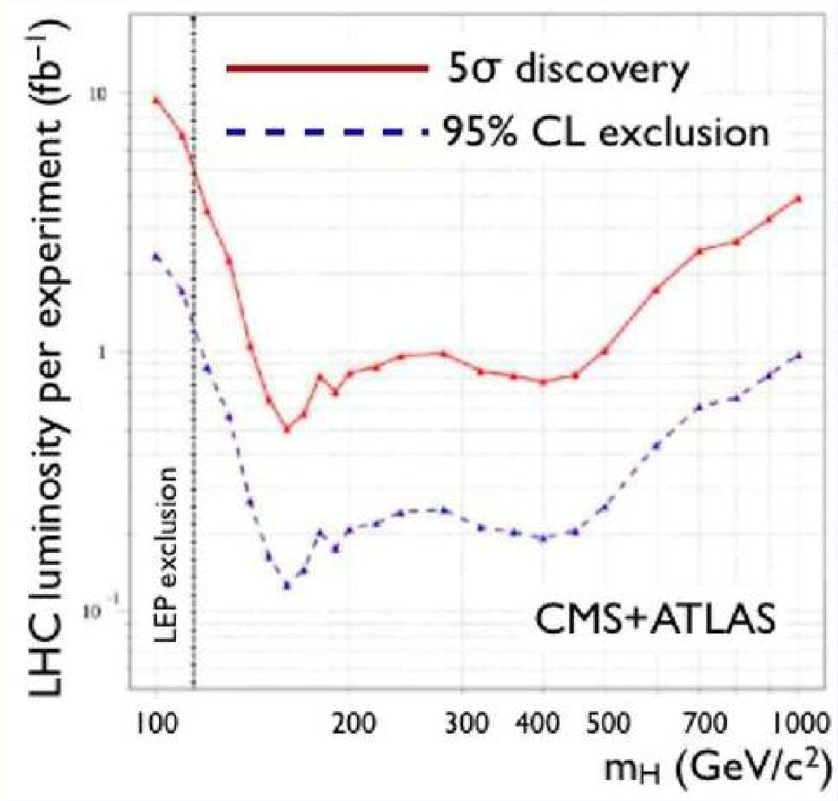
Experiments' view of LHC Upgrade

Physics motivation drives detector needs
Main detector changes
Comments on preferred sLHC options

- mainly from ATLAS point of view

Physics at LHC and sLHC

- LHC is foremost a discovery machine
  - In ~2 years will take enough data (10 fb^{-1}) to discover SM Higgs or rule it out
  - After ~8 years will have ~700 fb^{-1}, enough to discover SUSY to ~1 TeV, W'/Z' to ~5 TeV, many other possibilities
- But just what has been found?
  - Needs much more data --> sLHC
    - Measurement of many parameters
      - Deviation from SM values ==> New physics; needs high precision
- More data will also extend the discovery range to higher masses and rare processes



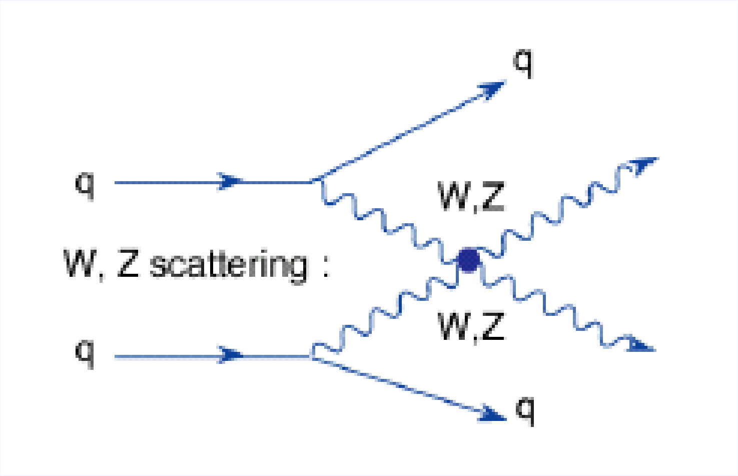
- References:
  - Michelangelo Mangano at SLHC Kick-off Meeting
  - F. Gianotti et al, Eur.Phys.J.C39:293-333,2005

Physics Goals

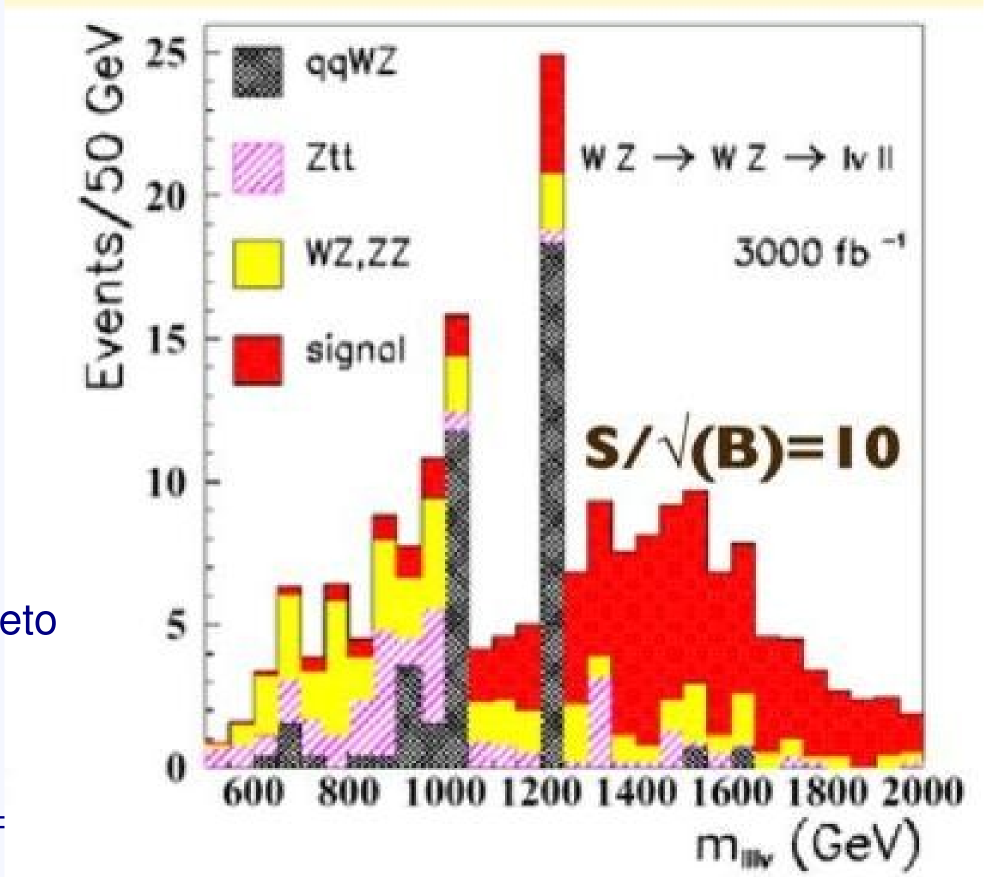
- Higgs couplings to WW, ZZ, HH
  - Check it is a SM model Higgs, deviations as signals BSM
- WW, ZZ scattering at high centre of mass (~1 TeV): understand EWSB
- W', Z' – new forces
- SUSY
  - If sparticles found at LHC, sparticle spectroscopy at sLHC
  - Multiple MSSM Higgses
  - If SUSY particles not found at LHC, increase mass search region at sLHC
- ...and more: Need results from LHC to understand which will be most important

Example: Electroweak Symmetry Breaking

- If a Higgs is found – check it makes vector boson scattering at ~1 TeV CM well behaved
- If not, then strong vector boson scattering needed ~1 TeV
- In either case it is important to study WW and ZZ scattering
  - Low statistics at LHC (few events); clear signal at sLHC even for 1.5 TeV WZ or ZZ resonance

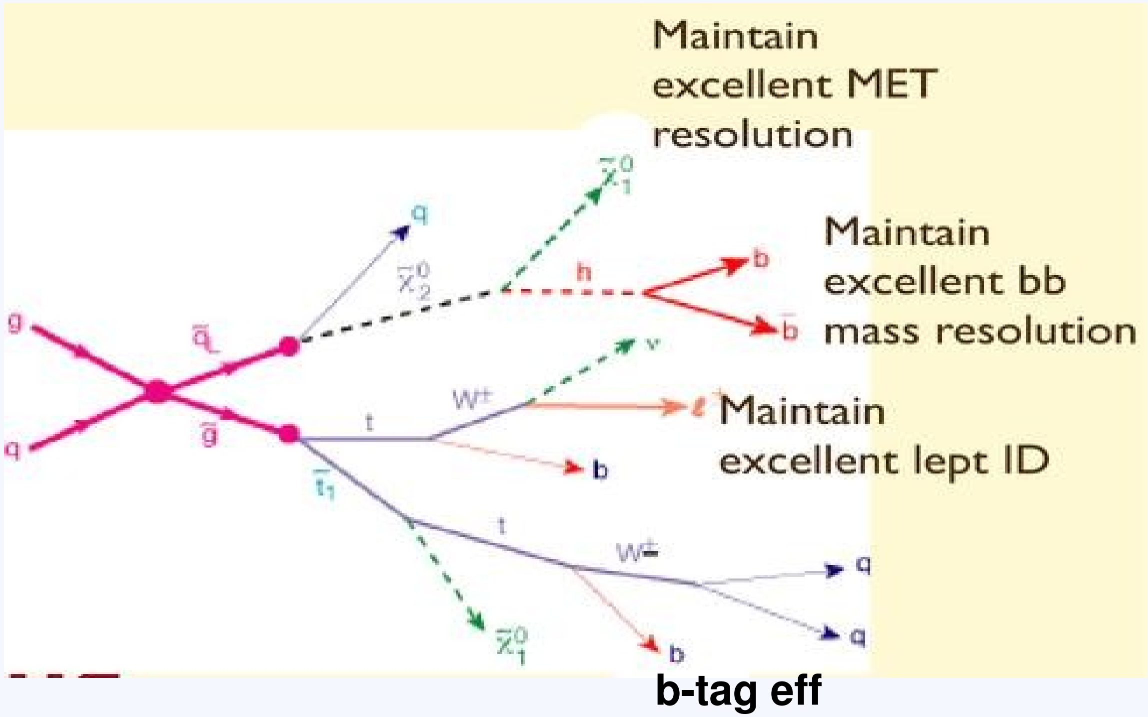


Quarks go forwards
No colour exchange: no jets in central region
Detectors need forward calorimetry and central jet veto



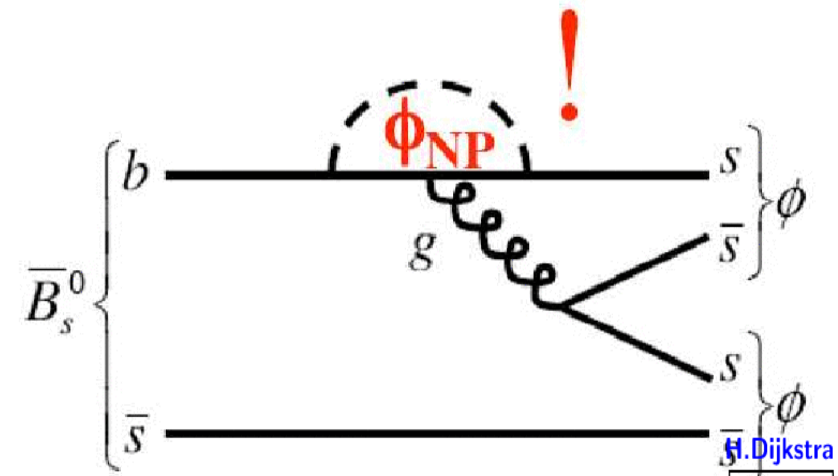
Physics Requirements for Detectors at sLHC

- Detector performance needs to be maintained despite the pile-up!
  - High-mass (~TeV) can tolerate some degradation; low back grounds – e.g. 5 TeV Z'
  - Vertex, missing E_t and p_t resolution remain important, and efficiencies, for many channels of interest
  - Electron ID and muons needed for W/Z, W'/Z', and SUSY



LHCb

- Would like 10x data set
- Do not need higher LHC luminosity
- Better trigger and faster DAQ --> higher event rate to tape
- Read all detectors at 40 MHz -->
  - Good trigger capabilities



Example channels

NP Measurement	10 fb^{-1}	100 fb^{-1}	σ(theory)
$\sigma(\phi_s)$ ($B_s \to \psi\phi$)	0.01	.003	0.002
$\sigma(\beta_s)$ ($B_s \to \phi\phi$)	0.05	.015	<0.002
Pol(γ) ($B_s \to \phi\gamma$)	0.09	0.02	<0.01
$\sigma(s0_{\mu\mu})$ ($B^0 \to K^*\mu\mu$)	0.3 GeV^2	0.07	<exp ?
BR($B_s \to \mu\mu$)	$> 5\sigma$ in SM	$< 10\%$ of BR	<exp

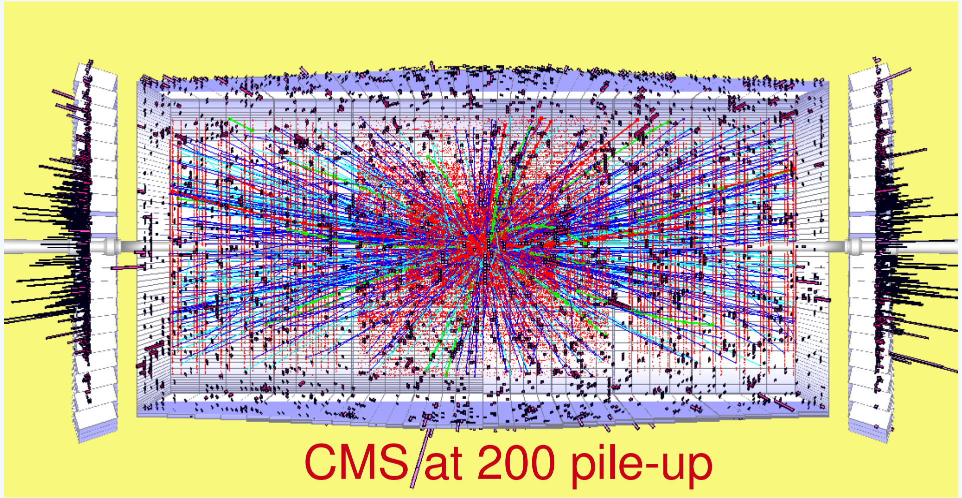
ALICE

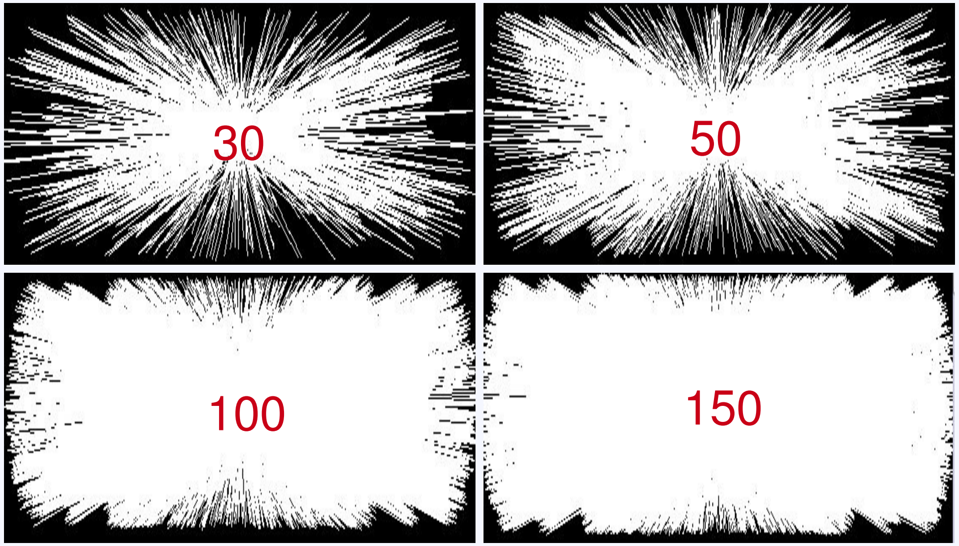
- Also do not need higher pp luminosity
  - Expect to continue needing low pp for ~2 weeks per year
- Considering higher heavy-ion luminosity
- Need data taken and analysed to see which way to go
  - Which improvements in detectors to follow up
- Would like smaller, thinner beam pipe
  - As do ATLAS and CMS

See e.g. Jean-Pierre Revol, LHCC upgrade session
CERN, September 23, 2008 and
Federico Antinori at LHCC Upgrade session
CERN, November 18, 2008

Jean-Pierre Revol
LHCC upgrade session
CERN, Septe

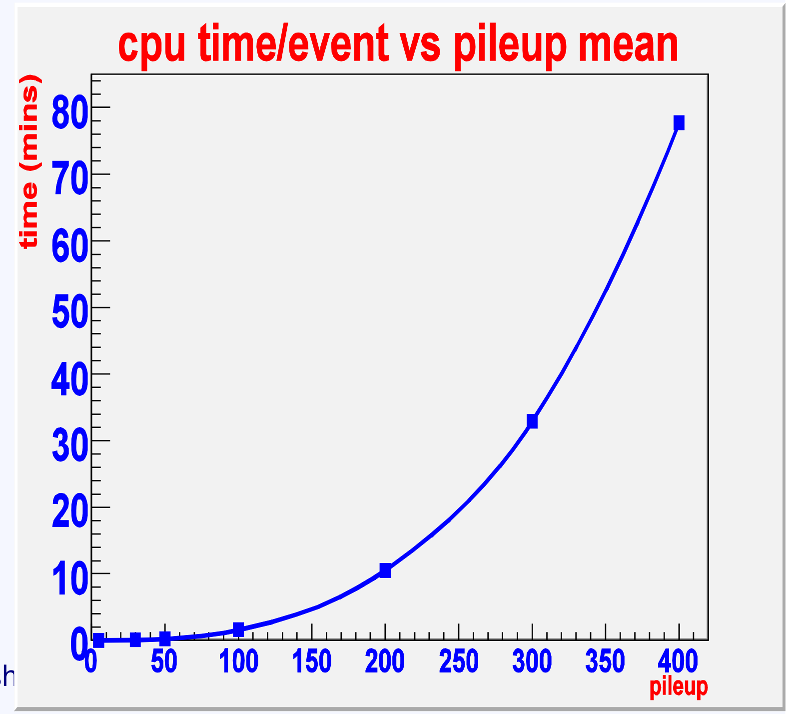
Pile-up: The difficulty





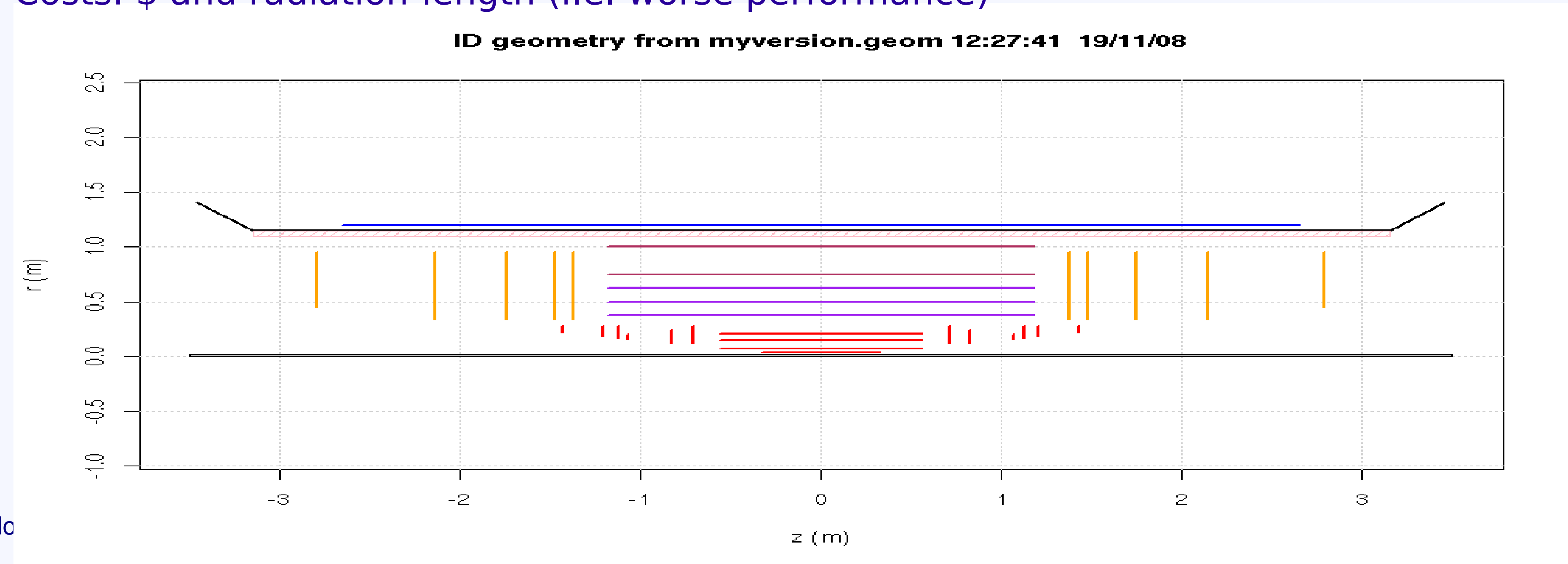
ATLAS

- Inner trackers need smaller detector elements; still pattern recognition problems
- Computing: some cpu-times grow as $N^3 \sim (400/20)^3 = 8000$ in ~10 years
  - Much faster than Moore's law
- Calorimeters suffer pile-up especially affecting low energy performance
  - Forward calorimeters develop many problems
- Muons suffer high hit rate, obscuring the hits we want

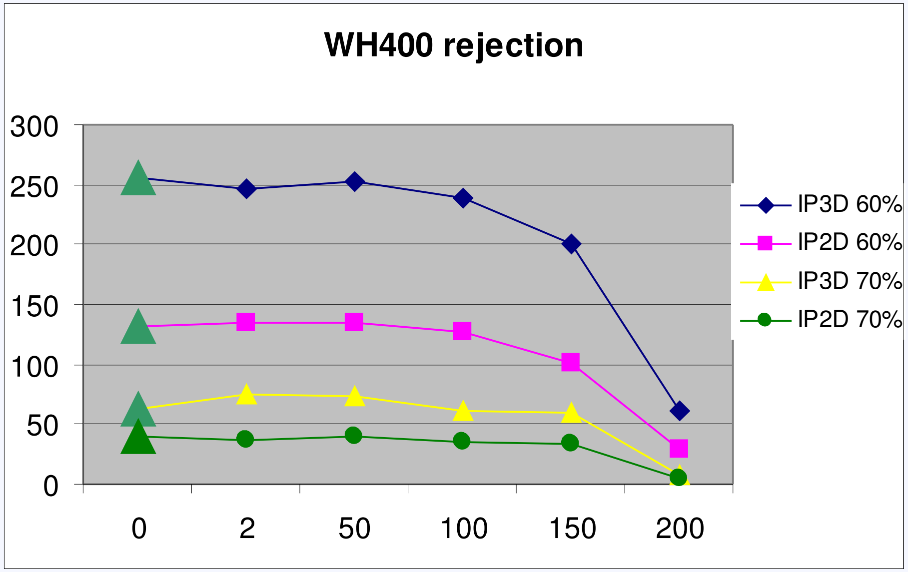


ATLAS Inner Tracker

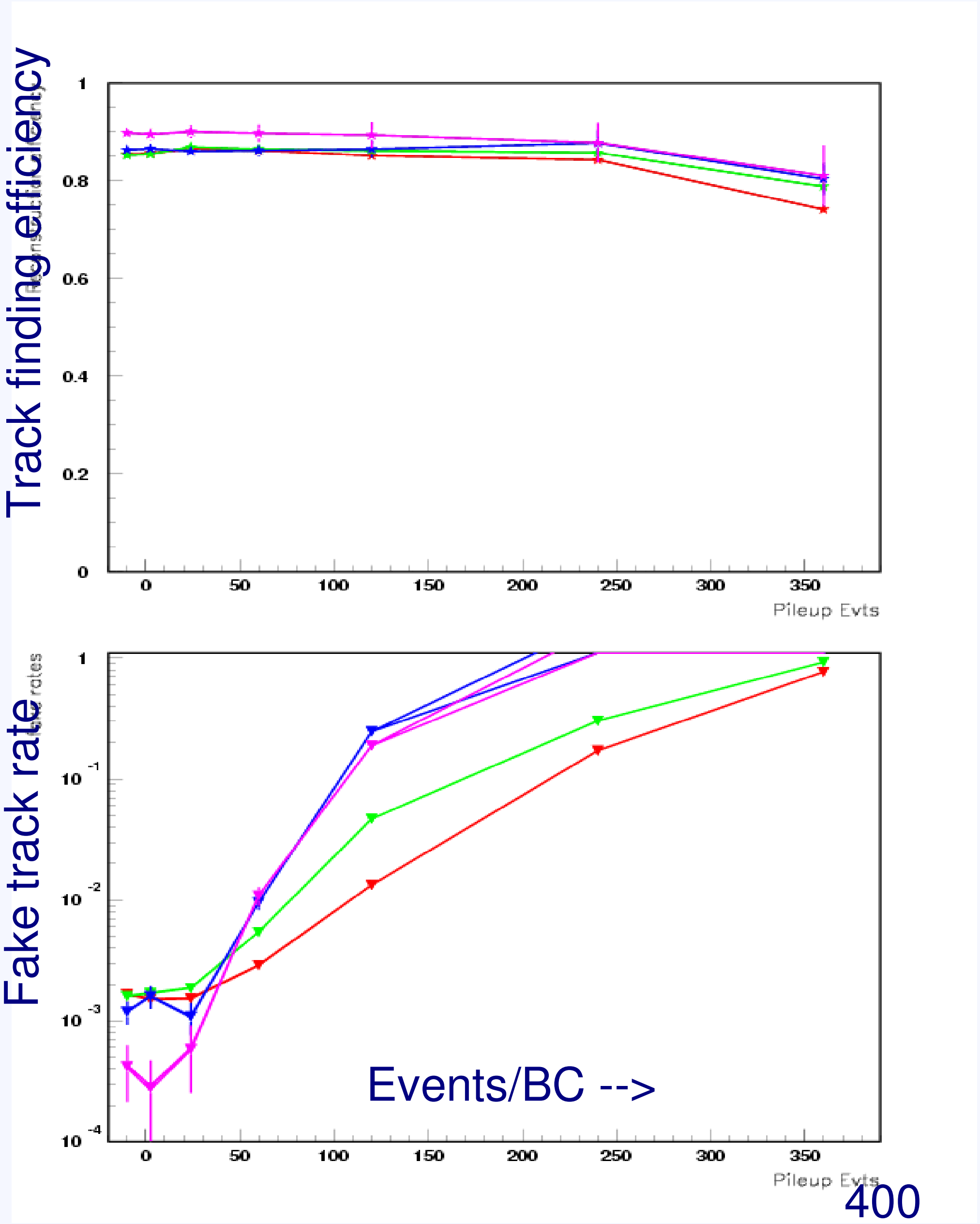
- Strawman layout conceived for ~200 pile-up events per BC
- Results now coming in:
  - Occupancy > 2 % in many regions (target was 1 %)
  - Gives large fake-track rate
  - Vertex measurment fails above 150 – 200 pile-up events
- We can (probably) fix this with higher granularity and better software:
  - Fifth pixel layer in place of first short-strip layer
  - Short strips everywhere else, including current long-strip area
- Costs: $ and radiation-length (i.e. worse performance)



ATLAS Strawman Layout Performance

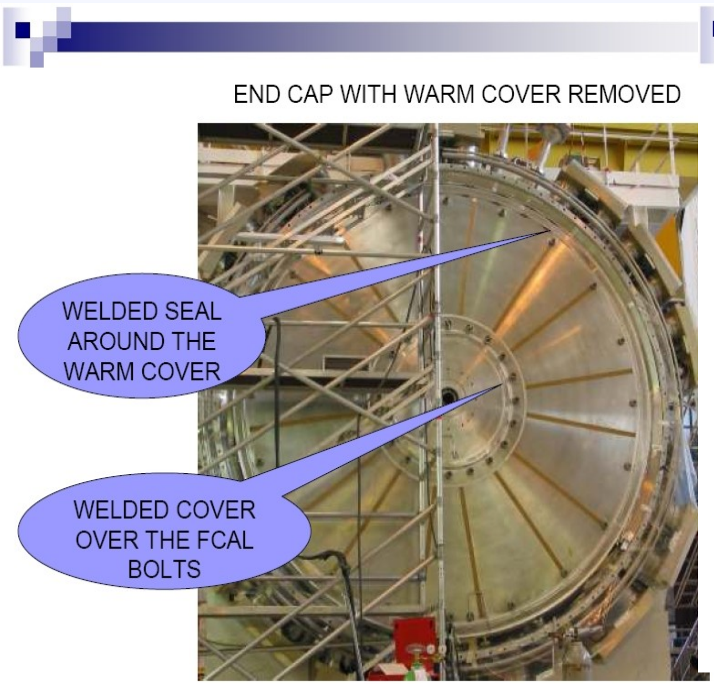


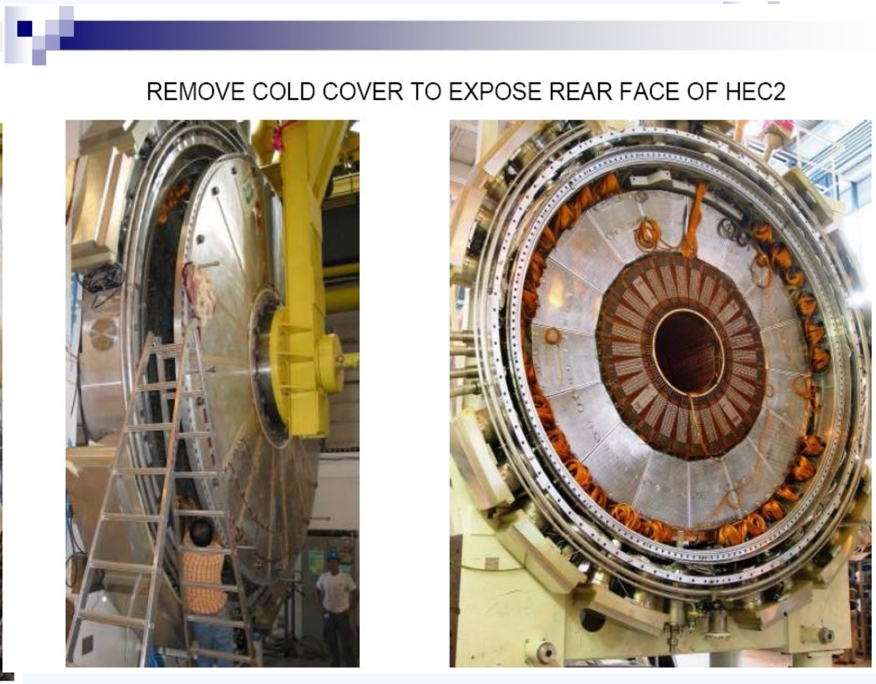
B-tagging performance vs pile-up

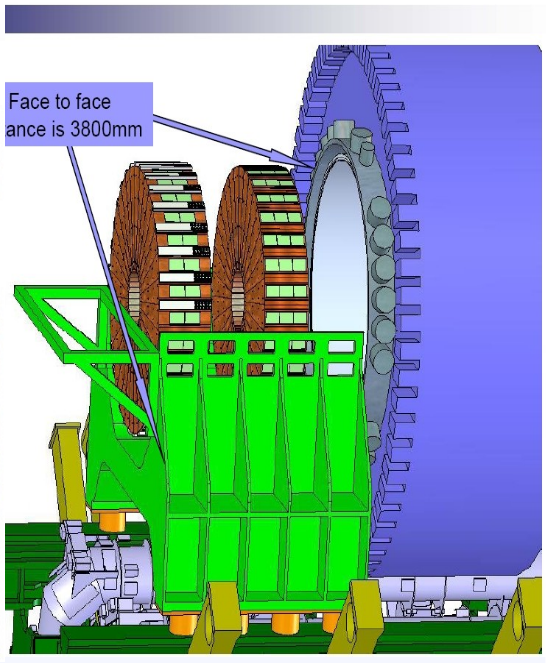


ATLAS Forward Calorimeter

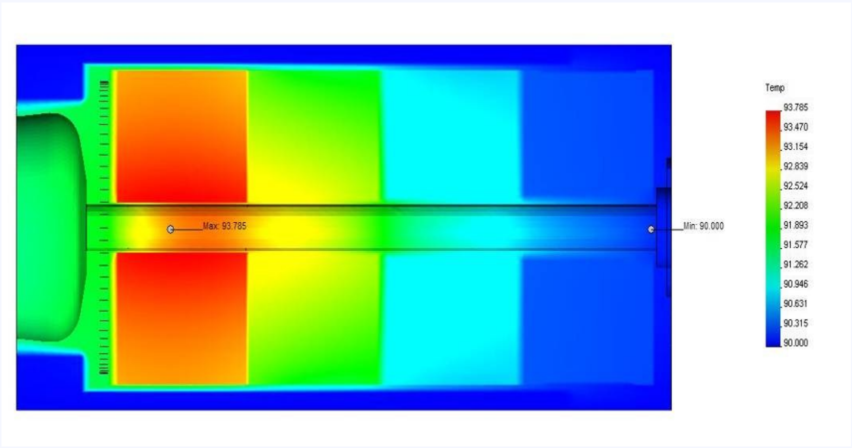
- Electronics in HEC may not last sLHC radiation dose
  - Need to see backgrounds at LHC and follow radiation damage at nominal LHC luminosity
  - Damage ~ integrated luminosity; independent of pile-up
  - Not fixed by shielding with mini-calorimeter in front
- Pile-up dependent effects:
  - Voltage drop across HV resistor; ion build-up in LAr gaps; LAr heating
  - Can be avoided with lower peak luminosity and reduced by mini-FCAL

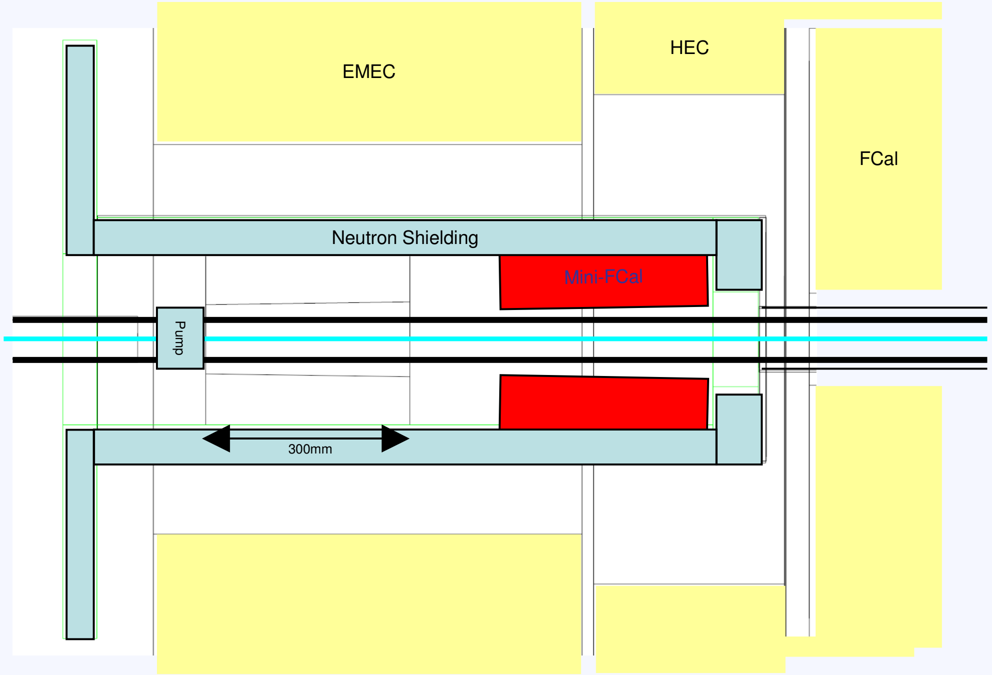






Mini-FCAL to shield current FCAL

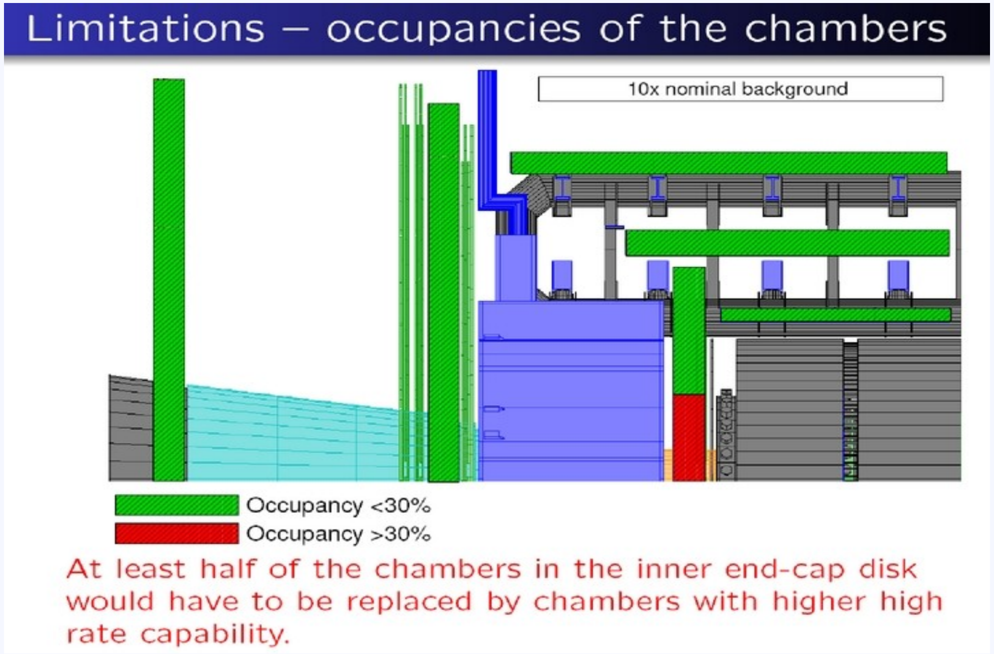


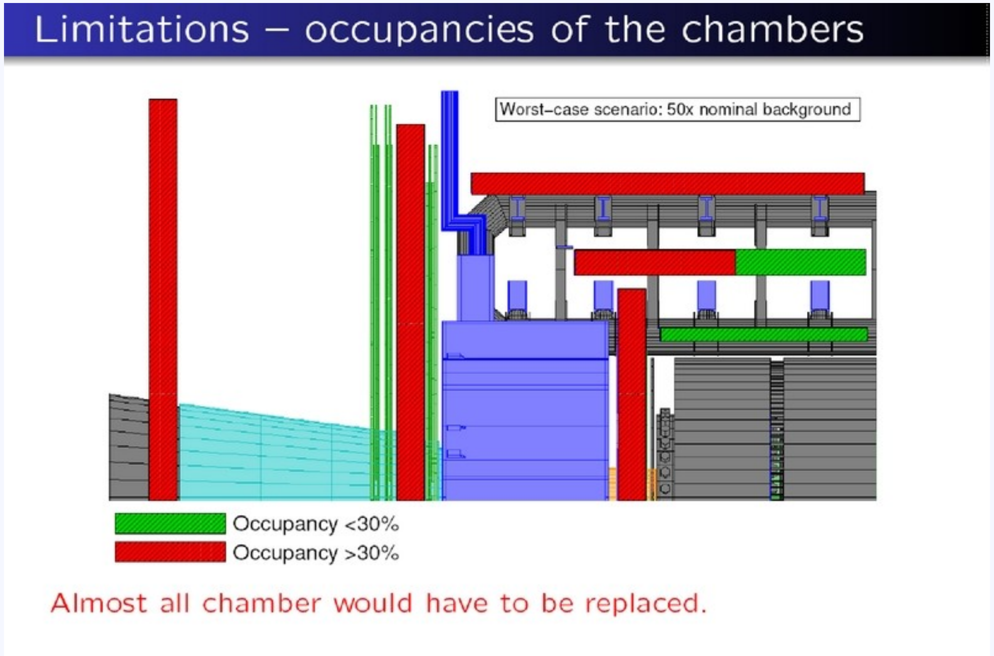


- Heat, HV resistor drop, ion build up can all be reduced with a shield
- Instrumenting the shield recovers the forward calorimetry
- Only useful if HEC electronics will survive – if we have to open the cryostat, it is probably better to put in a new LAr FCAL designed for the high rate

ATLAS Muons

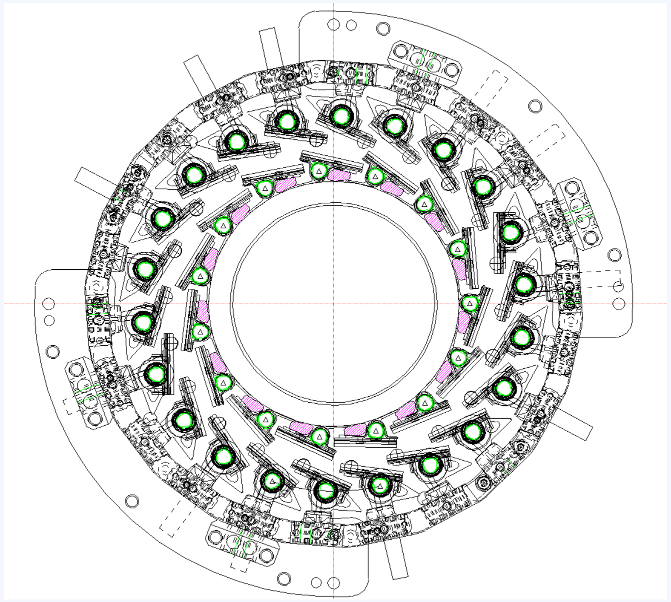
- Less pile-up --> Smaller region where chambers need to be replaced
- Question not only of money, but also schedule: 1200 large chambers cannot be replaced in a one-year shutdown.
- Need results from LHC to know the background





Beam pipes

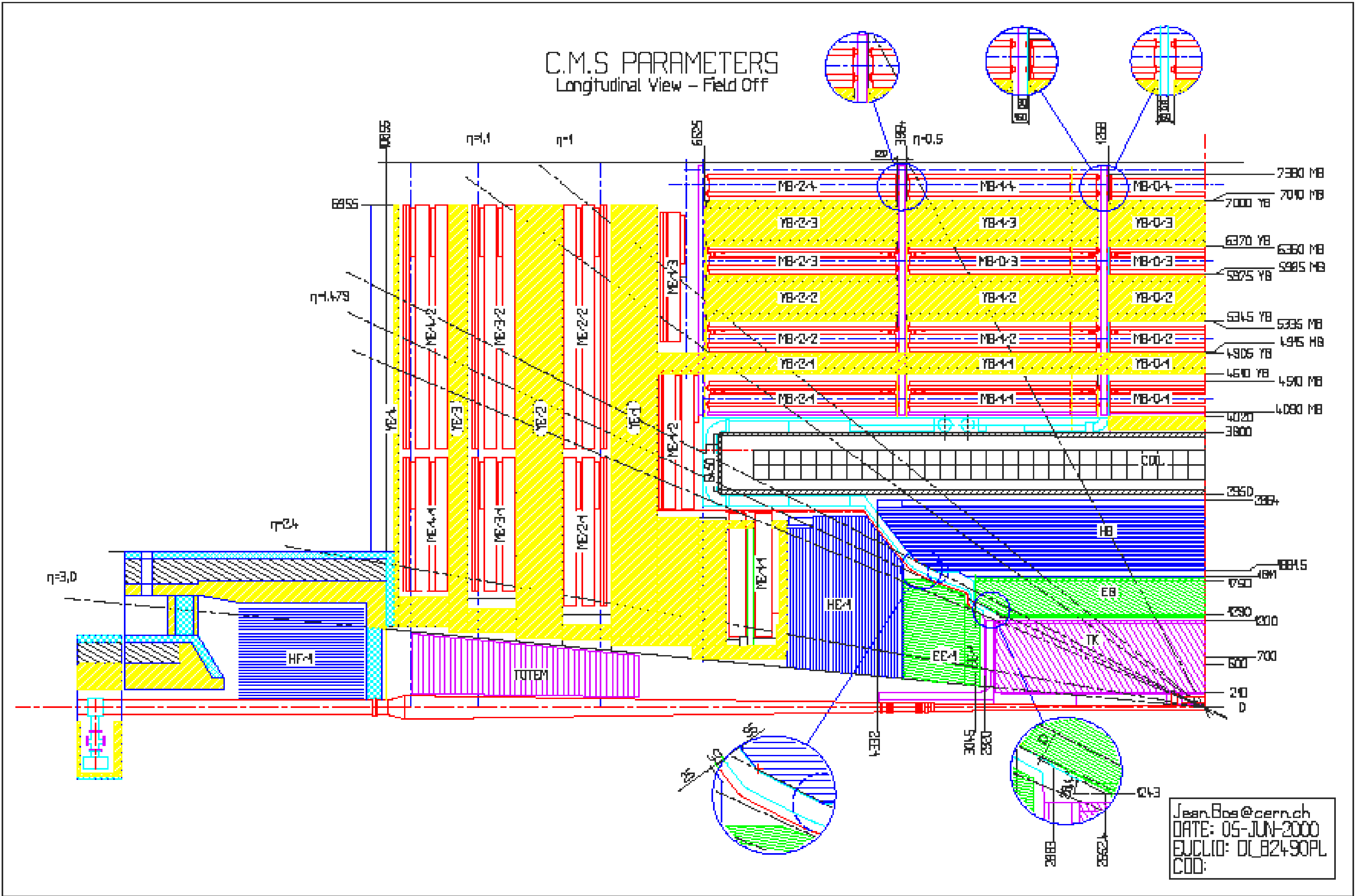
- Smaller beam-pipes allow detectors closer to the beam (except LHCb, where they are inside the beam-pipe)
- ATLAS Insertable B-Layer:
  - Needs to fit inside current pixel and outside beam-pipe – limited space
  - Need few mm reduction in beam-pipe diameter
  - Need to know very soon what is a safe size to engineer
    - i.e. not wait for the smallest possible – we will know it too late
  - Size depends on beam parameters (e.g. Totem needs, new IR design), collimators, alignment, movement of cavern floor, ...
  - Needs meetings between many groups
    - Suggestion to resurrect LEB (LHC Experiments Beam-pipes) group



Magnets in Experiments

- Early separation scheme proposed D0a, D0b; Q0+TAS could benefit various schemes
- There are many possible difficulties: deterioration of detector element performance, increased backgrounds (direct or through less shielding), engineering of supports, space for services, access scenarios, ...
- Studies carried out by Ian Dawson and Mike Shupe using Fluka and Gcalor now provide results on backgrounds at ATLAS
- Ref. https://edms.cern.ch/document/932316
- CMS is very different to ATLAS and does not see any possibility for these magnets as far as I know.
  - Either it goes in front of forward calorimeter, spoiling forward calorimetry
  - Or it gos a long way down-stream (~13 m)

CMS Space



C.M.S PARAMETERS
Longitudinal View – Field Off
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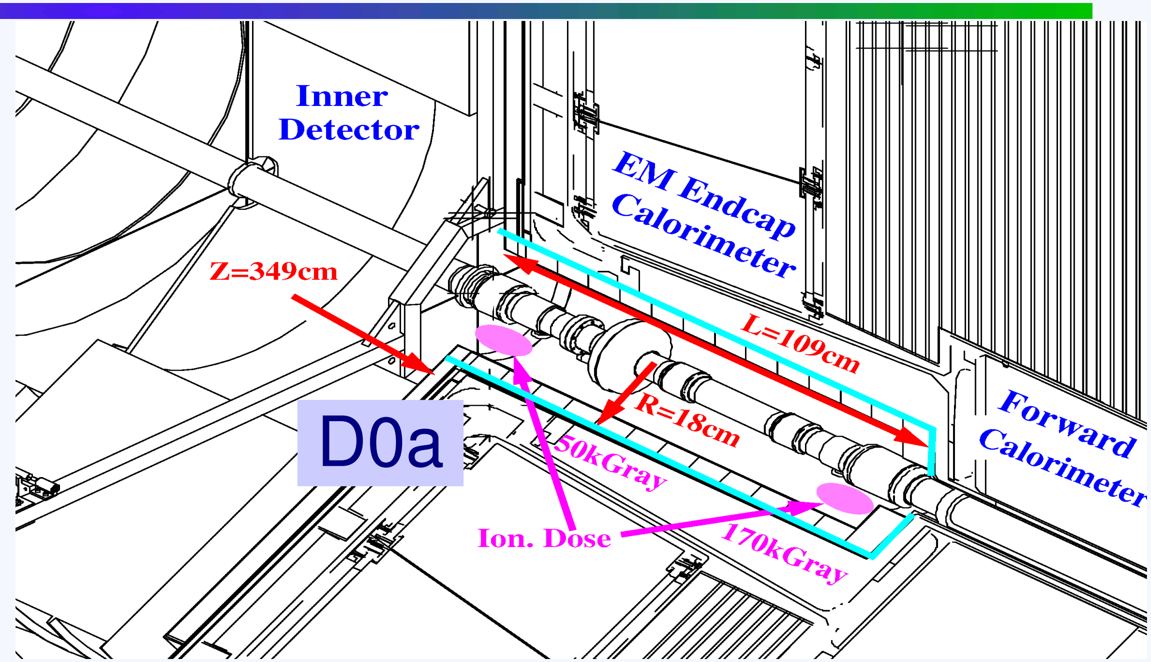
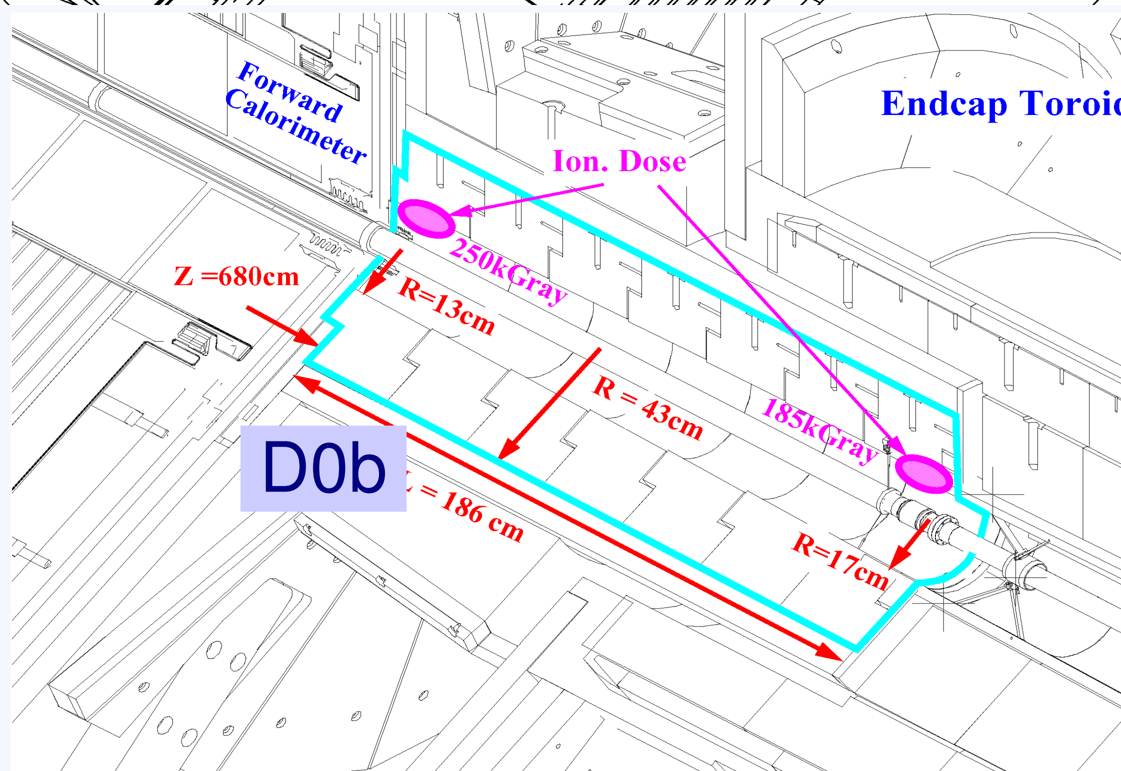
EUCLID: DL_B2490PL
COD:

Magnets in ATLAS

- D0a near ID, inside calorimeter
- D0b just behind calorimeter
- Best performance with both, but D0b alone is significant help
- D0a increases ID radiation ~ 50% in worst area; and spoils forward calorimetry
  - Latter is a show-stopper
- D0b has no effect on ID or calorimetry, but increases background in muon system





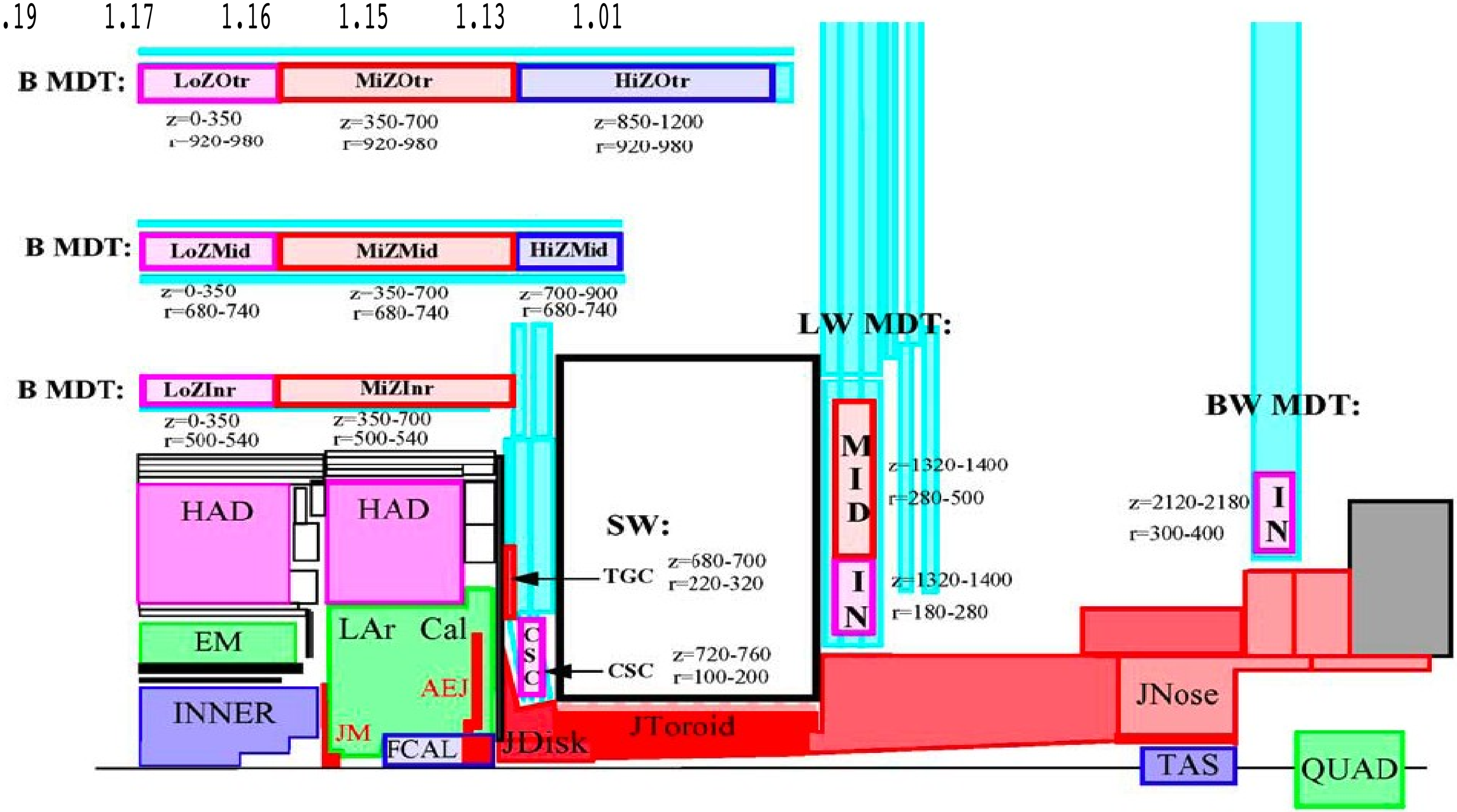
Effect of D0b

FLUX RATIO: UPG D0b 10k / Startup Base 11k

	N<100k	N>100k	Photons	Had>20M	Counts	Triggers
SW CSC	1.31	1.34	1.25	1.25	1.23	1.16
SW TGC	1.22	1.38	1.25	1.32	1.25	1.25
LW MDT In	1.07	1.00	1.01	1.03	1.01	1.01
LW MDT Out	1.15	1.08	1.05	1.04	1.07	1.14
BW MDT In	1.04	1.02	1.06	1.03	1.05	1.03
B RPC HiZMid	1.21	1.28	1.21	1.23	1.21	1.20
B RPC HiZOut	1.19	1.17	1.16	1.15	1.13	1.01

Ref Ian Dawson, Mike Shupe
EDMS doc. no. 932316

Remember: what matters is the count rate. 400 ev/BC without D0b is worse everywhere than 300 ev/BC with D0b



Effects of Slim Quadrupoles

Impact of standard TAS in JTT with standard beampipe on muon syst

FLUX RATIO: TASinJTT 15K / Startup Base 11k

	N<100k	N>100k	Photons	Had>20M	Counts
SW CSC	1.13	1.12	0.97	1.10	1.00
SW TGC	1.21	1.31	1.34	1.33	1.31
LW MDT In	1.20	0.80	0.30	0.77	0.38
LW MDT Out	1.88	1.49	0.73	1.29	0.86
BW MDT In	2.23	1.95	1.37	1.45	1.39
B RPC HiZMid	1.90	1.90	2.04	1.96	1.96
B RPC HiZOut	2.04	2.26	2.18	2.47	2.14

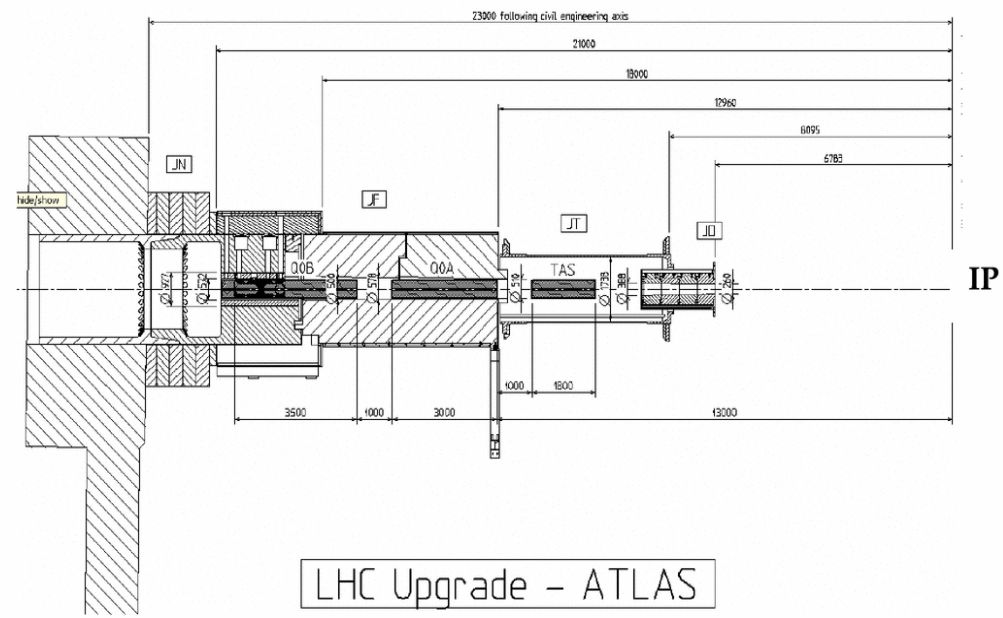


Figure 2: Integration of slim quadrupoles and TAS in the ATLAS insertion region.

- Factor 2 or more in outer barrel: much worse than 400 ev/BC option
- Very large area of muon chambers involved
- The TAS is positioned in the JT which is a weak section of shielding: restricted by the toroid vacuum vessel
- Currently carrying out a study to see if displacing the TAS and Q0 so the TAS is in the JF is OK
  - Not sure if this is any use: very short Q0 or inner triplet...

Summary

- The peak pile-up rate determines the cost and performance of ATLAS and CMS at sLHC
  - Luminosity levelling is very attractive
  - A good target would be to achieve 10 times nominal peak luminosity at 10 times the pileup, i.e. 200 events per BC max; less is better
- ATLAS, Alice and CMS all want smaller, thinner beampipes
  - Need to define very soon for phase-I for ATLAS
- Machine magnets in ATLAS and CMS are difficult
  - The need for WW scattering measurements rules out D0a in front of calorimeters
  - For ATLAS, the D0b looks worth further study (engineering stable supports, services space, maintenance…). The increase in muon system background is OK.
  - For ATLAS, any TAS/Q0 should not come forwards of the JF shielding. More studies needed to see if it is OK in the JF.

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