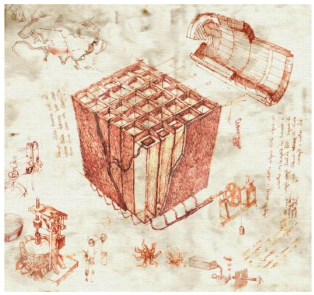
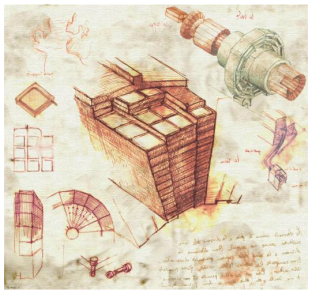
SLHC ECAL-HCAL Simulation Studies:
Technical needs and SM benchmark analyses





Chris Neu

University of Virginia

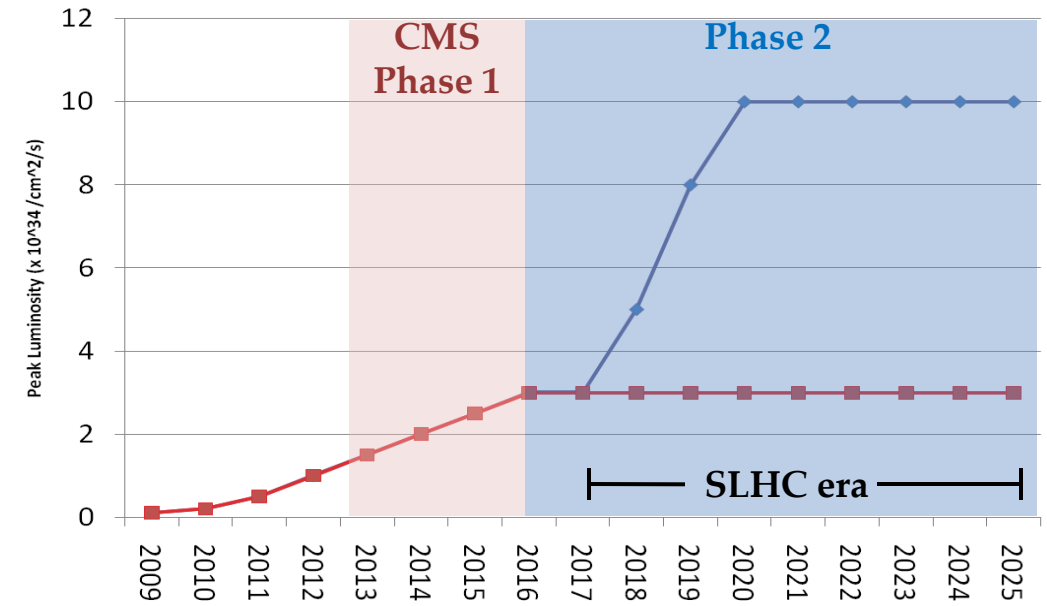
on behalf of the

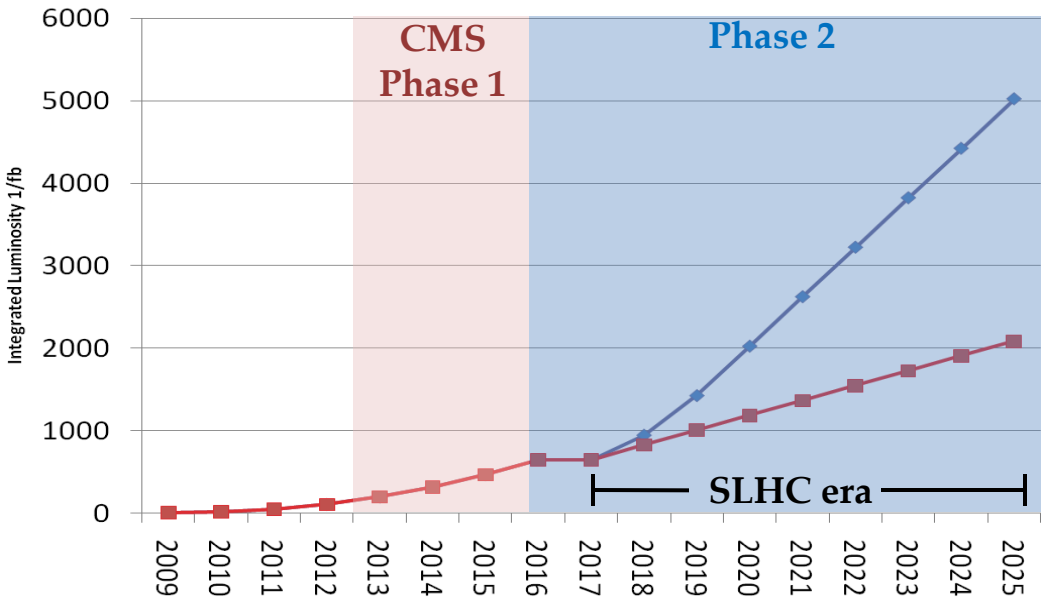
CMS SLHC Calorimetry Task Force

CMS Upgrade Workshop
29 October 2009

Motivation

- Phase 2 calorimetry upgrade
- Knowns:
  - Barrel is impossible to replace
  - Focus is the endcap region and beyond
  - HF has its own upgrade plan underway
- Unknowns:
  - **Machine parameters** not yet determined
  - **Endcap device** definition not yet determined
  - **Outcome of LHC era** not yet determined
- Despite this...
  - Canonical 6-year minimum lead time for upgrades
  - 2016 shutdown, upgrades online for 2017 running
  - Need decisions on endcap soon

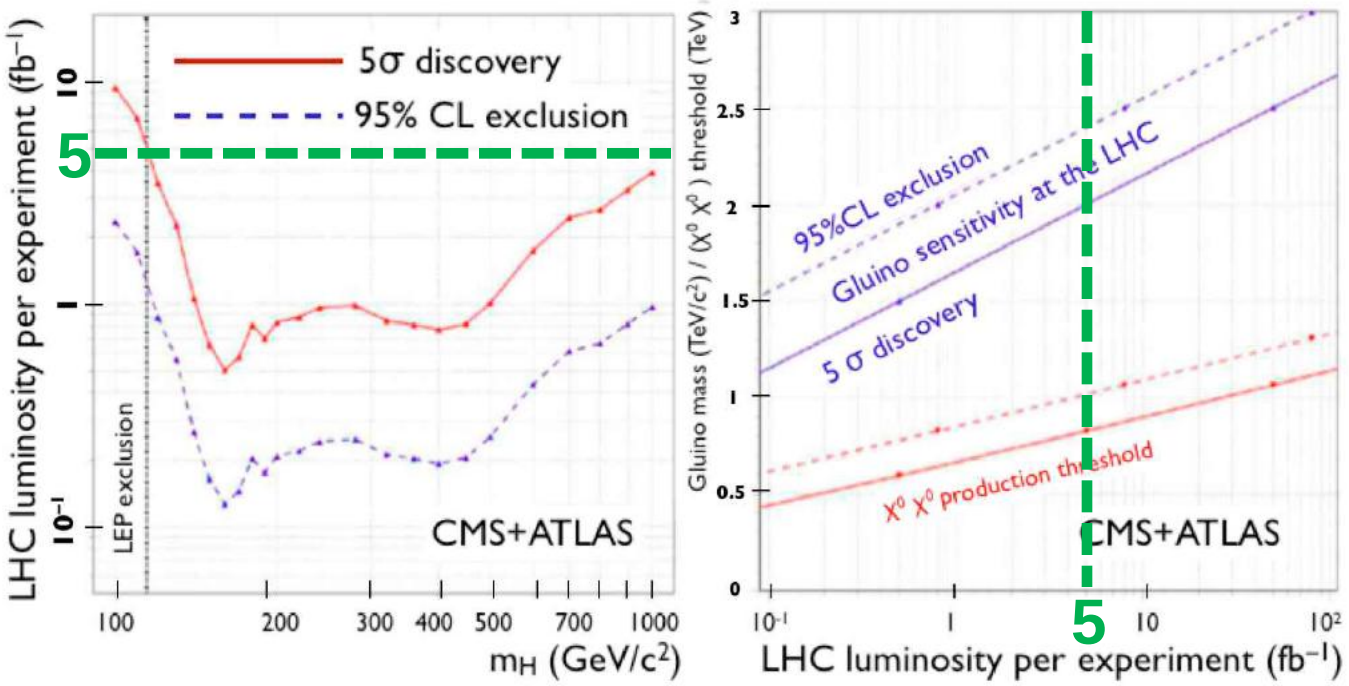




M. Nessi, 2008
http://indico.cern.ch/getFile.py/access?contribId=14&resId=1&materialId=slides&confId=38210

Making an Informed Decision

http://council-strategygroup.web.cern.ch/council-strategygroup/BB2/contributions/Blaising2.pdf



- Example of **two products of the 10^{34} LHC era**
  - L_{int} = 5/fb by, say, 2013
  - LHC will make a statement one way or another on SM Higgs and have sensitivity to gluino masses up to ~2.0-2.3 TeV
- **Would be ideal to know a priori** whether we produce limits or discoveries

Goals

- In the absence of prior knowledge to direct the endcap calorimetry upgrade design, **we can evaluate options in the context of a few physics topics** that could play an important role in SLHC era

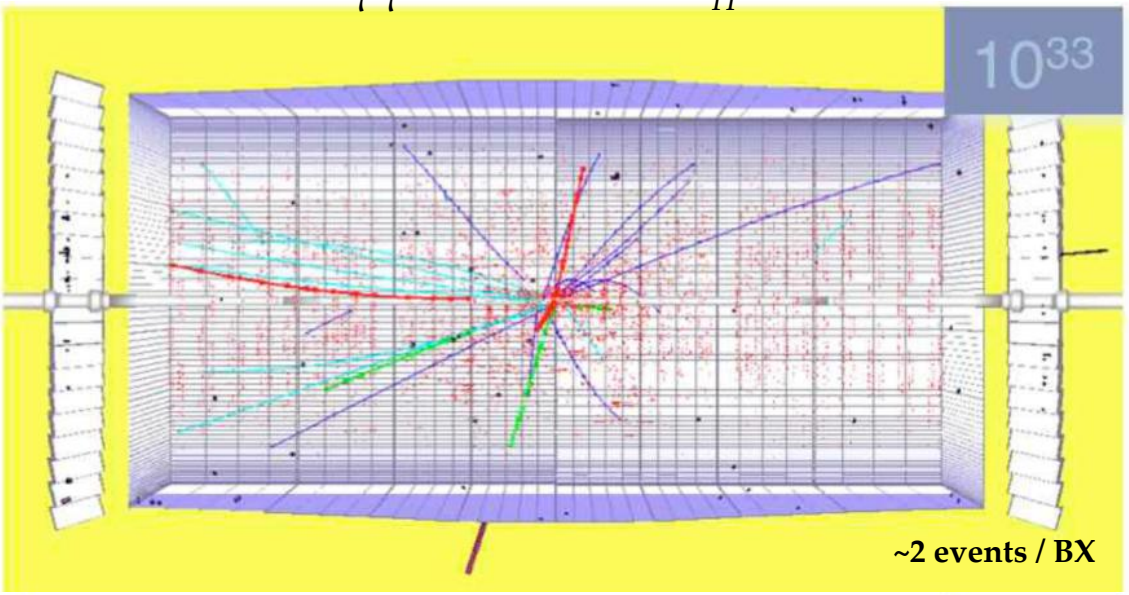
- **Goals here:**
  - present a list of physics topics to consider (SM and BSM)
  - present ideas on what simulation items are needed
  - generate discussion
  - solicit volunteers to take on tasks/topologies

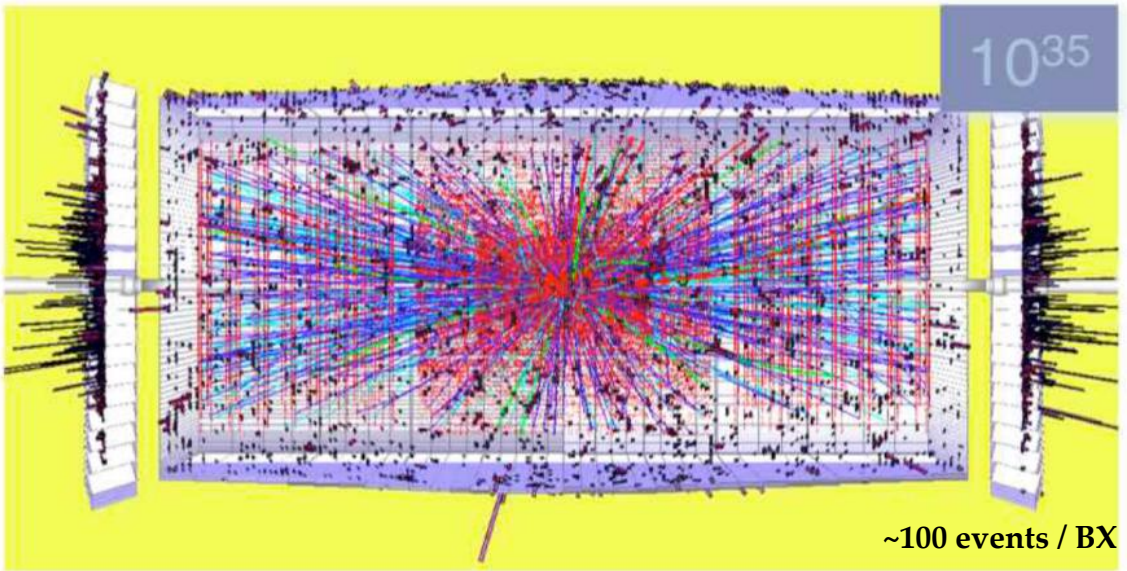
- Notes:
  - Seek to evaluate device options in the context of **realistic SLHC conditions**
    - Inclusion of pileup
    - Simulation of detector aging
  - Technical details:
    - Need to determine what level of simulated events is necessary. GEN-SIM-RECO?
    - What needs to be simulated? Be rigorous with calorimeter response only? Do a "lite" simulation of tracking?

Prerequisites: Pileup

- **Pileup is a major problem**
  - Determined by machine parameters – not yet sure how much there will be (see next slide)
  - Affects triggering, DAQ, object reconstruction, resolution, everything
  - In-time versus out-of-time interactions
  - Technically difficult to simulate
  - See following talks from Chuanzhe, Marat, Yuichi

$H \rightarrow ZZ \rightarrow \mu\mu ee$ event for $M_H = 300$ GeV

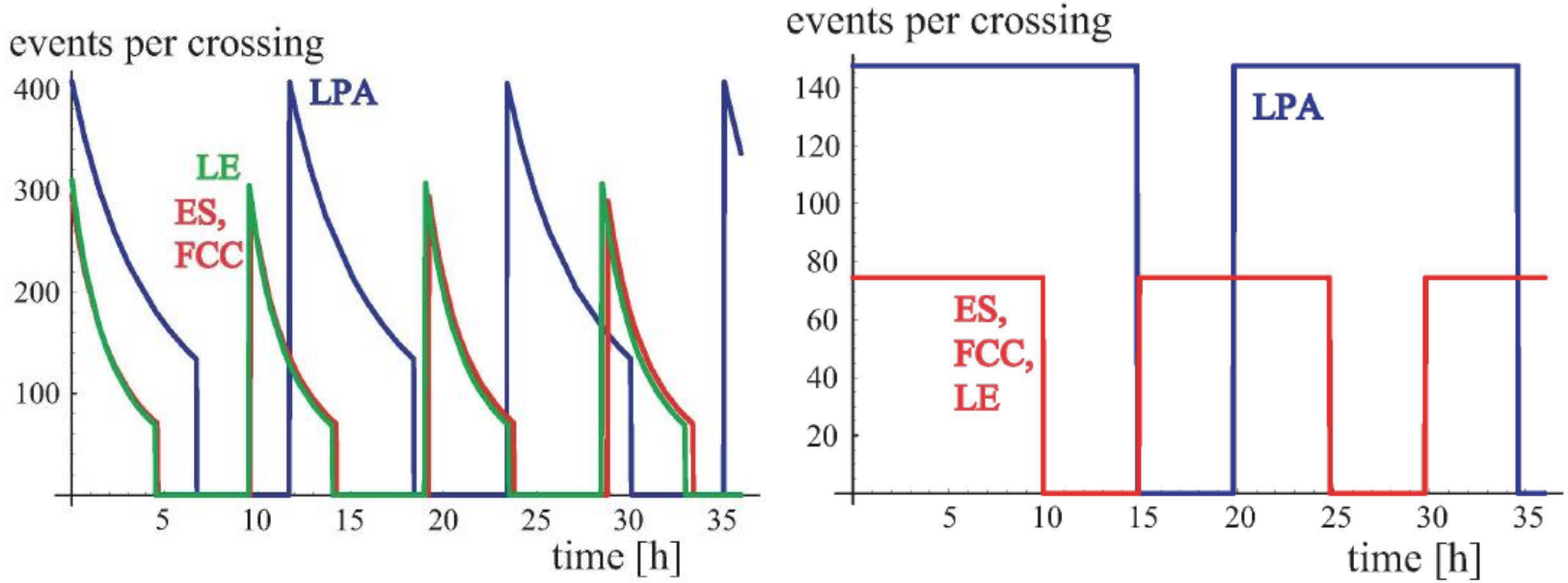




Displays from MLM's http://arxiv.org/PS_cache/arxiv/pdf/0910/0910.0030v1.pdf

Prerequisites: Pileup

Hypothetical 1.5-day cycle at the SLHC for different intxn region upgrade possibilities:



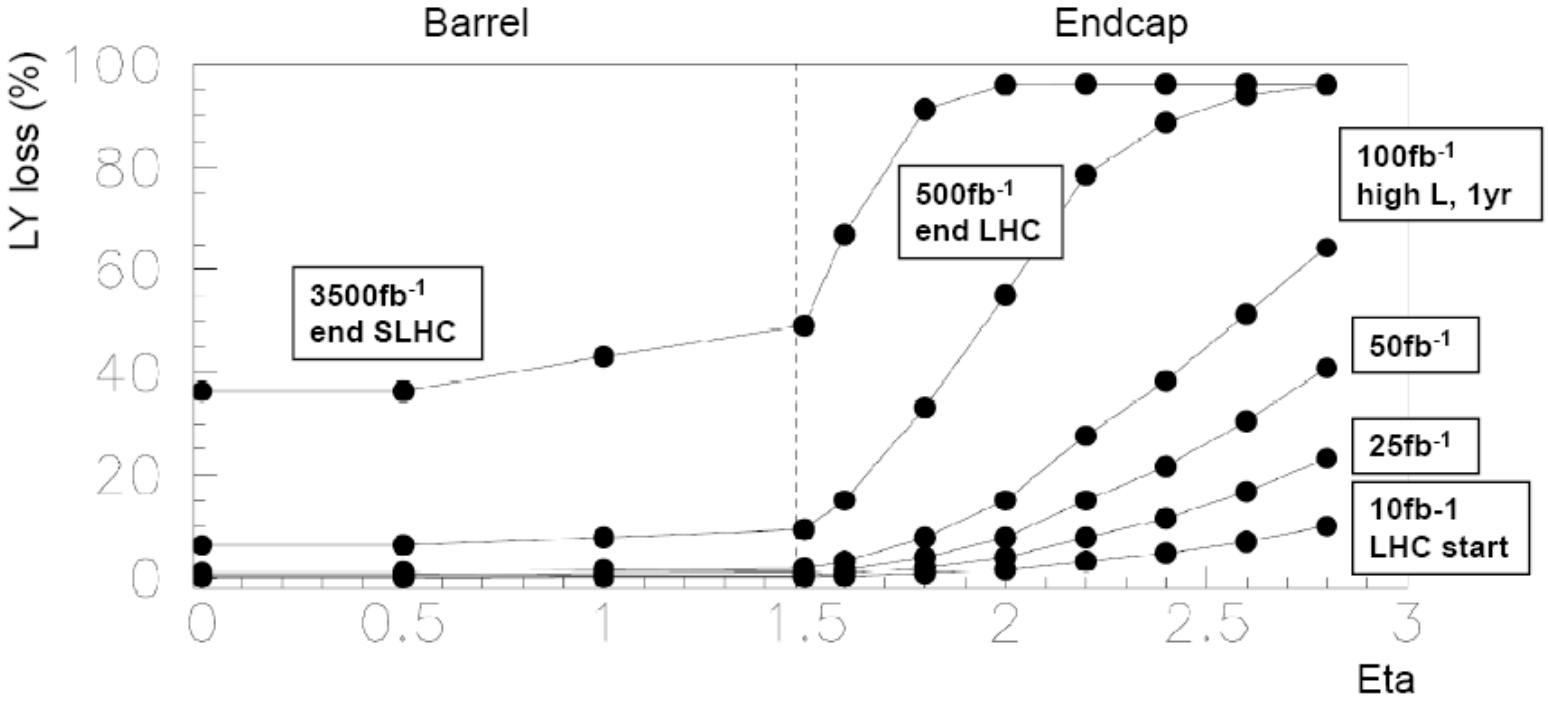
F. Zimmermann - http://indico.cern.ch/getFile.py/access?resId=0&materialId=slides&confId=55043

- Key:
  - LE: **low emittance**
  - ES: **early separation**
  - FCC: **full crab crossing**
  - LPA: **large Piwinski angle**
- Left: nominal running, right: **luminosity leveling**
- **Message:** Depending on IR upgrade choice, could have **a huge number of pileup** events per crossing (best case: O(~80), worst case: up to ~400 beg. of store)

Prerequisites: Aging

- As the SLHC detector operates, it will degrade over time from radiation damage
- It would be ideal to have a model of these effects for new devices

- Such a study was done for LHC era ECAL (D. Cockerill, et al.,)
  - Crystal light yield (LY) loss across ECAL as a function of L_{int}
  - Hadrons interacting with nuclei in the crystal – result is "stars" – areas of reduced transparency
  - Nothing in these studies on EM intxns, photodetector deterioration, irradiation of electronics

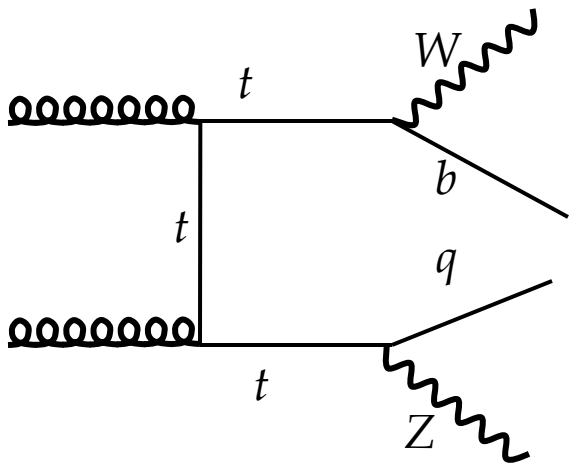


Benchmark Analyses

- Identify some benchmark analyses
  - Look at possibly important measurements/searches for SLHC era
  - Choose ones relevant to endcap calorimetry
  - I will introduce a few SM and Higgs ones, Greg will introduce a few BSM ones

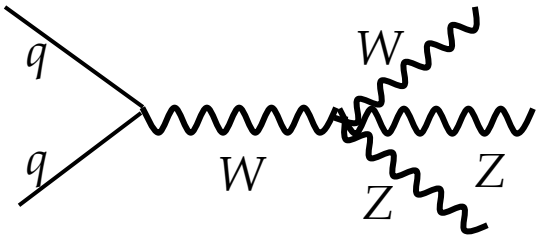
Benchmark Analyses

- Analysis 1: **Rare decays in ttbar production**
  - Reconstruction of top will be hard in the SLHC:
    - jet and MET resolution
    - lepton triggering
    - *b*-tagging
  - **Search for FCNC**
    - BR ($t \rightarrow Zq$) ~ O(10^{-14}) in SM; deviation would indicate NP
    - Current best limit is BR ($t \rightarrow Zq$) < 3.7% @ 95% CL; will be examined in LHC era
    - Large statistics sample of ttbar decays could push sensitivity to very low values
      - Even SLHC will not probe O(10^{-14})
      - Could reach 10^{-6} sensitivity where some NP models come into play
    - **Issues for endcap calorimetry:**
      - electron ID coverage (looking for rare process via $Z \rightarrow \ell\ell$) and resolution
      - jet ID and resolution (reconstruction of each top)



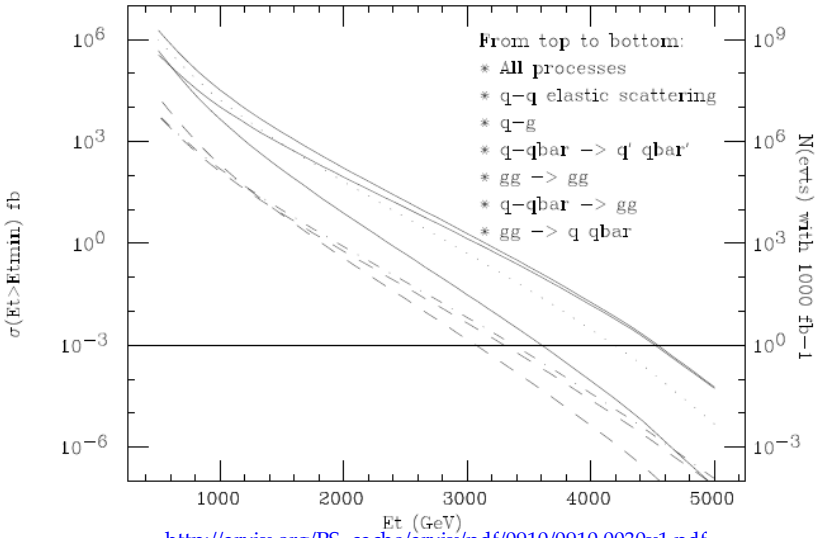
Benchmark Analyses

- Analysis 2: **Triple gauge boson production**
  - Diboson production easily within reach of LHC era program
  - Three and four boson processes required by SM but never before seen
    - Ex: **ZZW production**:



    - 5-lepton final state would be clean and spectacular
  - Important to probe **quartic gauge couplings** for first time
  - **Issues for endcap:** electron ID coverage, energy resolution

- Analysis 3: **Jet differential xsec v. pT**
  - SLHC era: handful of jets w/ $E_T > 4$ TeV
  - NP could manifest itself in high pT tail
  - **Issues for endcap:** jet energy resolution

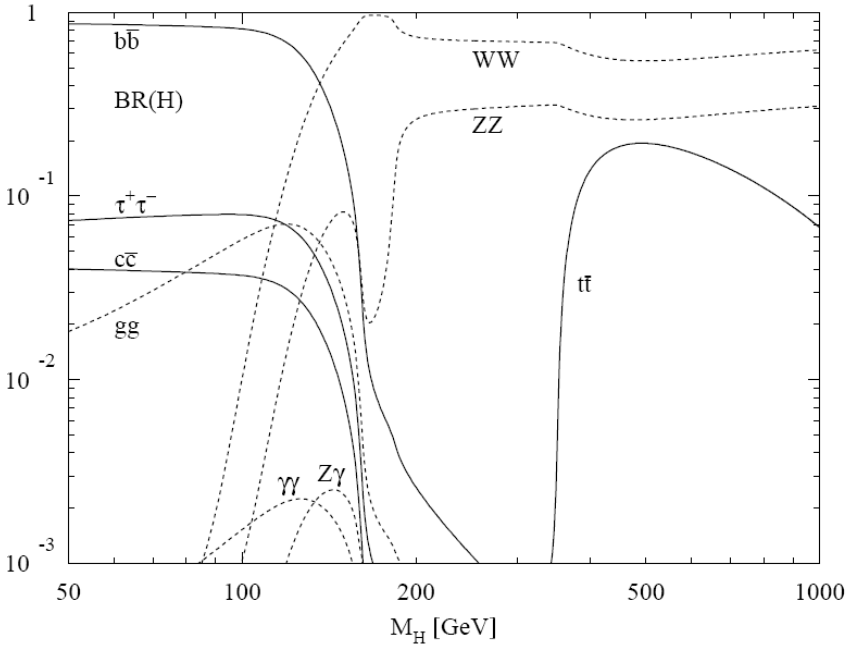


http://arxiv.org/PS_cache/arxiv/pdf/0910/0910.0030v1.pdf

Benchmark Analyses

- Analysis 3: **Observation of SM Higgs decay $H \rightarrow Z\gamma$**

- Higgs search is a vital component of LHC era program
- SLHC decisions for endcap calorimetry should keep impact on Higgs program in mind



- Assume then that we discover a SM-like Higgs with a mass around 120 GeV via $H \rightarrow \gamma\gamma$ during LHC era
  - What Higgs is it?
  - Need info on its couplings to fermions and bosons

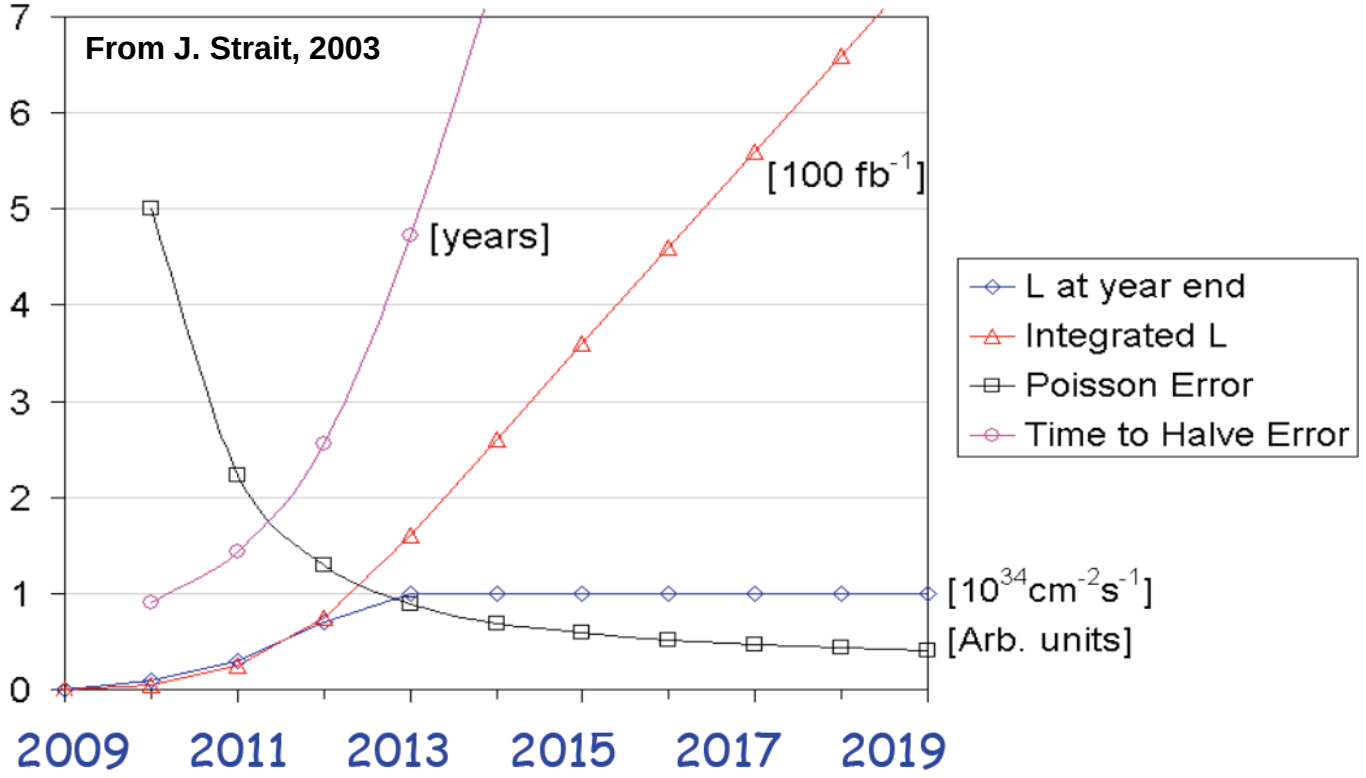
- Search for rare decay $H \rightarrow Z\gamma$:
  - Final state is $\ell\ell\gamma$
  - **Issues for endcap calorimetry**: electron and photon coverage (looking for rare process via $Z \rightarrow \ell\ell$ and additional photon)

Summary

- We need to soon make a decision on the endcap calorimetry device to be used at CMS in the SLHC era
- Important factors will be performance in high pileup environment and radiation damage over time
- It would be good to evaluate choices in the context of their impact on SM and BSM measurements/searches we seek to do in the SLHC era
- I have presented a few SM analyses to consider for benchmarking
  - Not an exhaustive list
  - Not a profound list
  - Other ideas are welcome, intended to generate discussion

Backup

Why Have an Upgrade?



- Conclusion: If $L_{inst} = 10^{34}$ /cm^{2}s is achieved by 2013, then within ~5 years the statistical error on Poisson processes is cut in half wrt 2013 level
- But after that, the "halving time" grows exponentially if nothing changes
  - So UPGRADE the machine!