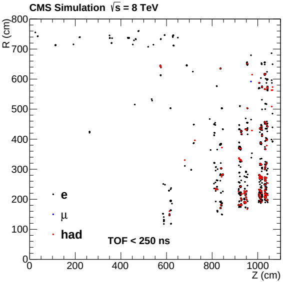
Back up :: RZ-view simhit plots :: lots to learn

$0 < \textbf{tof} < 50\ \textbf{ns}$



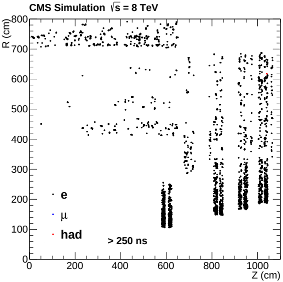
- Prompt Muons are visible
- Punch-through in MB1 and ME1/1, ME2/1
- $e^{\pm}$ not always related to muons or hadrons

$50 < \textbf{tof} < 250\ \textbf{ns}$



- $e^{\pm}$ hits in MB4
- $e^{\pm}$ hits in Endcap
- due to fast neutrons?
- Hadron hits in ME3/1, ME4/1 (HF backsplash)

$250\ \textbf{ns} < \textbf{tof}$



- Mostly $e^{\pm}$ hits
- Single hadron hit (but not enough?)
- $\frac{n \to p}{n \to \gamma \to e} \approx \mathcal{O}(10^3)$