View from experiments including special physics run

- Physics goals for 2012
  - p-p and Heavy Ions
- Views about p-p beam parameters
- Special runs
- Some comments about the schedule

Beware that discussions within detectors are still ongoing ⇒ final position by Chamonix

View from experiments including special physics run

- Physics goals for 2012
  - p-p and Heavy Ions
- Views about p-p beam parameters
- Special runs
- Some comments about the schedule

Beware that discussions are still going on within detectors ⇒ final position by Chamonix

A quick look at the past

Goals for 2011

Integrated Luminosity (pb^{-1})

Proton running

- Goal for 2011 was already set a year ago:
  1 fb^{-1} delivered to each of IP1, IP5 and IP8 at 3.5 TeV (or >3.5TeV)
- Can probably do better for IP1 and IP5
  - **You** can make the SM Higgs visible or … history

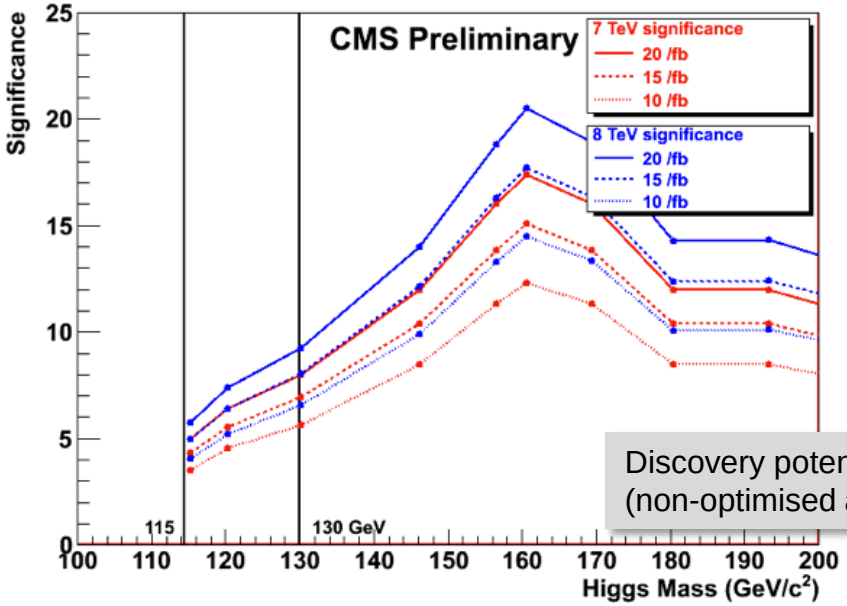
Gimme five … fb^{-1} ?

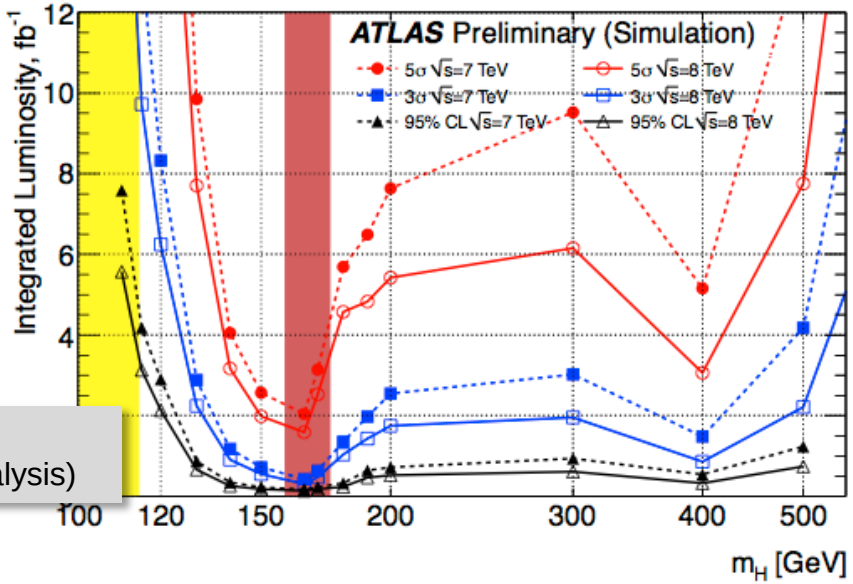
- But it will actually be a challenge to deliver 1fb^{-1} to IP8
  - consider maximum luminosity and pile-up tolerable to LHCb
    - ✂Already a big effort from LHCb side to "help" reaching the target:
      L_{max} : from 2e32 to 3e32 and μ_{max} : from 0.5 to 2.5
  - One fb^{-1} will be just reachable if we make proper choices
    - ✂with lumi leveling (no decay): 3e32 * 110 days * 0.35 = 1 fb^{-1}

fraction in stable beams

Target luminosity for p-p runs

- Minimal result for 2012:
  either evidence of Higgs or exclusion at 95% CL down to 115 GeV
  - If evidence, study properties, look for SUSY partners
- 5 σ discovery down to 115 GeV at √s=8TeV requires > 15 fb^{-1}
  - Difficult to tell precisely as we are at the edge of experimental sensitivity



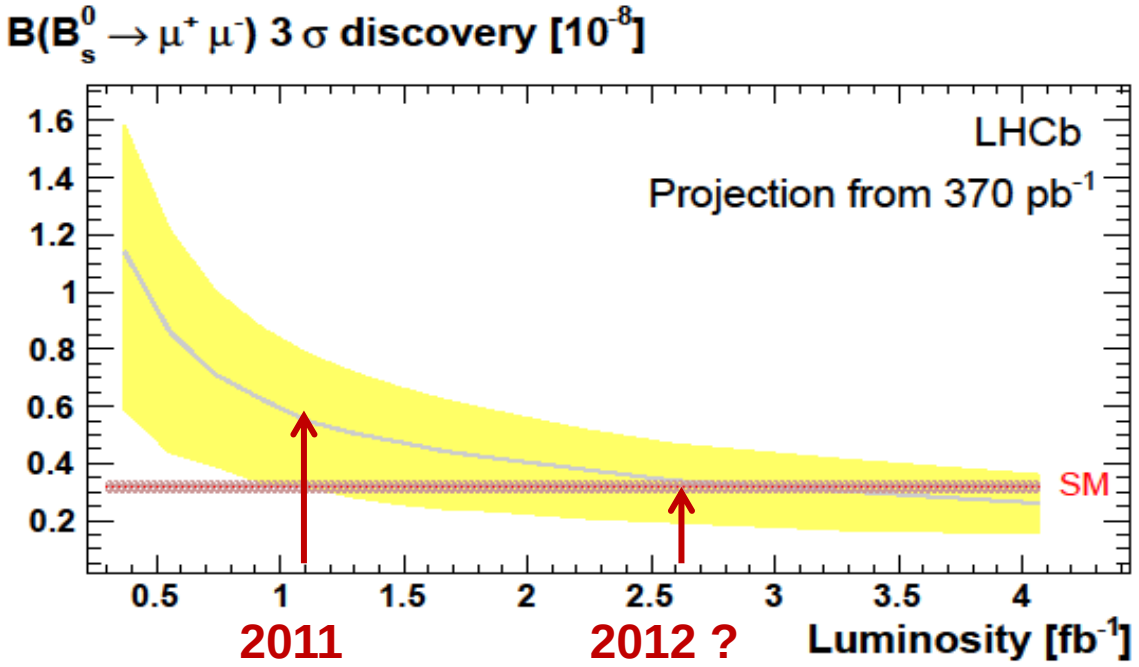


Discovery potential
(non-optimised analysis)

- Ideally the target for p-p operation in 2012 should be **~20 fb^{-1}**
  - Remember that it's the last data taking until at least late 2014

Complete p-p physics program

- The Higgs discovery is just the tip of the iceberg
  - Essential physics program beyond that
- SUSY
  - SUSY is not dead and the most important search regions are accessible with 2 to 4 times greater sensitivity at 8 TeV versus 7 TeV.
- Flavor physics
  - $B_S \rightarrow \mu^+\mu^-$: strongly suppressed in S.M. (BR=3e-9)
  - CP violation
  - **~1.5 fb^{-1}** is the clear target for LHCb
- Exotics (e.g. W', Z')
- Forward physics
  - Elastic interactions at small t
  - Diffractive scattering



Guidelines for p-p program optimization

- Clearly the goal is to **maximize integrated luminosity useful for physics**
- Trivial statement with non-trivial implications:
  - Peak luminosity is not the final goal and should not be maximized at the cost of smaller integrated luminosity
    - Any theoretical improvement in peak luminosity should be weighted against the cost in commissioning time and lower beam availability
  - Luminosity is only useful to the extent that it can be used by the experiments
    - E.g. higher pile-up causes loss of efficiency, both at the trigger and reconstruction/analysis level, partially counterbalancing the increased delivered luminosity
    - If necessary to run with lower pileup, $\sqrt{s}$=8 TeV increases the signal to background ration for all Higgs masses and this could be used to lower pileup without loss in sensitivity relative to 7 TeV

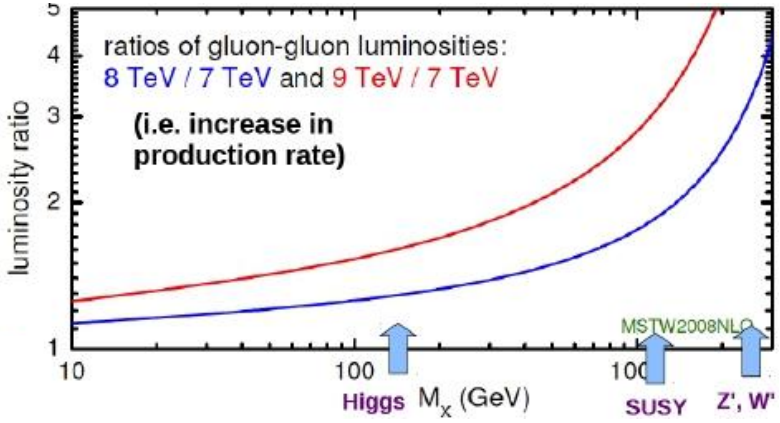
View from experiments including special physics run

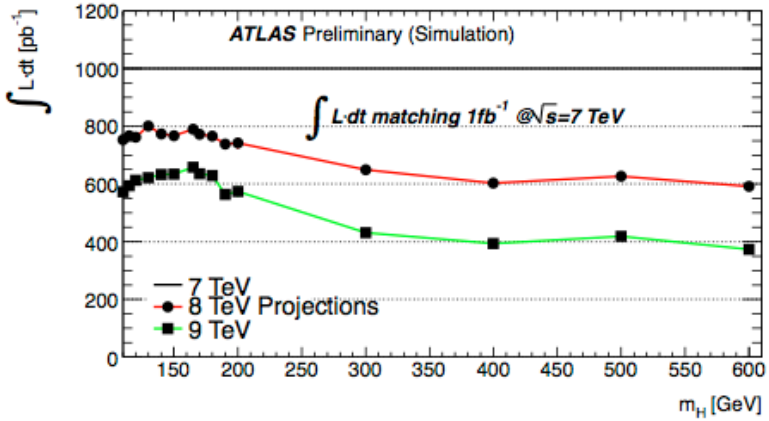
- Physics goals for 2012
  - p-p and Heavy Ions
- Views about p-p beam parameters
- Special runs
- Some comments about the schedule

Beware that discussions are still going on within detectors ⇒ final position by Chamonix

Beam Energy

- Experiments **support increasing energy to 8 TeV (… or more)**
  - ~14% more luminosity
  - ~25% less data needed for the same Higgs discovery significance
  - ~10% higher mass reach for exotics
  - Extended SUSY reach with 2 to 4 times greater sensitivity





- The recommendation is also **to start right away at the highest reachable energy**
  - The only way to secure maximum integrated luminosity
  - And minimize drawbacks
    - E.g. the need to generate 8 TeV MC sample in a short time or the non trivial combination of 7TeV and 8TeV data

Squeeze and bunch length

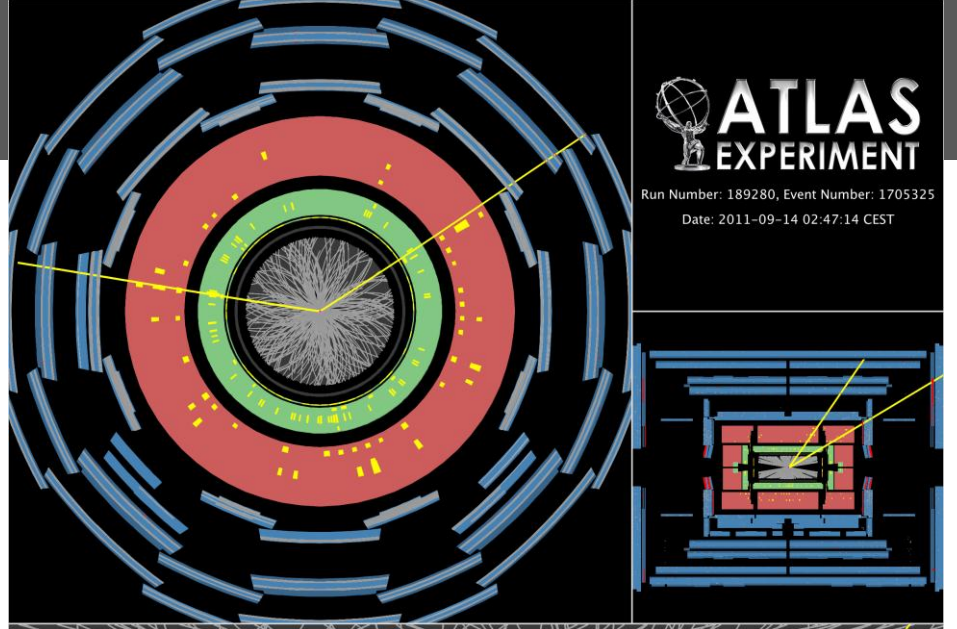
- Define β* values with following criteria:
  - ATLAS and CMS:
    - Smallest possible
  - LHCb
    - Such that it would be compatible with the inclined crossing (more later)
    - And would give a factor 2 range for leveling, to maintain stable luminosity over long fills
  - Alice:
    - Squeeze at least to a value that allow running the satellite-main filling scheme with natural satellites (~3m)
    - Consider more squeeze to provide headroom for luminosity leveling
    - But: evaluate effect on polarity reversal scheme (more later)
  - An approach could be to bring all experiments to 3m after ramp and squeeze, then squeeze more the high luminosity ones
- Bunch length
  - Increasing the bunch length by up to ~10% would still be acceptable
    - The recommendation though is to aim at fixing the ideal length as early as possible and keep it stable

Bunch separation

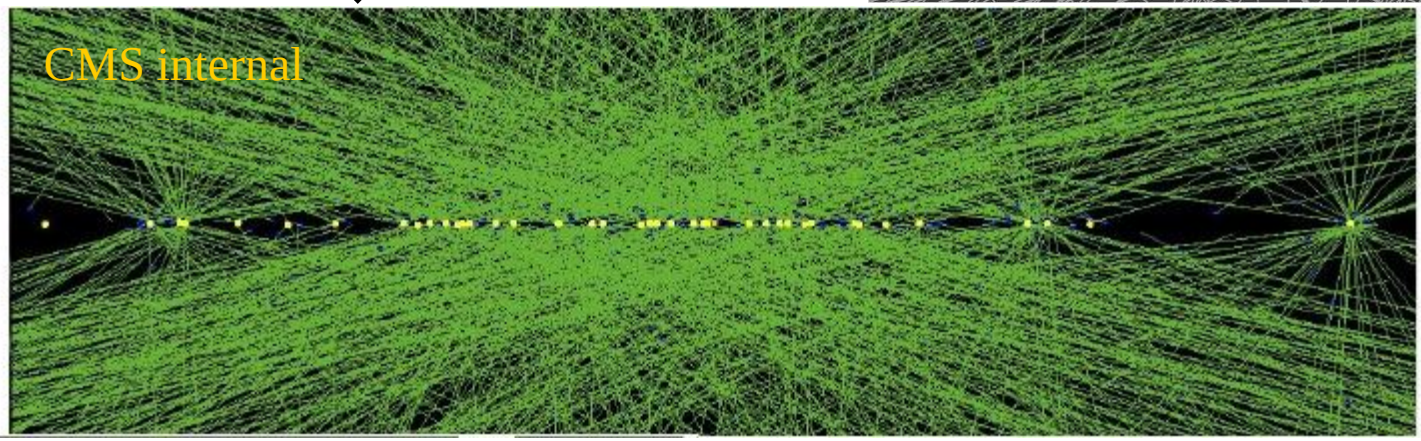
- It seems clear that filling schemes with 50 ns bunch separation would provide significantly larger integrated luminosity than schemes with 25 ns
  - Actual estimates differ, but our working hypothesis is to assume that the difference would be at least of order 50%
    - Considering lower peak luminosity, extra scrubbing, maybe different squeeze
- Under those assumptions we support **50 ns separation as a default scenario for next year**
  - This implies an average pileup between 20 and 30
- At the moment no real show-stopper has been found up to peak pileup of 30 (see later slides) **but:**
  - Detailed analysis it's still ongoing: if we identify some hard limit we will need to investigate ways to cap the pile-up (lower bunch charge, lumi-leveling), even at the expense of some luminosity
  - For the longer term 25 ns remains the preferred scenario
    - We need to foresee tests to establish the running conditions

High-pileup events

- Z→μμ candidate with 20 reconstructed vertices

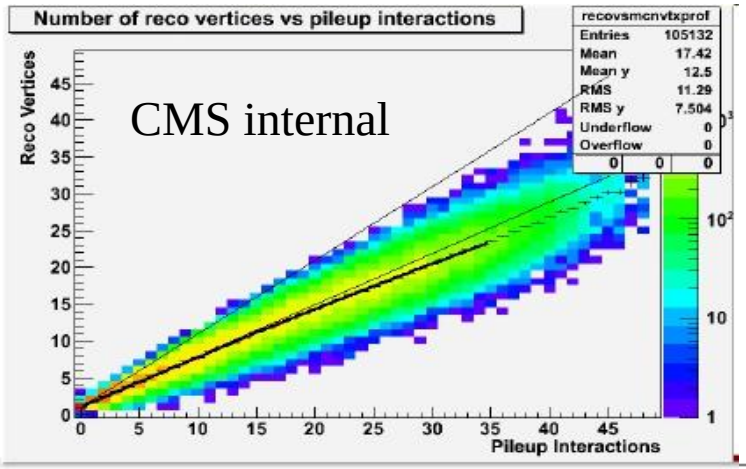


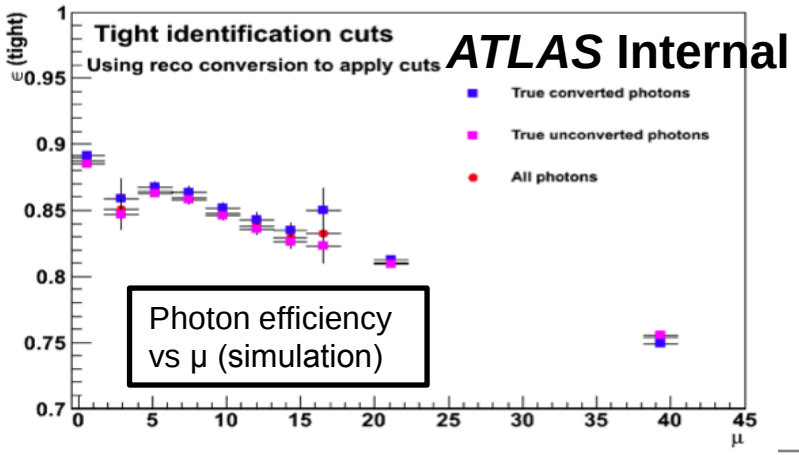
- Event with 40 reconstructed vertices



Effects of pileup on experiments

- Some that probably can be mitigated
  - Worse vertex reconstruction efficiency, offset in energy, higher rates of low-pt jets
    - if mitigation implies raising thresholds there will be anyway an impact on physics
- … and some that cannot
  - Degradation of energy resolution, need for more disk/CPU resources
- A couple of examples:
  - Vertex multiplicity should scale linearly with μ if reconstruction efficiency is constant
    - We observe deviation after μ~20
  - Shower shapes perturbation affect electrons and photon identification efficiencies
    - But remember that there are 2 photons in H→γγ
  - Algorithms are still not optimized for high pile-up: improvements are expected
- For next year's μ we expect nevertheless to gain overall with the higher L





Collisions for ALICE in p-p

- There is an agreement to provide luminosity to ALICE by colliding main bunches with satellites as successfully tested at end of 2011
  - More colliding bunches for other experiments
  - In the assumption of running with 50ns bunch separation
- Tests in 2011 have indicated that natural satellites provide ~3 times lower luminosity than required by ALICE
- Two alternatives:
  - Enhanced satellites: tested but still manual procedure
  - More squeeze in IP2
- The squeeze-based approach seems to be the preferred one from the experiments point of you as
  - Population in satellites is kept to a minimum → ideal for other experiments

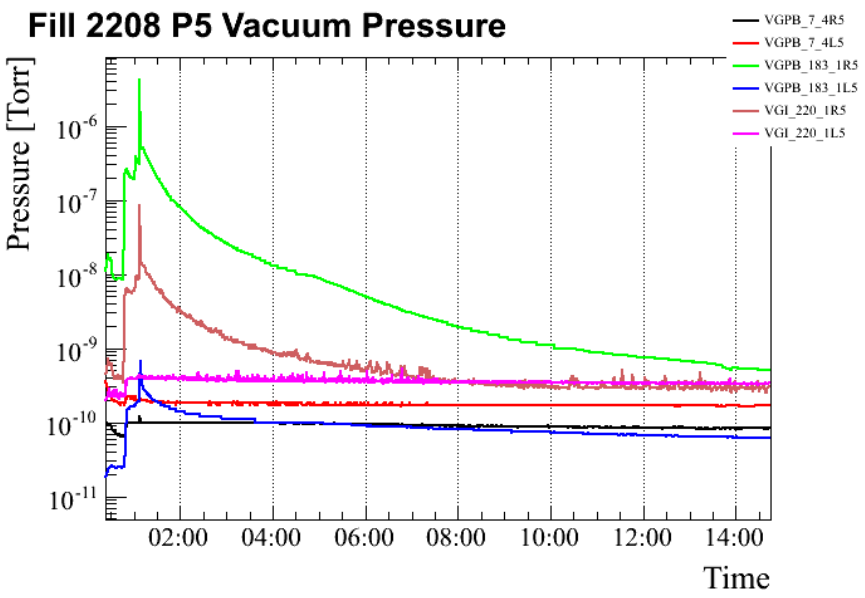
Optimization of polarity changes in ALICE and LHCb

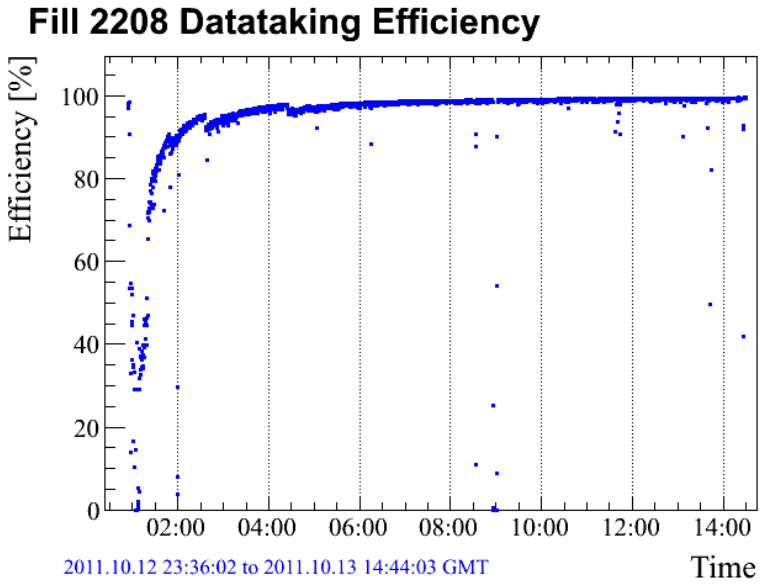
- ALICE:
  - Could we port the latest Heavy Ion crossing scheme to p-p?
    - Fixed external angle at injection & ramp => no need to re-do injection protection for polarity reversals
    - But at 50ns, more and stronger long-range effects make it impossible ?
      - Does it depend on β*/crossing choice?
- LHCb
  - Polarity reversals are required for **each ~100pb-1** to minimize systematics
  - At present the internal crossing angle (caused by the spectrometer and its compensators) and external crossing angle are both in the horizontal plane
    - Full crossing angle with positive (down) polarity large (~1040 µrad)
    - Full crossing angle with negative (up) polarity small (~40 µrad)
  - Proposal: move external crossing angle to the vertical plane
  - Advantages of tilted crossing angle:
    - External crossing angle decoupled from dipole polarity
    - Absolute value of effective crossing angle independent of dipole polarity
  - Possible approach/issues
    - Turn the crossing plane to vertical at flat top before the squeeze
      - Most likely it would be impossible to do it at injection
    - Lumi-leveling would be in both planes
      - Slightly more involved operational procedure, but no principle problem
    - Would this scheme impose limitations on β*?
  - To be set up right from the beginning to ensure uniform data taking

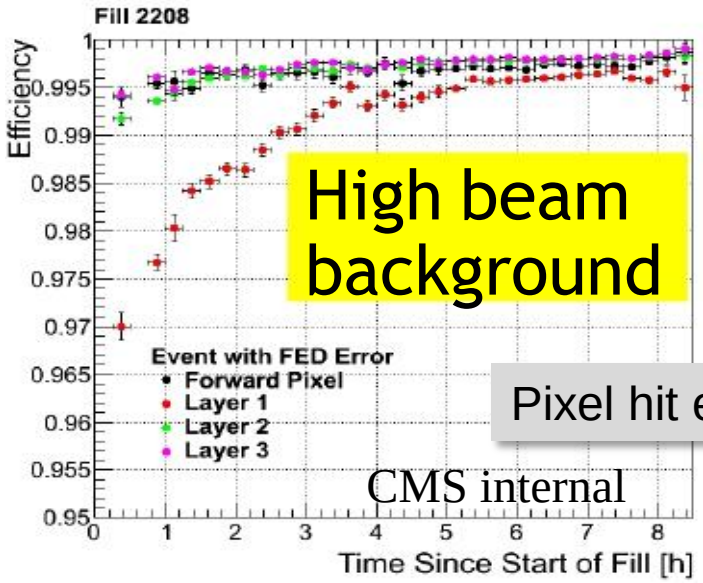
Vacuum situation

- ALICE
  - Need vacuum pressure left and right of IP2 to remain **below 5×10^{-9} mbar** (with current bunch intensities) to be able to switch on the TPC with proton beams
    - Hopefully the intervention on bad fingers contact will help
- CMS
  - Data taking suffers from bad vacuum conditions at 18.3 m right of CMS
    - Vacuum conditions almost systematically start degrading at injection
    - Vacuum degrades in spikes
    - Often the situation recovers before stable beams
  - Efficiency drops significantly when vacuum exceeds 10^{-8} mbar
  - **Needs to be understood before data taking in 2012**
    - Beware that no local intervention is possible during Christmas shutdown
- ATLAS and LHCb
  - For the moment the level of background seems under control

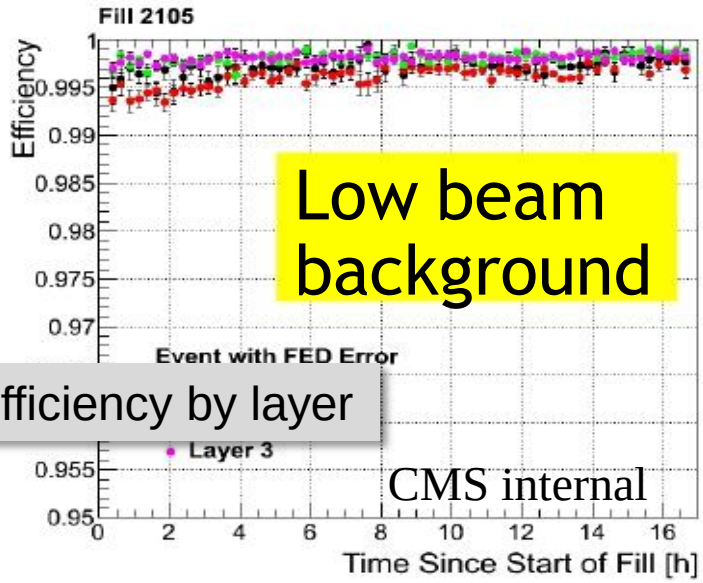
CMS vacuum issues – a typical bad fill







High beam background



Low beam background

Pixel hit efficiency by layer

CMS internal

CMS internal

Another hint for discussion

- Should we discuss how to streamline the start of fill procedure to optimize the way we start taking data as soon as the beams are colliding?
  - Order of optimizations, stable beam, LHCb luminosity ramp etc.
    - Potential gain in integrated luminosity
  - I'm afraid that this risks to quickly become politically incorrect… especially if we decide to optimize after declaring stable beams
    - But who goes first? Should we do it in alphabetical order ☺ ?
- The question have been raised about the possibility of collapsing LHCb right after the combined ramp and squeeze and while ATLAS and CMS are being squeezed from 3m down to the final beta*
  - In addition to losing less luminosity at the beginning of the fill, this would also partially decouple the effects on the Atlas/CMS optimization due to the LHCb luminosity ramp
- More in general LHCb would like to get rid of the human confirmation for the leveling steps
  - The automatic procedure has been extensively tested

View from experiments including special physics run

- Physics goals for 2012
  - p-p and Heavy Ions
- Views about p-p beam parameters
- Special runs
- Some comments about the schedule

Beware that discussions are still going on within detectors ⇒ final position by Chamonix

Heavy ions physics program

- Types of beams
  - The default plan for 2012 is to take data with p-Pb collisions only
    - We will ideally need though both p-Pb and Pb-p beam setups
  - There have been requests about possible data takings with Pb-Pb or with p-p at different C.M. energies, but those are not part of the default plan at the moment
- Energies
  - By default we assume to run at $\sqrt{s} = \sqrt{(Z_1 Z_2 / A_1 A_2)}$ x 8 TeV ~ 5 TeV
  - Would other C.M. energies be possible if it would turn out to be useful for physics purposes?
- Under those conditions LHCb will also join the run
  - At least the p-Pb part; still unclear about Pb-p

Heavy Ions Physics goal

- Double physics goal:
  - Baseline measurements for the nucleus–nucleus program
  - QCD studies: e.g. parton saturation at low x
- The ideal goal for p-Pb physics program is 100 nb^{-1}
  - See: “Proton–nucleus collisions at the LHC: scientific opportunities and requirements 2012”, *J. Phys. G: Nucl. Part. Phys.* **39**
    - Largely driven by a dedicated workshop recently held at CERN
    - John Jowett is one of the co-authors
- Luminosity target for 2012
  - 100 nb^{-1} sounds „a bit“ too much for next year... given an expected luminosity of ~$3x10^{28}$ $cm^{-2}s^{-1}$
  - A minimal target for physics is to collect >10 nb^{-1} in p-Pb configuration
    - ALICE consider 30 nb^{-1} a more relevant target from physics point of you
    - It is worth exploring the option of operating with fatter p bunches to achieve higher luminosity

View from experiments including special physics run

- Physics goals for 2012
  - p-p and Heavy Ions
- Views about beam parameters
- Special runs
- Some comments about the schedule

Beware that discussions are still going on within detectors ⇒ final position by Chamonix

Special runs for 2012

- Keep them to the essential, given emphasis on luminosity production
- Two higher priority tasks
  - Luminosity calibration, as we go to different beam energy
  - High beta physics
- Other options could be considered
  - High/low pileup runs
  - 25 ns extended data taking

- Detailed schedule will be proposed by Chamonix, but the general guidelines are:
  - To cluster them towards the second part of the year
    - With the exception of a first VdM scan
  - To reduce the total time allocation to something less than this year's

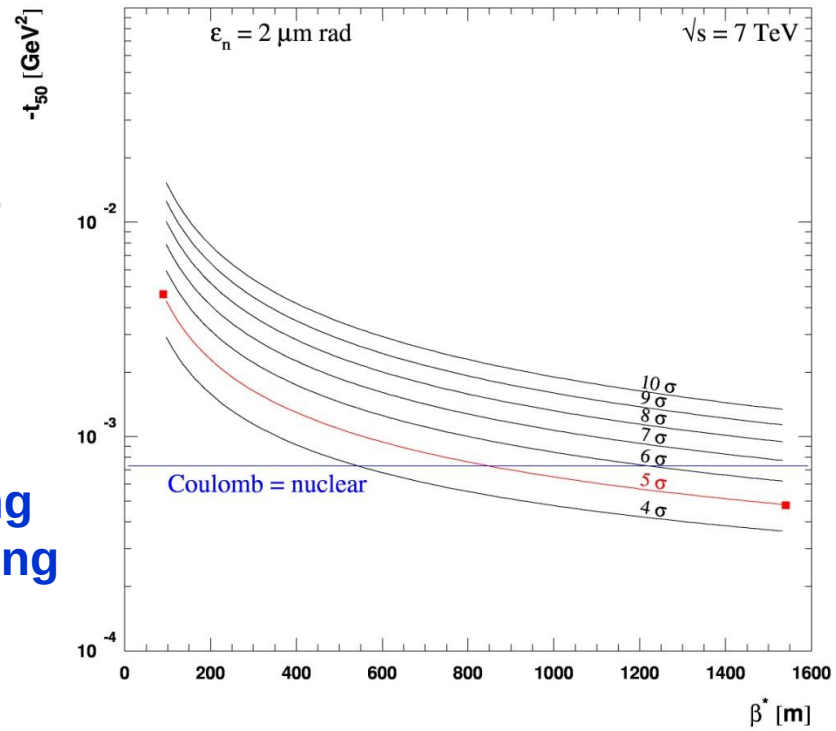
Luminosity calibration

- At least one VdM scan will be requested by all experiments, in particular assuming a change in beam energy
- There is interest to perform the scan with higher β*, with either un-squeezed beams or before the last squeeze step (β*=3m?) to:
  - Perform the scan at sufficiently low mu (~1-2), so as not to confuse VdM calibration with mu-dependent corrections.
    - At 8 TeV cm, β* = 0.7 m and~ 7E10 p/bunch ⇒ μ~ 6.5: this is way too high
    - Going to 1x10^{10} p/bunch the statistics would be too low for some detectors
    - The ideal peak μ value of ~1.5-2, corresponds to about 3.5-4.0 E10 p/bunch, which may be unsafe from the viewpoint of the BPM system
  - Keep transverse luminous size larger than vertex resolution, to investigate correlations between horizontal and vertical beam transverse profiles
    - VdM procedure assumes x and y scans to be un-correlated ⇒ systematic error to the measurement
- There are, however, potential limitations with doing a scan at high β*
  - E.g. we may be on the low side from the viewpoint of statistics
  - More investigation is still needed

Please note that Lumi Days 2012 event is scheduled
from 29 February 2012 to 01 March 2012
https://indico.cern.ch/conferenceDisplay.py?confId=162948

High beta

- Two alternative physics goals
  - Diffractive physics at β*=90m (mainly TOTEM)
  - Reach of Coulomb interference region for elastic scattering (high β*)
- Only one of the two programs can probably be supported next year
  - Priority would be for the second point **provided that it would be realistic to reach the interference region**
- Roman pots would profit from running in low-beta low-intensity p-p runs after technical stops
  - Useful for calibration
  - Need to get to ~6 mm
  - **What could be done without re-doing a beam based alignment but including the pots in loss maps?**



View from experiments including special physics run

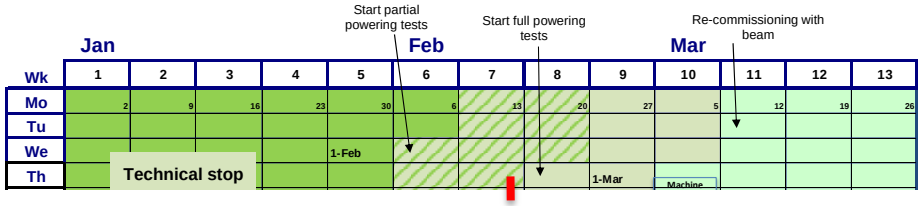
- Physics goals for 2012
  - p-p and Heavy Ions
- Views about beam parameters
- Special runs
- Some comments about the schedule

Beware that discussions are still going on within detectors ⇒ final position by Chamonix

A naïve to schedule optimization

- 158 days of physics

This MD period comes really too early
Can we consider delaying it?



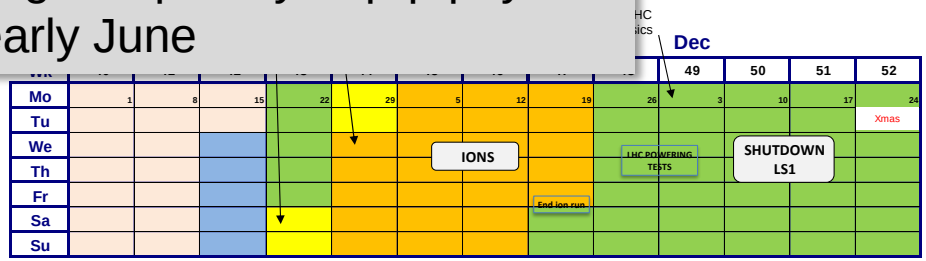
Scrubbing run

Apr May June

Wk	14	15	16	17	18	19	20	21	22	23	24	25	26
Mo	2	Easter 9	16	23	30	7	14	21	Whit 28	4	11	18	25
Tu					1st May								
We													
Th			MD				Ascension						
Fr	G. Friday												
Sa													
Su													

Do we really need so much scrubbing for 50 ns?
Could we limit this period to a minimu

ICHEP 2012 starts on July 4th
Give highest priority to p-p physics until early June



Conclusions

- 2012 will be a crucial year for experiments!
- The experiments support running in p-p at 8 TeV and 50 ns bunch separation to maximize the physics reach before LS1
  - No hard limitation from pileup is expected for next year
- The main goal for the Heavy Ion program will be to run with p-Pb

- Collecting the required integrated luminosity for all physics goals will be very challenging
  but **we are confident that you will manage to surprise us again**

- The program of special runs will be kept to the essential

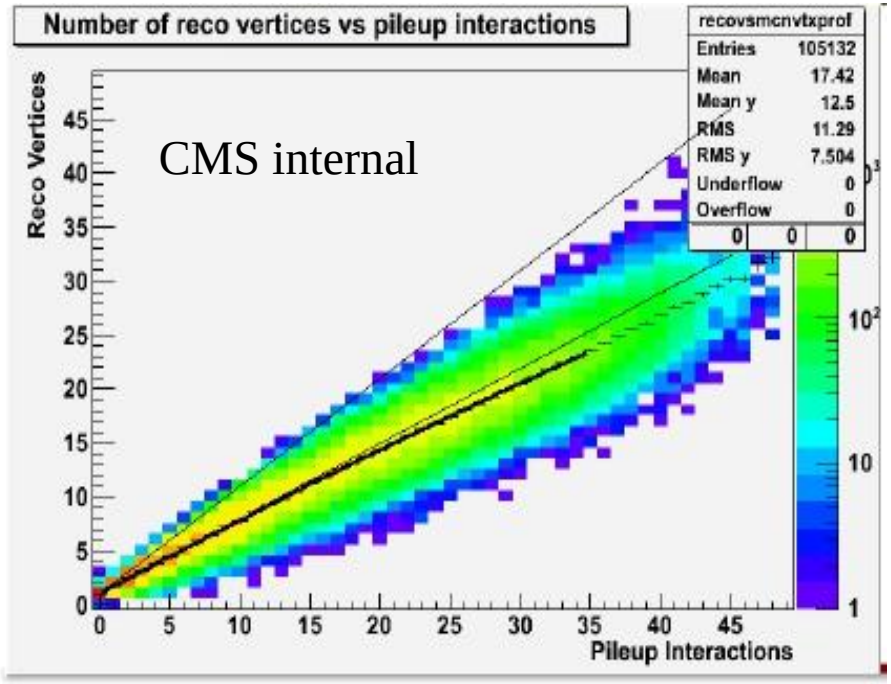
THANK YOU all for an exceptional 2011!!

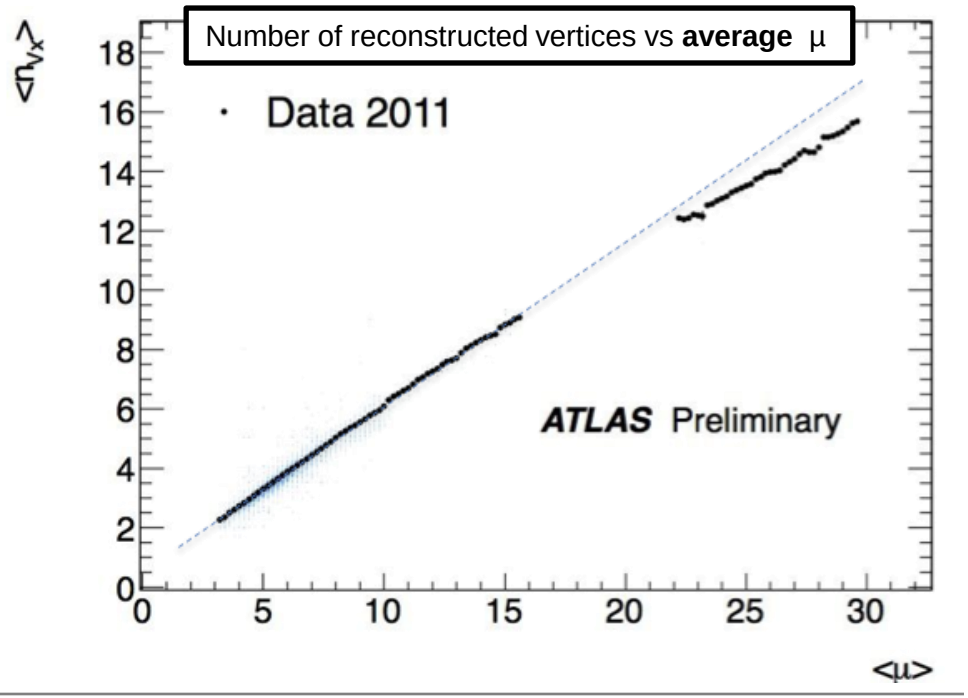
… looking forward for an even “brighter” 2012

BACKUP

Tracking and vertex reconstruction

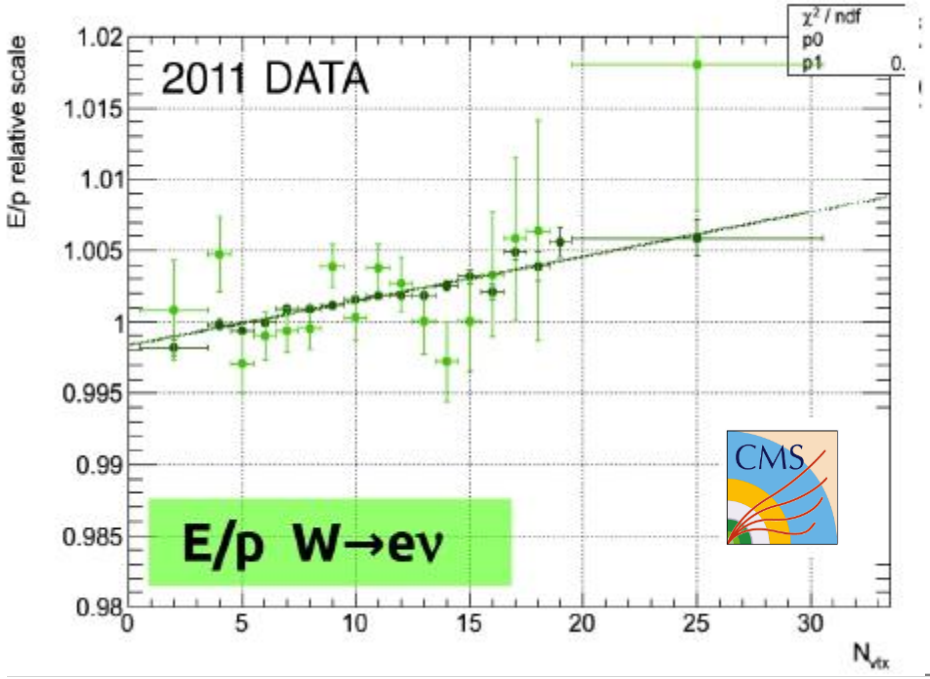
- Average vertex multiplicity should scale linearly with μ if reconstruction efficiency is constant
  - We observe instead deviation after μ~20
  - Due to vertex merging and decreased tracking efficiency
- Beware that algorithms are not optimized for high pile-up
  - Improvements are expected

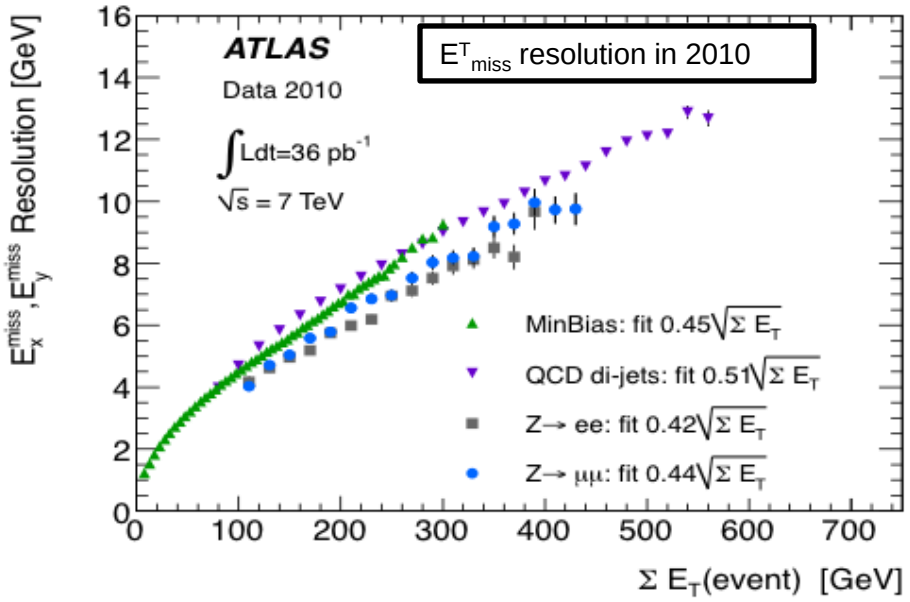




Energy resolution

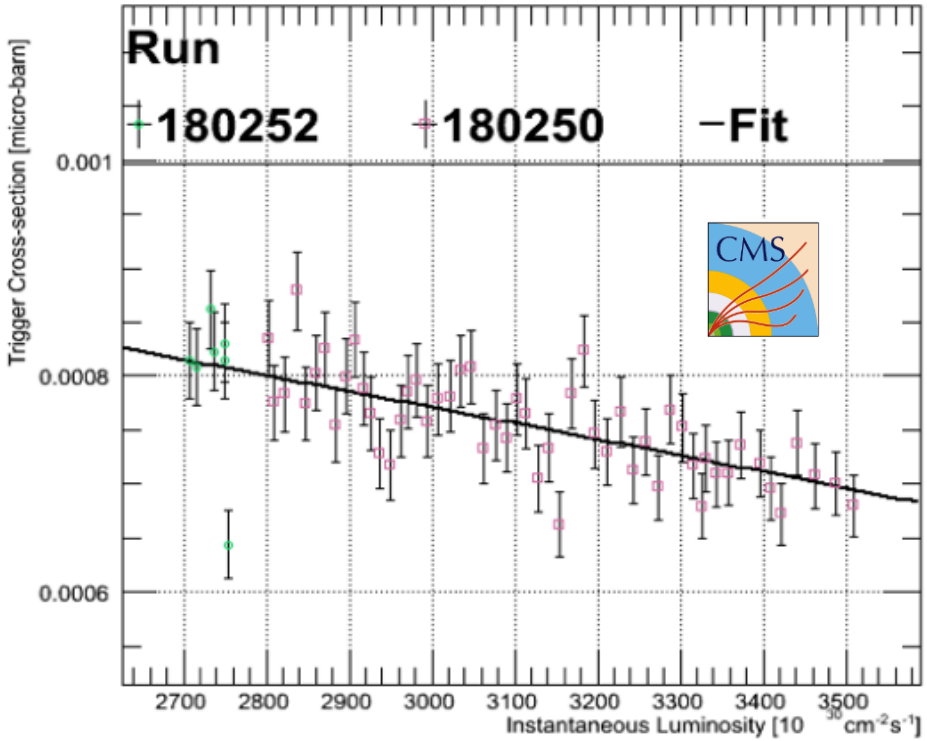
- Pileup events deposit extra energy, giving offset in reconstructed object energies
  - Average offset can be corrected
- The higher fluctuations result also in a smearing of the resolution
  - E.g. missing transverse energy resolution scales with the square root of the total transverse energy that scales itself with pile-up

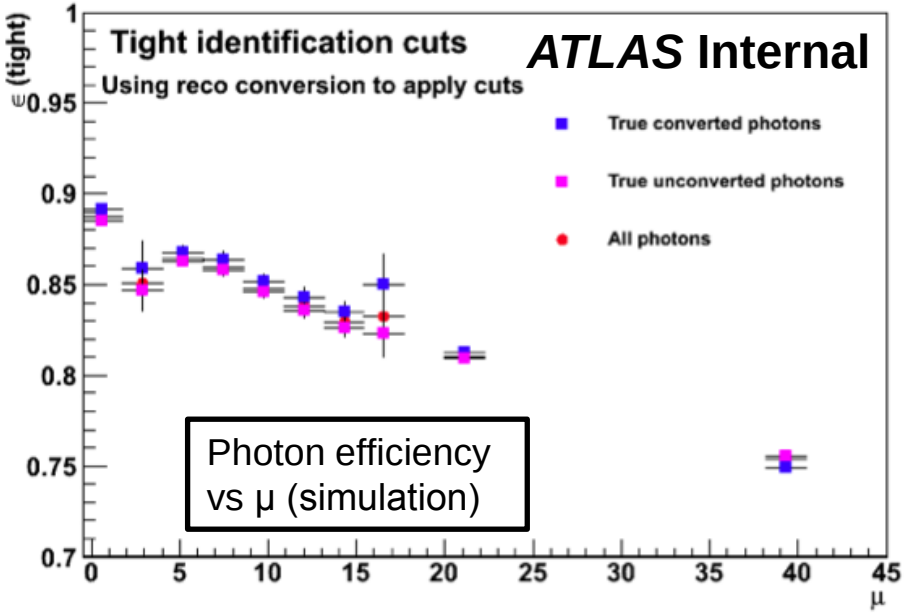




Electron/photon reconstruction efficiency

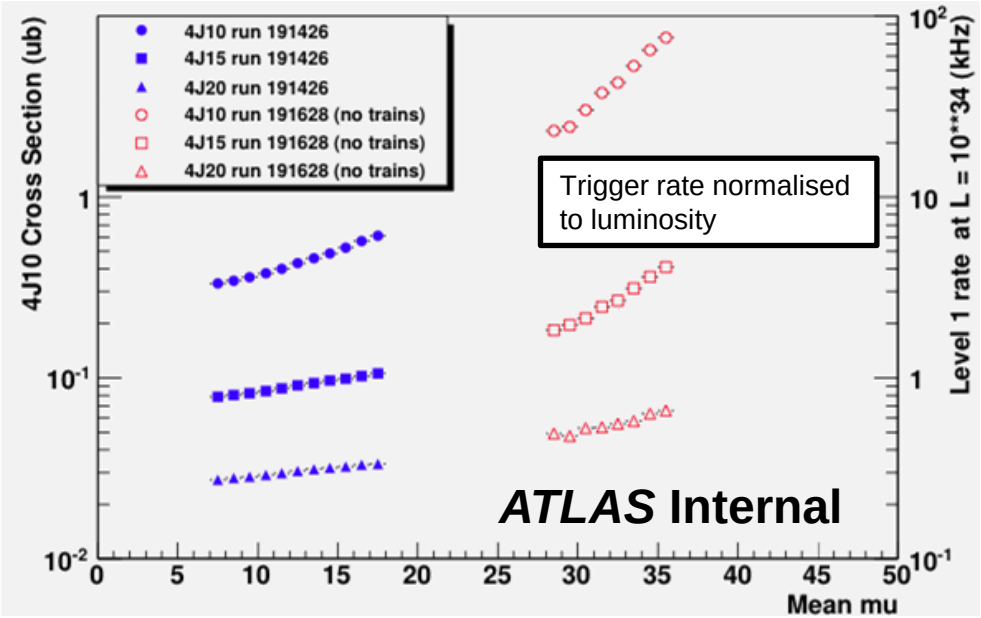
- Electrons and photon identification efficiency depends on shower shapes in calorimeter
  - We hope to recover some of the performance by optimizing shower shape cuts for high pile-up
  - But remember that there are 2 photons in H→γγ …..

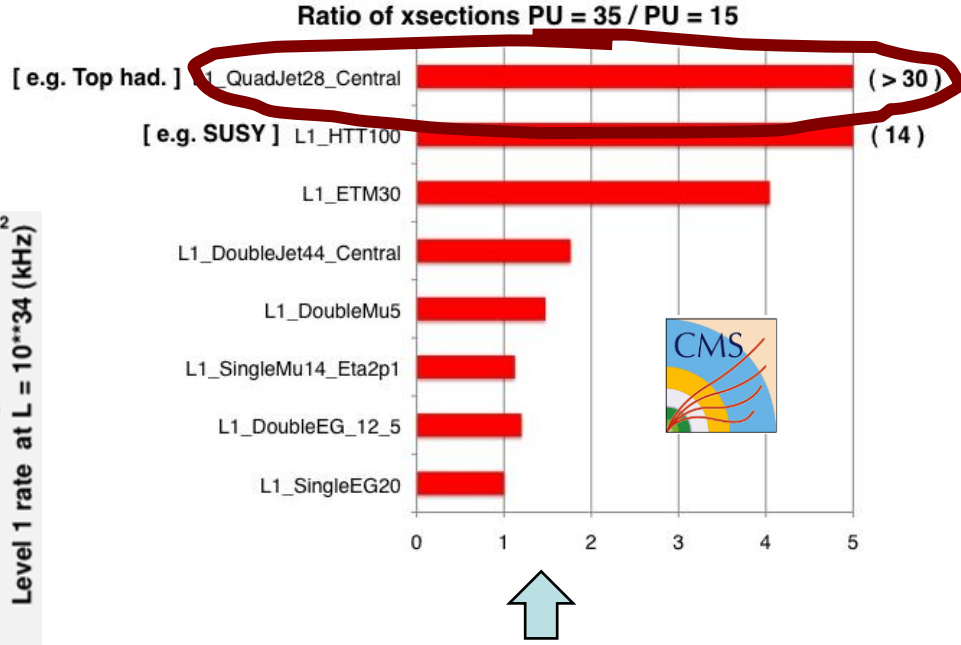




Jet multiplicity

- Multiplicity of low-p_T jets increases non-linearly with pile-up
  - Can be mitigated by pile-up subtraction
- Hard to maintain trigger acceptance for multiple low-pT objects
  - Raising thresholds affects physics reach





4 Jets trigger rates

Other effects

- Event sizes and detector occupancies grow
  - Higher data throughput, hence load on DAQ
  - More disk resources needed
- Reconstruction complexity/time will naively scale with the number of tracks
  - Increased trigger CPU needs
  - Need to adapt algorithms and cuts
  - Increased offline CPU needs
  - E.g. CMS will need HLT farm extension to run @50ns resulting in μ=32
    - Baseline option being evaluated: increase of CPU by 50%
  - Similar figures are expected for ATLAS