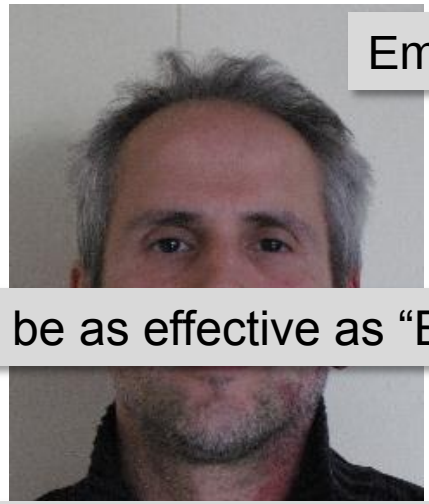
Experiments Expectations, Plans and Constraints

- Physics goals for 2012
  - p-p and Heavy Ions
- Views about p-p beam parameters
- Special runs
- Schedule

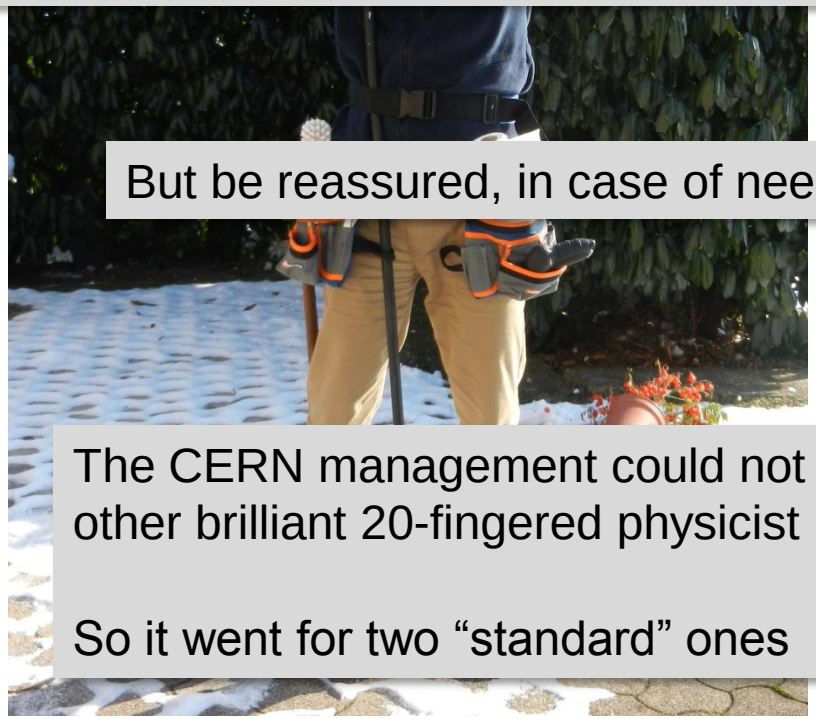
Change in personnel



Emilio

Please be kind to us… we may need sometime to be as effective as “Bob le Builder”

But be reassured, in case of need Massi promised to give us a hand…..



The CERN management could not find any other brilliant 20-fingered physicist

So it went for two “standard” ones

Benedetto

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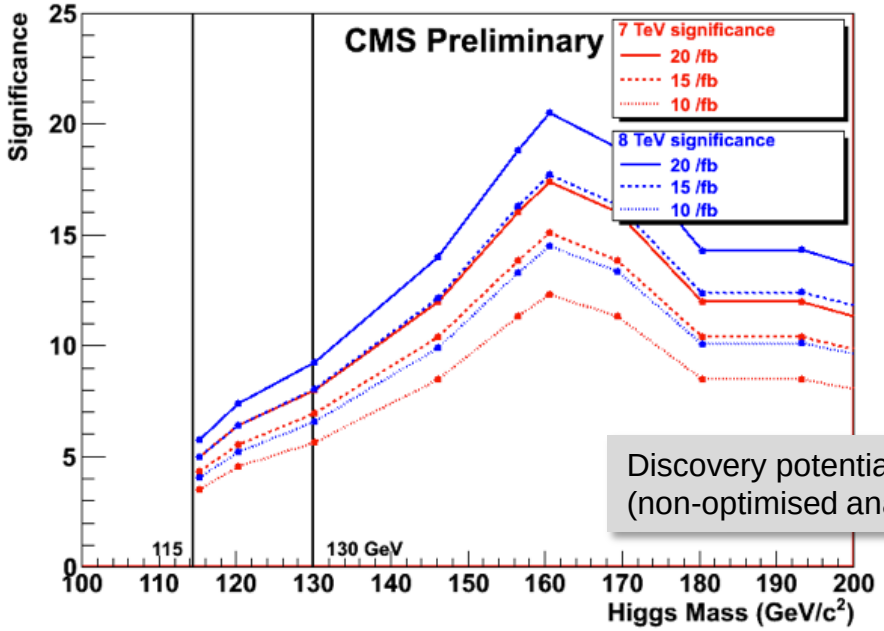
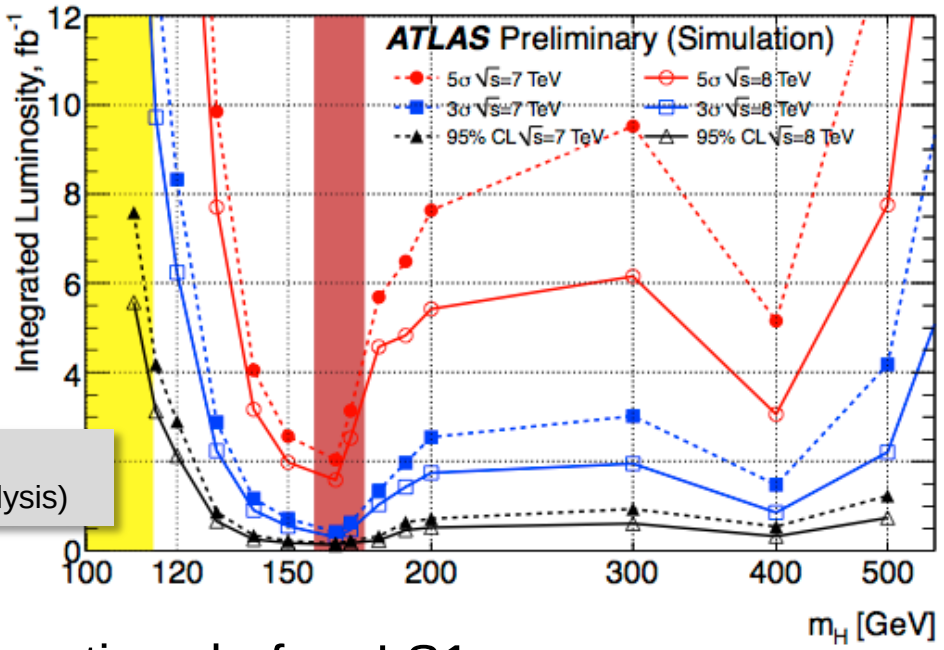
Target luminosity for p-p runs

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



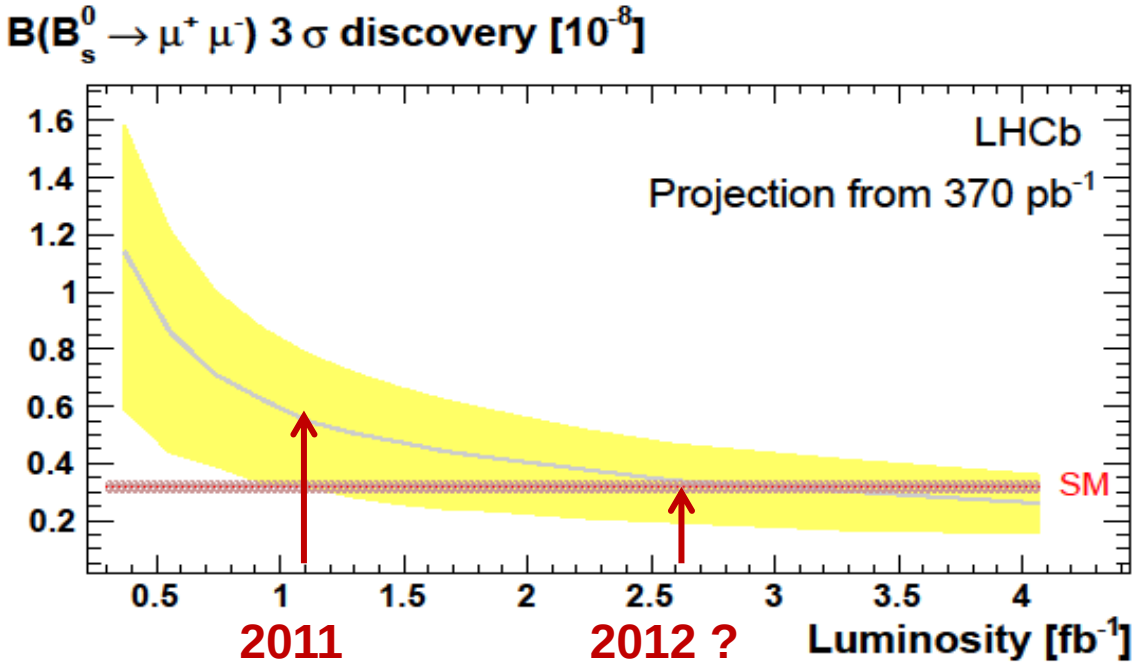
Discovery potential
(non-optimised analysis)



- Ideal target is **~20 fb^{-1}** for p-p operations before LS1
  - To accommodate possible inefficiencies due to high pileup

Overview of p-p physics program

- The Higgs discovery is just the tip of the iceberg
  - Essential physics program beyond that
- SUSY
  - 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

- Clear goal: **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

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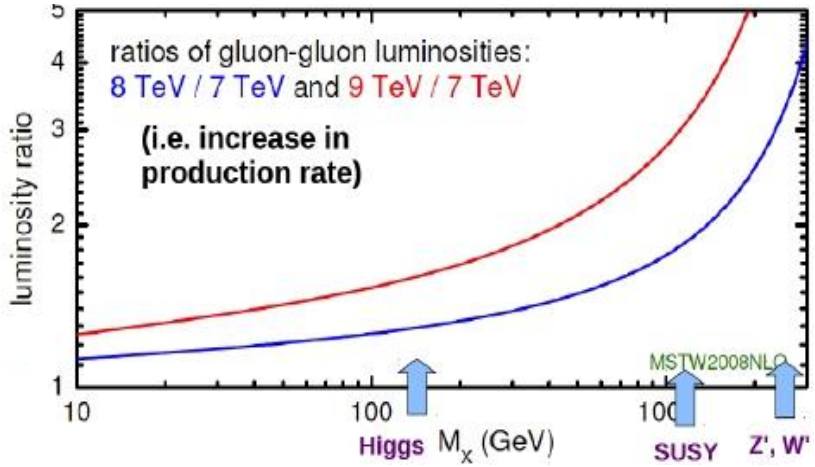
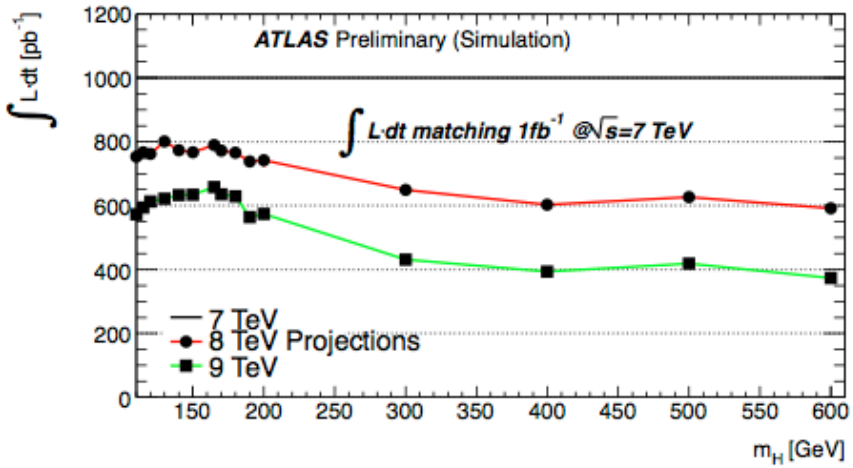
Beam Energy

- Experiments **support increasing energy to 8 TeV** provided that there are no additional risks nor delays
  - ~14% more luminosity
  - ~20% 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

Squeeze and bunch length

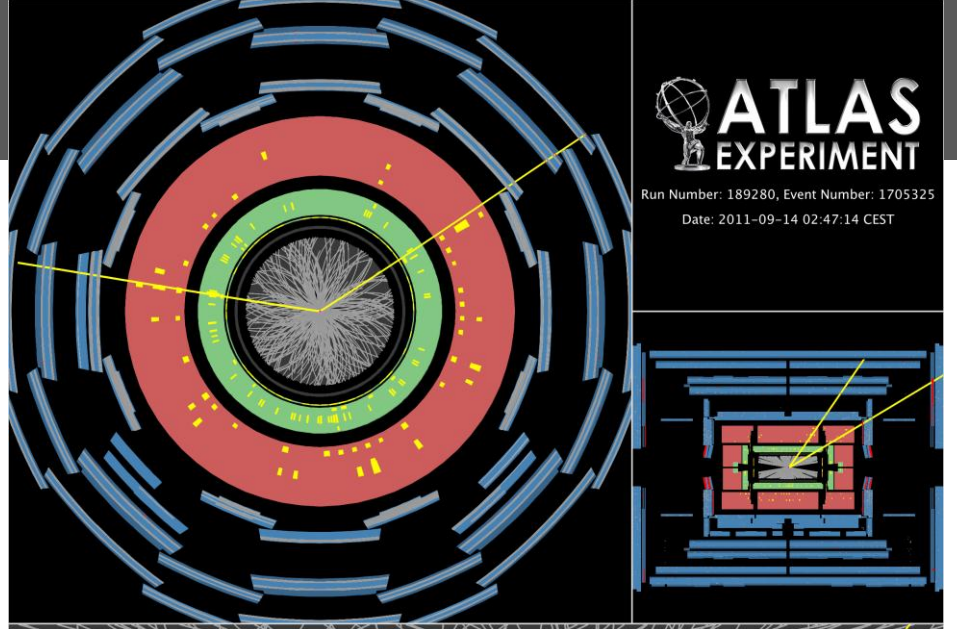
- Define β* values with following criteria:
  - ATLAS and CMS:
    - Smallest possible
  - LHCb
    - Minimum compatible with the inclined crossing (more later)
    - Allowing a factor 2 range for leveling (keep stable luminosity over long fills)
  - Alice:
    - Squeeze to a sufficient extent to allow satellite-main filling scheme with natural satellites (3m?)
  - A possible approach: bring all experiments to 3m after ramp and squeeze, then squeeze further for the high luminosity ones
- Bunch length
  - Increasing bunch length by up to ~10% would be acceptable
    - Recommendation: fix the ideal length before the start of physics and keep it stable

Bunch separation

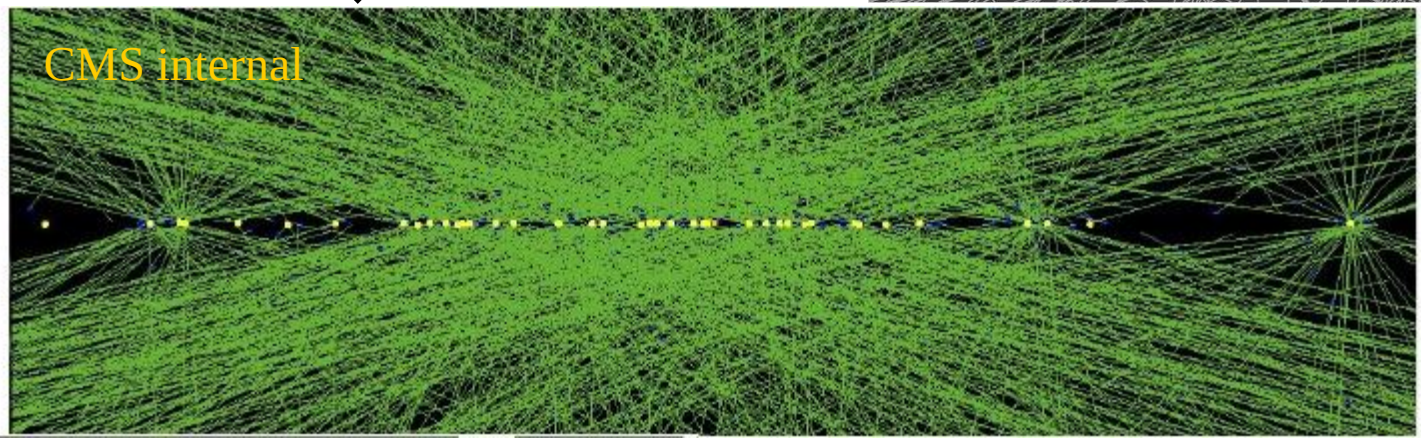
- It seems clear filling schemes with 50 ns bunch separation provide significantly larger integrated luminosity than schemes with 25 ns
  - Actual estimates differ, but our working hypothesis is that the difference would be between 30 and 50%
    - Lower peak luminosity, extra scrubbing, maybe different squeeze…
- Under these assumptions we support **50 ns separation as a default scenario for this year**
  - This implies a peak average pileup around 30
- No real show-stopper expected up to peak pileup of 30 (see later slides) **but:**
  - Detailed analyses still ongoing: if hard limits are identified, will need to investigate ways to cap the pile-up (lower bunch charge, lumi-leveling), even at the expense of some luminosity
  - It is important to underline that for the longer term 25 ns remains the preferred scenario
    - Make sure to plan sufficient MDs to establish 25 ns feasibility

High-pileup events

- Z→μμ candidate with 20 reconstructed vertices

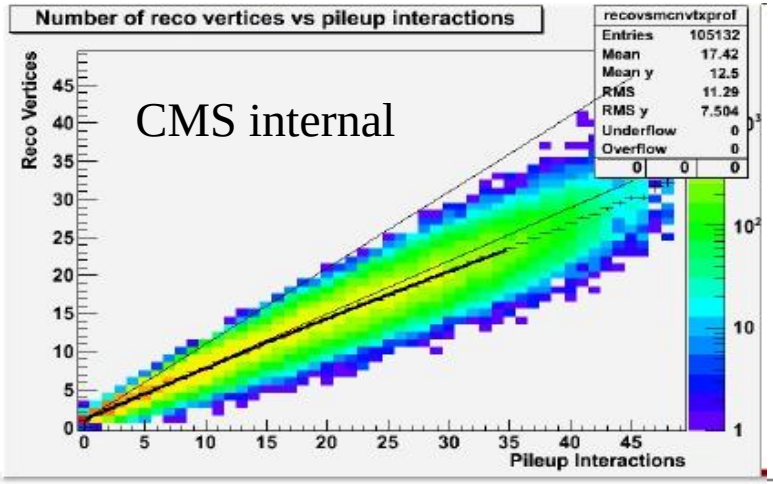


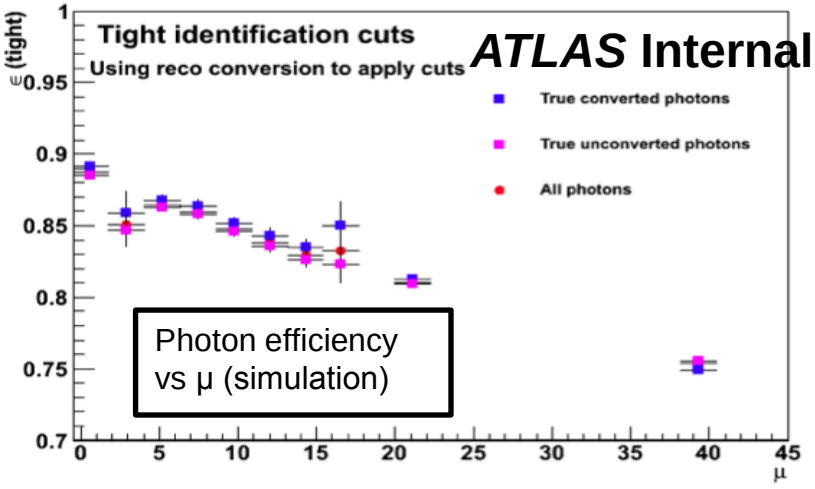
- Event with 40 reconstructed vertices



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
- With this 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 is the preferred one
  - Population in satellites is kept to a minimum → ideal for other experiments

Crossing angle in LHCb

- Polarity reversals would ideally take place every ~100/pb to minimize systematics
- In 2011, internal and external crossing angles were both in the horizontal plane
  - Very different total crossing angles for the two polarities (~1040 μrad vs ~40 μrad - the latter is very small and presents problems)
- Move the external crossing angle to the vertical plane:
  - Absolute value of effective crossing angle independent of dipole polarity
- Need to maintain horizontal crossing angle at injection; two options:
  - Rotate after reaching β*=3m at all IPs but before the final squeeze of ATLAS and CMS
  - Rotate after reaching final β* and establishing collisions for the other experiments
- Optimal procedure and effects on setup time and efficiency have still to be assessed
  - May have an influence on the number and timing of polarity changes
- Essential to establish final procedure during commissioning and use it from the start of p-p running

Other points for discussion

- Consider streamlining the start of fill procedure to declare stable beams as soon as collisions are established
  - … before optimizations for the experiments are performed
    - Potential gain in integrated luminosity
- Eliminate need for human confirmation for the LHCb leveling steps
  - The automatic procedure has been extensively tested
- Complete implementation of procedure for lumi-leveling of ATLAS and CMS in case it is necessary

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Heavy ions physics program

- Types of beams
  - The default plan for 2012 is to take data with p-Pb collisions only
    - ALICE requests both p-Pb and Pb-p beam setups
    - Still unclear if ALICE will also need polarity reversals for both setups
  - Additional requests for data taking with p-p at different C.M. energies are also being considered
- Energy of p-Pb
  - Most likely the request will be to run at equivalent proton energy of 3.5 TeV but 4 TeV is still being considered
    - Same Pb energy as Pb-Pb run with no serious luminosity loss
- Beam optics
  - Target is smallest β* (0.6m?) for ALICE, ATLAS and CMS
    - Is this feasible?
- LHCb will also join the run for the p-Pb part
  - We assume no squeeze beyond 3m will be possible
  - We need to investigate a suitable filling scheme

Heavy Ions Physics goal

- Double physics goal:
  - Baseline measurements for the nucleus–nucleus program
  - QCD studies: e.g. parton saturation at low x
- The final goal of the 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**
- Luminosity target for 2012
  - 100 nb^{-1} sounds „a bit“ too much for this year... given an expected luminosity of ~$3x10^{28}$ $cm^{-2}s^{-1}$
  - **30 nb^{-1}** is the realistic target
    - Is it worth exploring the option of operating with fatter p bunches to achieve higher luminosity?

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Special runs for 2012

- Keep them to the essential, given emphasis on luminosity production
- Two higher priority tasks
  - Luminosity calibration
    - Essential as we go to different beam energy
  - High beta physics
- Other options would be considered if possible
  - Very high and/or low pileup runs
  - Some stable beams at 25 ns
- General guidelines:
  - Concentrate special runs towards the second part of the year
    - After ICHEP deadline
  - Reduce total time allocated to somewhat less than last year's

Luminosity calibration

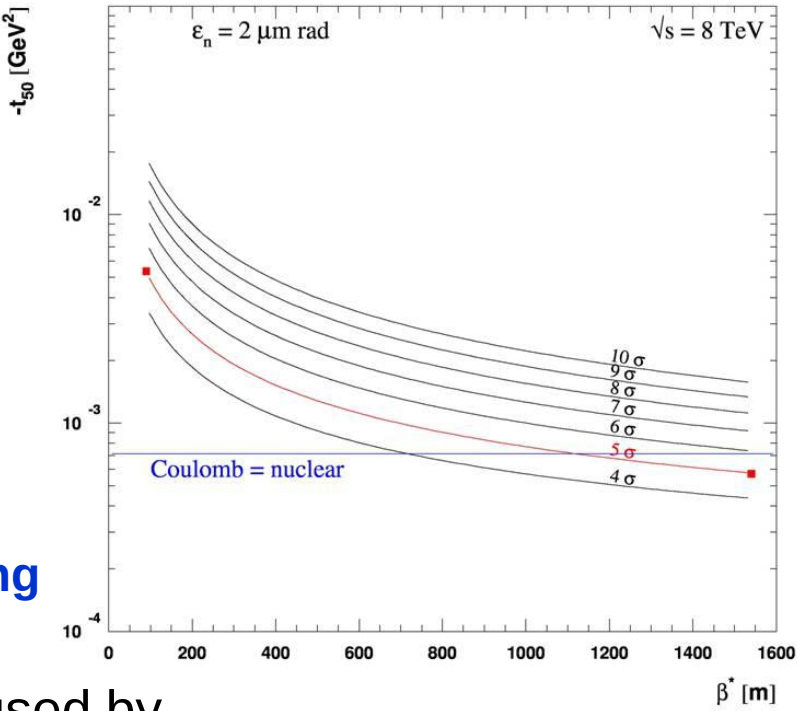
- At least one VdM scan with β*=11m to reach ultimate precision
  - Perform the scan at sufficiently low mu (~1-2), so as not to confuse VdM calibration with mu-dependent corrections
  - Keep transverse luminous size larger than vertex resolution, to investigate correlations between horizontal and vertical beam transverse profiles
- Still discussing whether to schedule it early or after ICHEP
- If the precision scan goes later we could ask for one at nominal β* during the intensity ramp-up

- CMS is interested in few “mini-scans” at end of fill to set reference points

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 physics goals
  - Diffractive physics at β*=90m (mainly TOTEM)
  - Highest β* to approach Coulomb interference region for elastic scattering
- Only one of physics run can be supported within the present schedule
  - Tentative proposal is to go for a mixed setup with 90m in IP5 and 500m in IP1



- Roman pots would profit from running in low-beta low-intensity p-p runs after technical stops for calibration
  - Need to get to ~6 mm
  - **What can be done without re-doing a beam based alignment but including the pots in loss maps?**
- ALFA confirmed that no damage is caused by pots warming up during high luminosity runs
  - ALFA will stay in for the complete p-p run

Miscellanea

- Early beam splashes are requested by most experiments
  - Details to be finalized
- Luminosity leveling tests
  - Can be carried out at an early stage during intensity ramp with the goal of assessing effect on luminosity lifetime
    - For both ATLAS and CMS
  - Establish complete procedure later if needed
- Low pileup sample
  - ATLAS needs to collect ~10M events at very low PU (<0.01)
    - <10h of data taking should be sufficient
  - Such low value should be reachable with large separation (close to 3 σ for both beams if possible) at nominal bunch population
    - We propose to use part of the early fills in the luminosity ramp-up
    - No special run necessary

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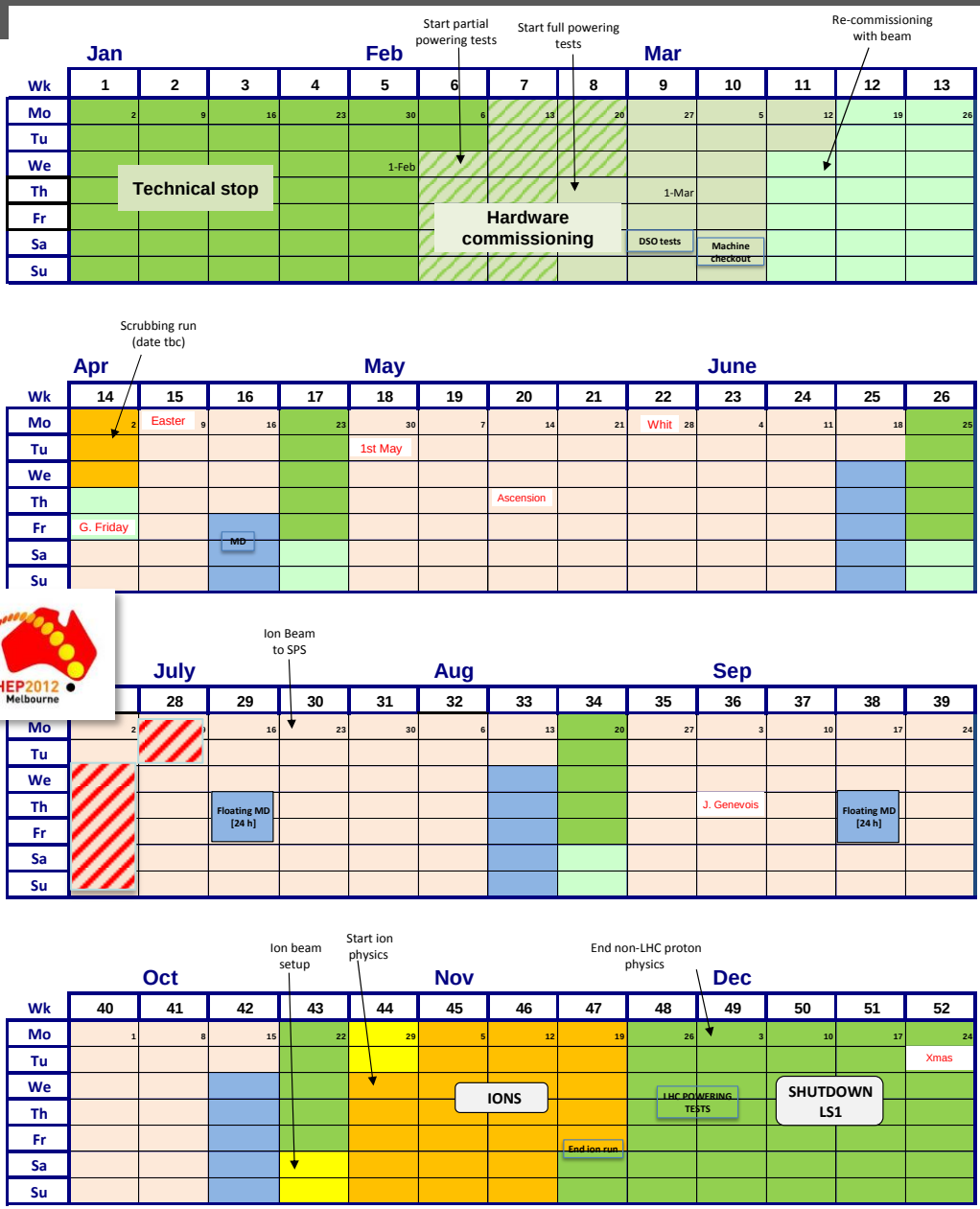
Few remarks on the schedule

- Several optimization already applied + repair of non-conformity in IP5
  - ⇒ Mike's new schedule
- 155 days of physics
  - Including special runs
- $6x10^{33}$ $cm^{-2}s^{-1}$ x 145 days x H **≈ 15 fb^{-1}** (H = Hubner factor ~ 0.2)
- Reaching 20 fb^{-1} is tough!
  - Plan for fastest possible intensity ramp-up!
  - Then keep stable conditions to max machine availability
- Aim to get 5 fb^{-1} for ICHEP
  - By first week of 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 this year but there may be some loss in efficiency
- 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

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

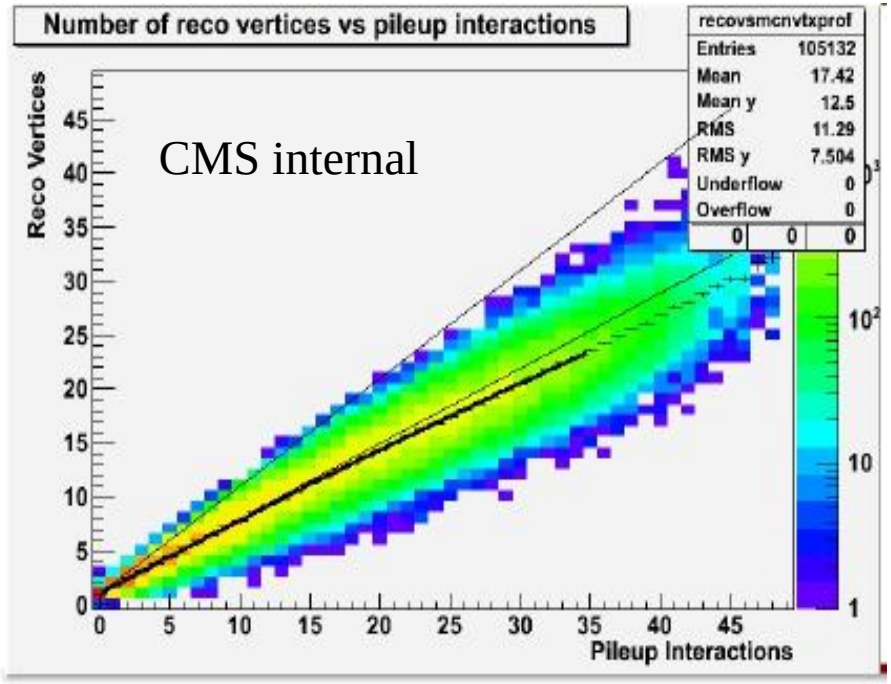
Gimme five … fb^{-1} ?

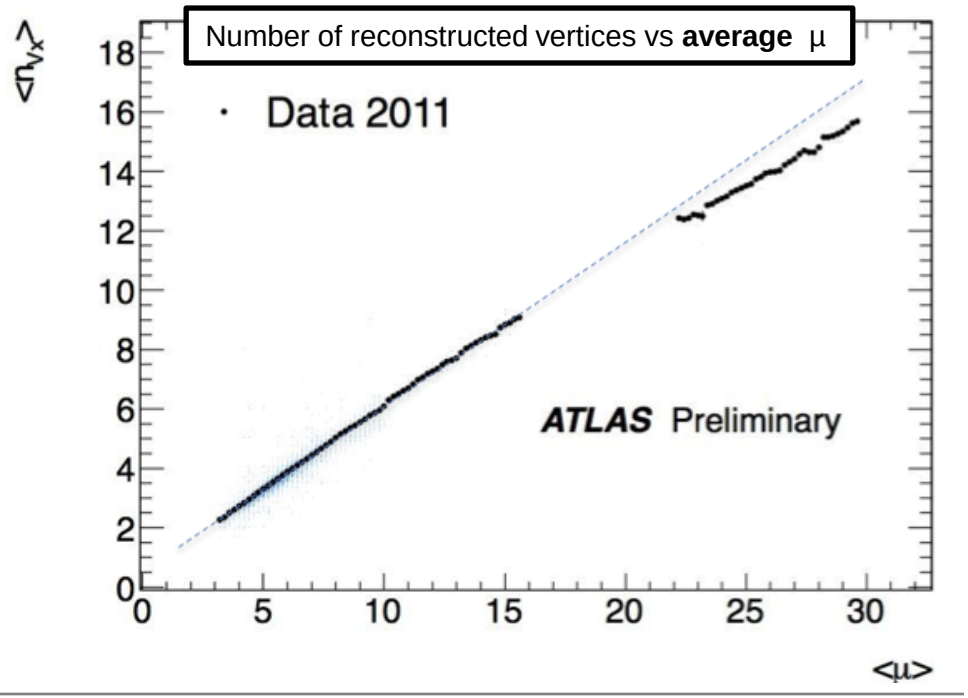
- But it will actually be a challenge to deliver 1fb^{-1} to IP8
  - consider maximum luminosity and pile-up tolerable to LHCb
    - ✂Already a big effort from LHCb side to "help" reaching the target:
      L_{max} : from 2e32 to 3e32 and μ_{max} : from 0.5 to 2.5
  - One fb^{-1} will be just reachable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

fraction in stable beams

Tracking and vertex reconstruction

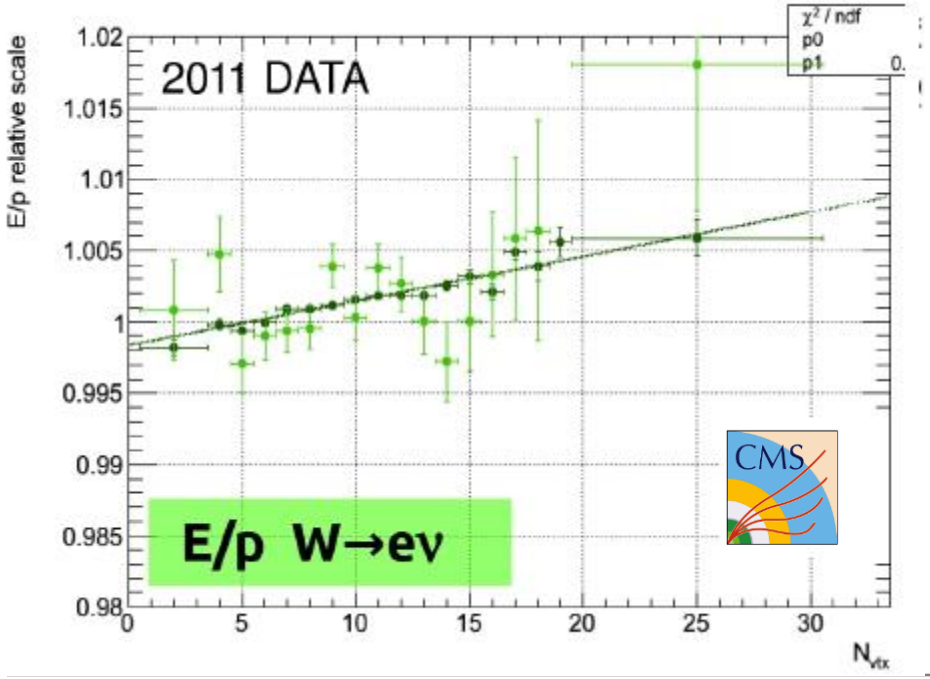
- Average vertex multiplicity should scale linearly with μ if reconstruction efficiency is constant
  - We observe instead deviation after μ~20
  - Due to vertex merging and decreased tracking efficiency
- Beware that algorithms are not optimized for high pile-up
  - Improvements are expected

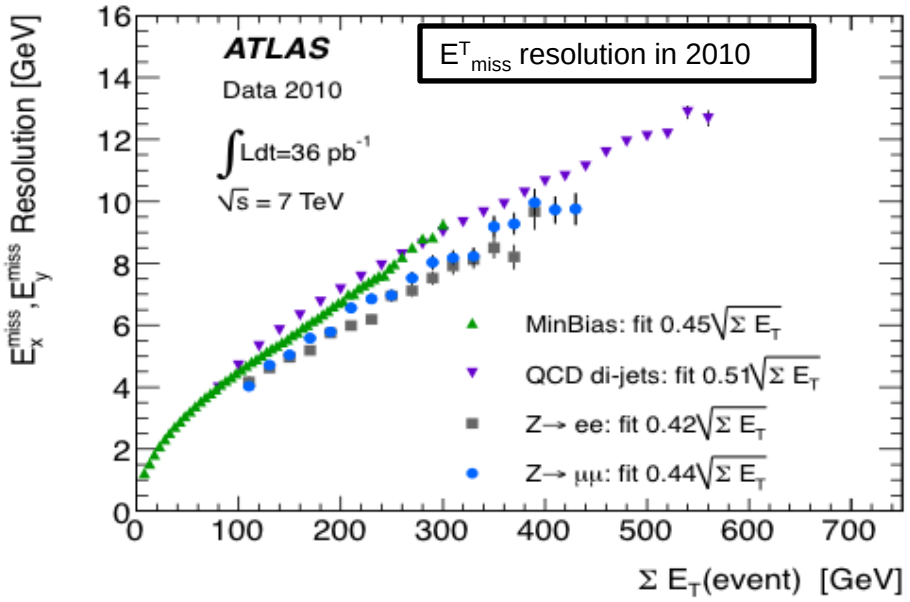




Energy resolution

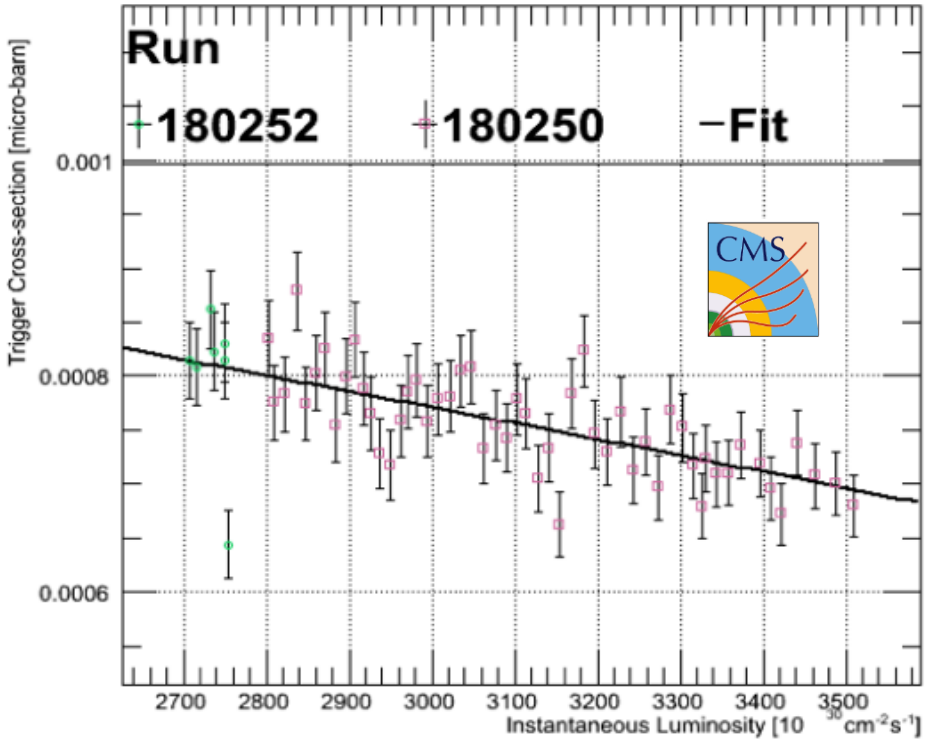
- Pileup events deposit extra energy, giving offset in reconstructed object energies
  - Average offset can be corrected
- The higher fluctuations result also in a smearing of the resolution
  - E.g. missing transverse energy resolution scales with the square root of the total transverse energy that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

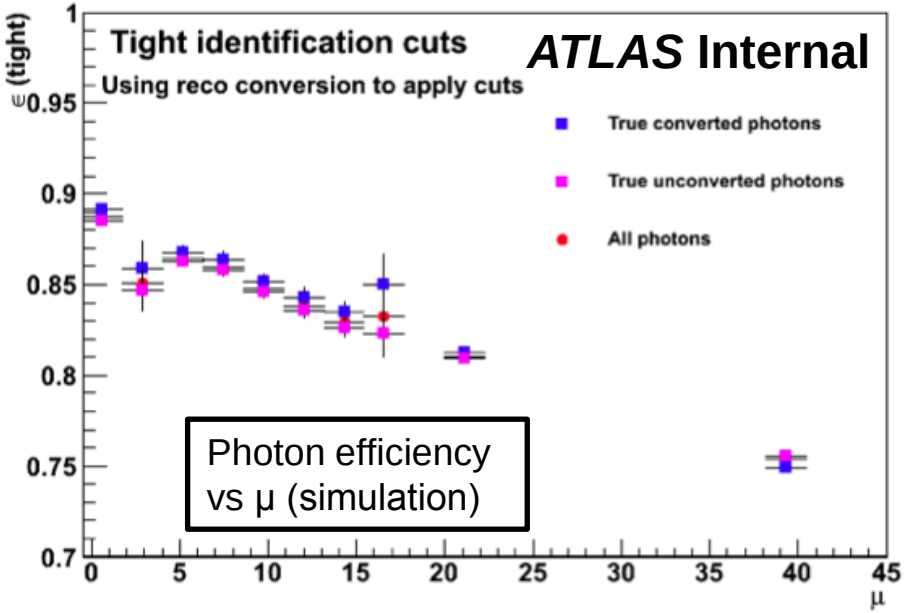




Electron/photon reconstruction efficiency

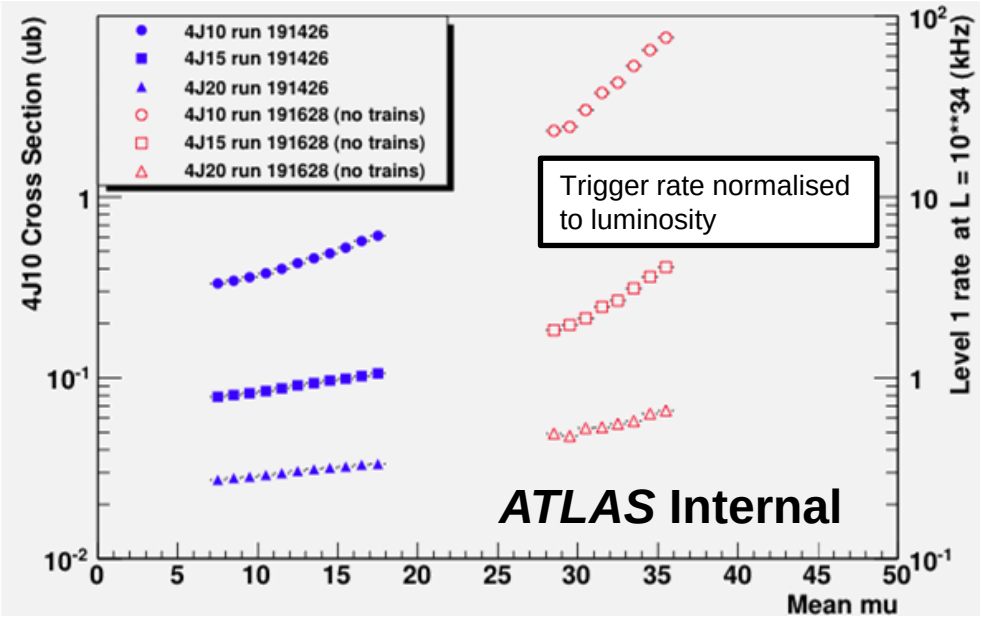
- Electrons and photon identification efficiency depends on shower shapes in calorimeter
  - We hope to recover some of the performance by optimizing shower shape cuts for high pile-up
  - But remember that there are 2 photons in H→γγ …..

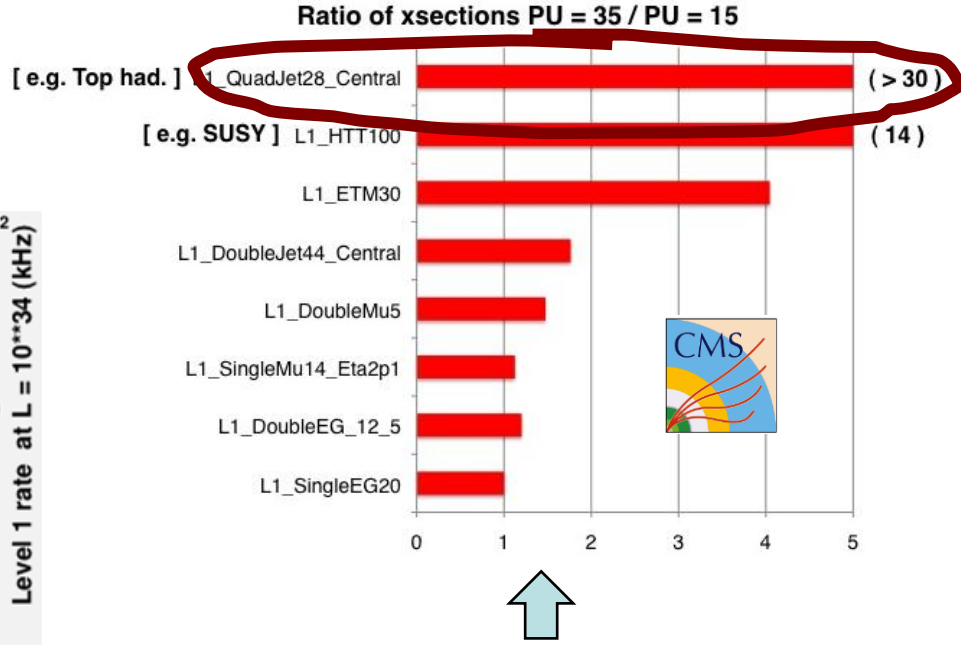




Jet multiplicity

- 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

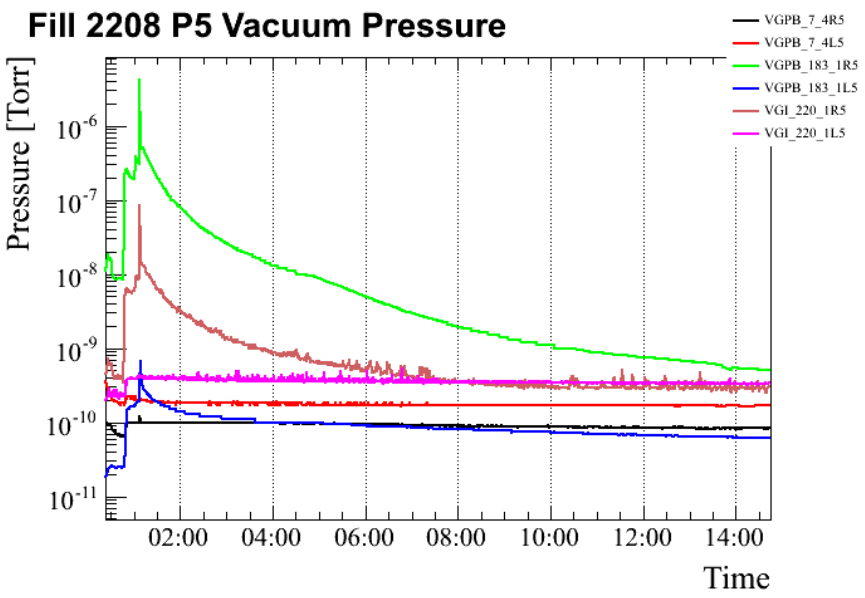
Other effects

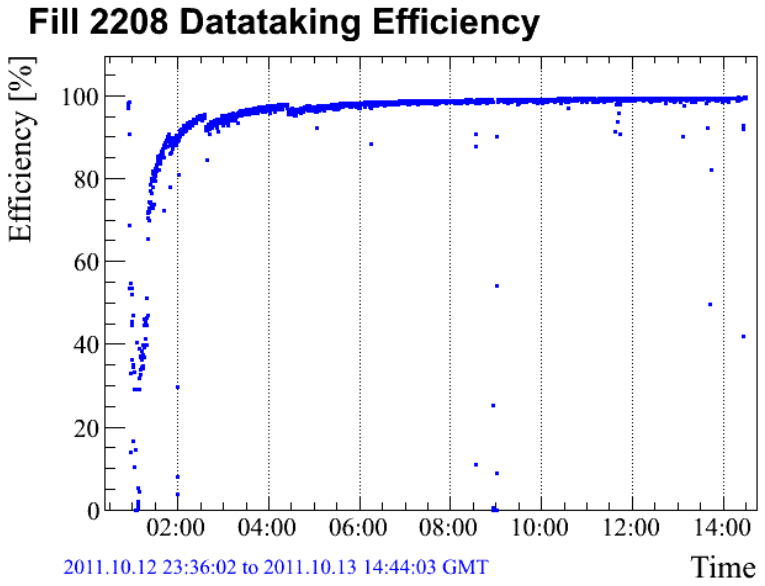
- Event sizes and detector occupancies grow
  - Higher data throughput, hence load on DAQ
  - More disk resources needed
- Reconstruction complexity/time will naively scale with the number of tracks
  - Increased trigger CPU needs
  - Need to adapt algorithms and cuts
  - Increased offline CPU needs
  - 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

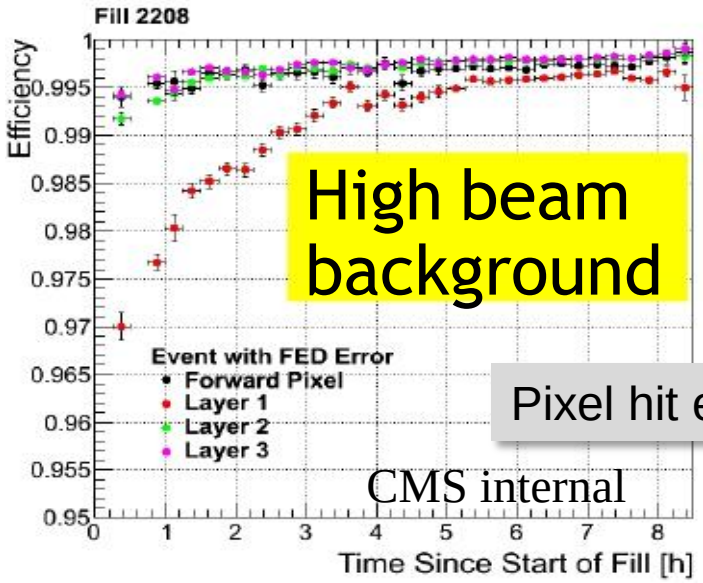
Vacuum situation

- 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

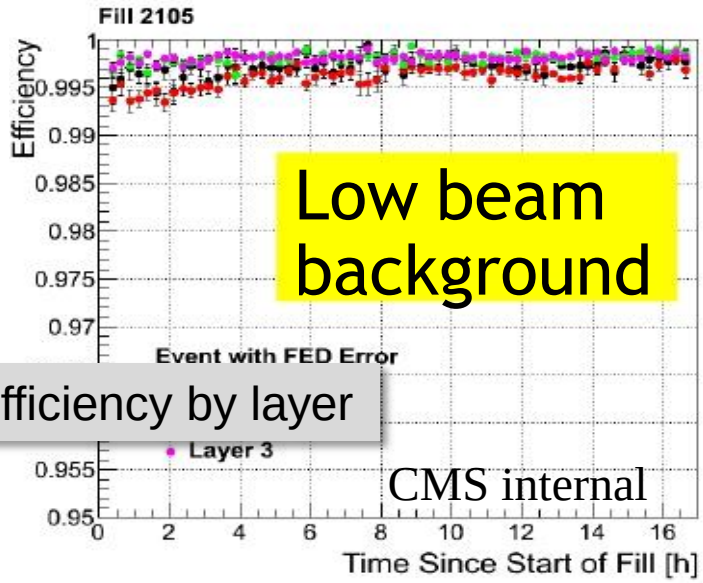
CMS vacuum issues – a typical bad fill







High beam background



Low beam background

Pixel hit efficiency by layer

CMS internal

CMS internal