ATLAS: Detector Operation, Upgrade Plans and Computing

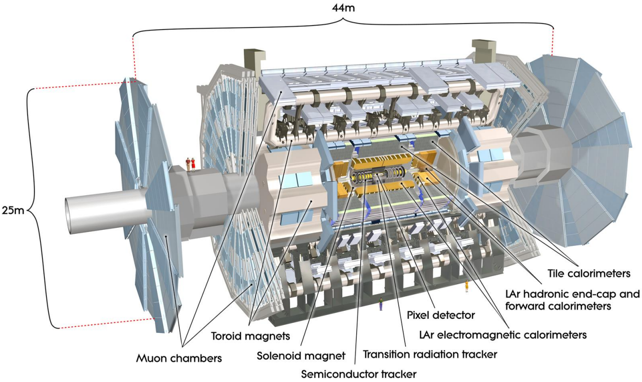
MPP Project Review 2012

Martin Nagel
on behalf of the MPP ATLAS group

Outline

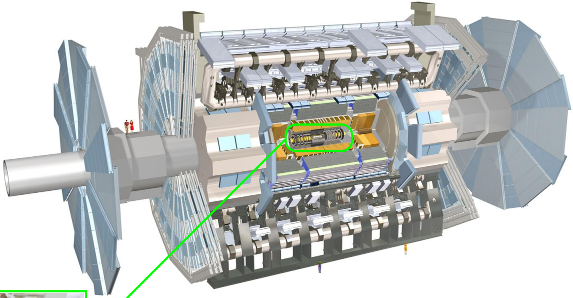
ATLAS

- General purpose detector for proton-proton and heavy ion collisions with full angular coverage
- installed in Large Hadron Collider at CERN

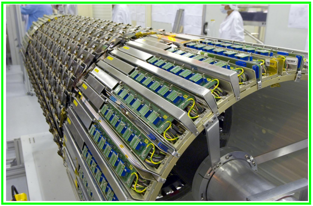


- 25 m high, 44 m long, 7000 t heavy
- superconducting air-core toroidal magnets in eight-fold symmetry outside the calorimeters

MPP in ATLAS (Siegfried Bethke)



SCT



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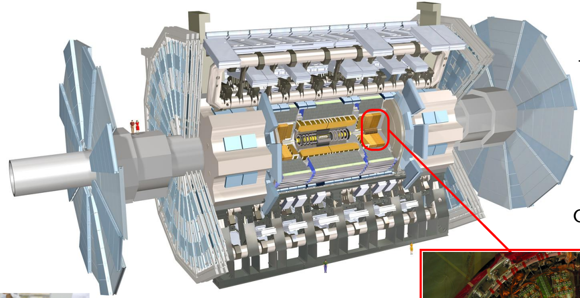

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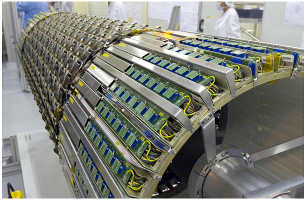

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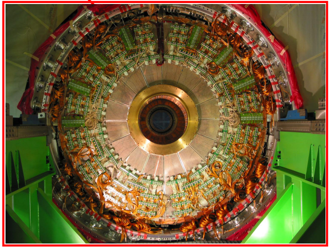
HEC



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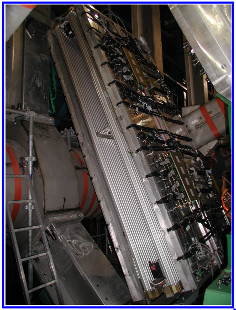
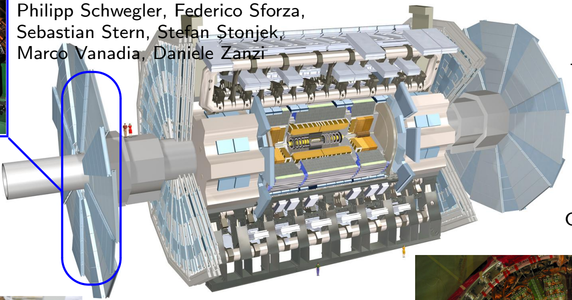


MDT

Bernhard Bittner, Johanna Bronner, Daniele Capriotti, Katharina Ecker, Michael Flowerdew, Maximilian Goblirsch-Kolb, Sandra Kortner (Minerva), Oliver Kortner, Hubert Kroha, Alessandro Manfredini, Sebastian Nowak, Christoph Pahl, Robert Richter, Rikhard Sandstrom, Philipp Schwegler, Federico Sforza, Sebastian Stern, Stefan Stonjek, Marco Vanadia, Daniele Zanzi



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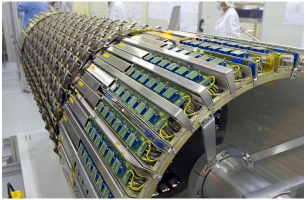

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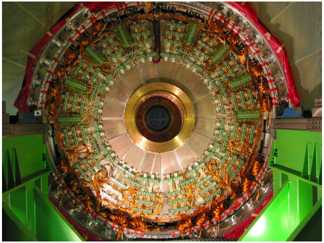

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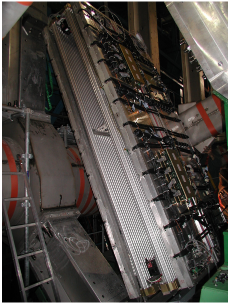

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Gabriele Compostella
Stefan Kluth
Rolf Seuster
Hans von der Schmitt

Computing

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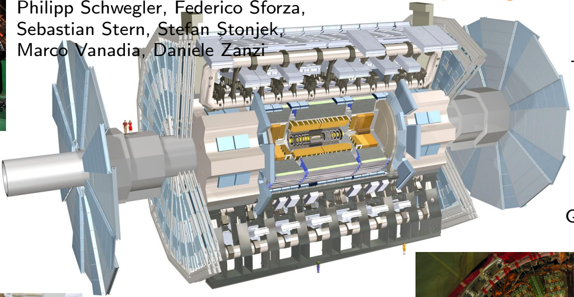

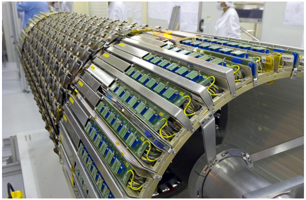

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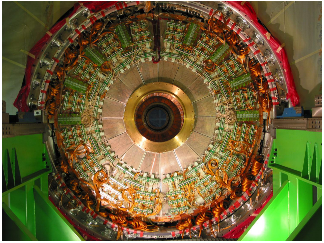
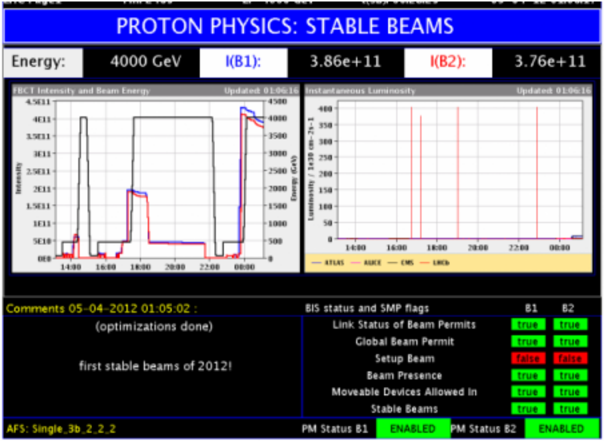


Geneva, 5 April 2012, 0:38 CEST: New world record collision energy of 8 TeV



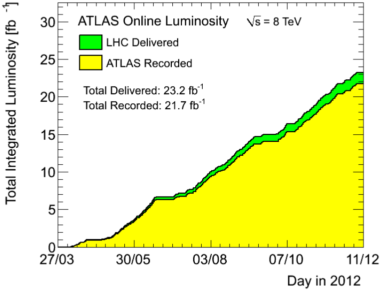
LHC performance in 2012

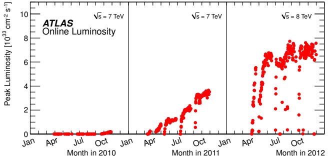
Total integrated luminosity

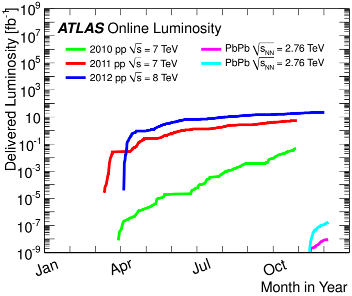
- 2010: 45 pb^{-1}
- 2011: 5.25 fb^{-1}
- 2012: 21.7 fb^{-1} (goal was 16 fb^{-1})

New world record collision energy of 8 TeV

- 50 ns (filled) bunch spacing
- 1380 bunches/beam
- Peak instantaneous luminosity: 7.73 $\cdot 10^{33} \mathrm{cm}^{-2} \mathrm{s}^{-1}$ (24.08.2012)







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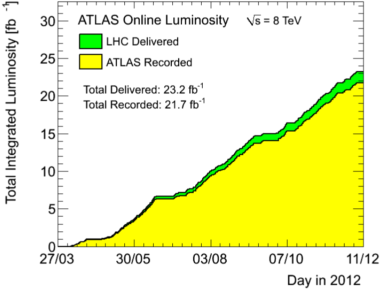
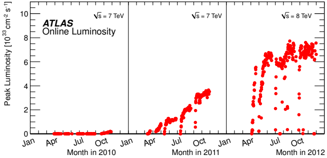
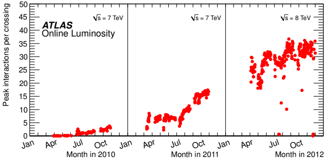
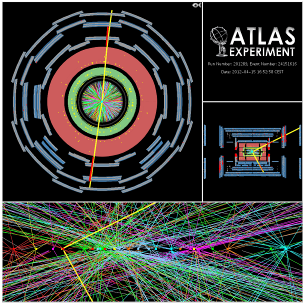








ATLAS performance, MPP contributions in 2012

ATLAS p-p run: April-Sept. 2012										
Inner Tracker			Calorimeters		Muon Spectrometer				Magnets	
Pixel	SCT	TRT	LAr	Tile	MDT	RPC	CSC	TGC	Solenoid	Toroid
100	99.3	99.5	97.0	99.6	99.9	99.8	99.9	99.9	99.7	99.2
All good for physics: 93.7%										

Luminosity weighted relative detector uptime and good quality data delivery during 2012 stable beams in pp collisions at $\sqrt{s}$=8 TeV between April 4th and September 17th (in %) – corresponding to 14.0 fb^{-1} of recorded data. The inefficiencies in the LAr calorimeter will partially be recovered in the future.

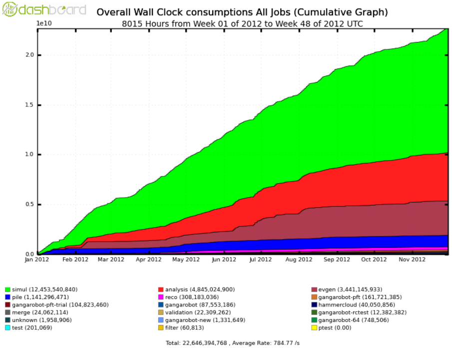
- Inefficiencies in the LAr calorimeter are mostly due to noise bursts and HV trips
- After reprocessing, LAr reaches comparable high efficiency (99.6% for period H-L)

- Performance work
  - SCT: inner tracker alignment
  - HEC: topological clusters, local hadron calibration, MET performance studies, LV hardware/software, HEC local expert on call
  - MDT: muon chamber alignment and calibration, operation of muon calibration centre, muon DQ expert on call (S. Stern)
- Coordinating roles
  - ATLAS Speakers Committee chair: Hubert Kroha
  - Computing coordinator: Hans von der Schmitt
  - Software coordinator: Rolf Seuster
  - Higgs co-coordinator: Sandra Kortner
  - LAr Speakers Committee chair: Sven Menke
  - Muon combined performance co-coordinator: Oliver Kortner
  - Muon calibration coordinator: Michael Flowerdew

	2012												2013		2012-13	2012-13	2012-13
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	Alloc	Req	Alloc/Req
Germany - MPI		7.2	6.6	32.2	23.7	16.4	32.8	5.2	26.3	21.0	26.9	9.2	11.2	7.2	226	173	130%

Computing

The MPP ATLAS Computing group is operating a Tier2 centre at Rechenzentrum Garching, as part of the Worldwide LHC Computing Grid (WLCG)



← Wall clock time (WCT) consumption in 2012: shows what type of jobs consume most CPU time

simulation

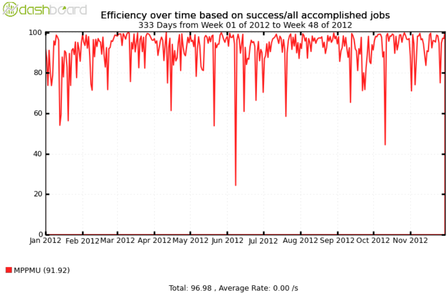
user analysis

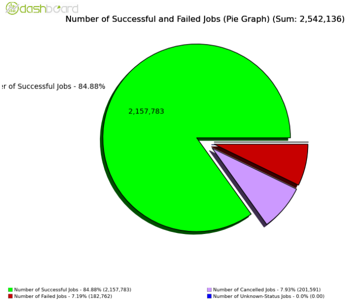
event generation

Within the DE cloud in 2012, the **highest contribution in terms of run jobs** comes from the federated MPPMU + LRZ-LMU Tier2 site

Grid job efficiency over time →

- Good performance all through 2012
- Issues were resolved quickly and without any noticeable impact on Atlas activities





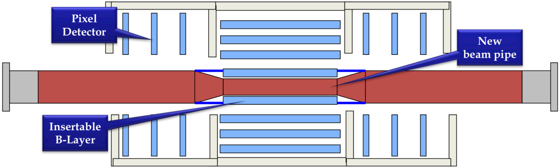
← Overall Grid job efficiency at MPPMU:

- Number of failed grid jobs < 10%
- considered 'usual' within highly distributed systems
- Studies to reduce failure rate: large efforts required for small improvements ⇒ more efficient to just resubmit jobs

Timeline for LHC and detector upgrades

Year	Event	MPP contributions
2009	**Start of LHC**	
	Run 1: $\sqrt{s} = 7/8\mathrm{TeV}$, $\mathcal{L} \sim 3 \cdot 10^{33}\mathrm{cm}^{-2}\mathrm{s}^{-1}$, $\sim 20\mathrm{fb}^{-1}$ delivered	
2013-14	**Phase 0: LHC shut-down to prepare machine for design energy and nominal luminosity**	IBL installation; sMDT installation
	Run 2: $\sqrt{s} = 13 - 14\mathrm{TeV}$, ramp up to nominal luminosity ($10^{34}\mathrm{cm}^{-2}\mathrm{s}^{-1}$), deliver $\sim 50 - 100\mathrm{fb}^{-1}$	
2018	**Phase 1: Injector and LHC upgrade to full design luminosity**	
	Run 3: Ramp up luminosity to $\sim 2\times$ nominal, accumulate a few hundred fb^{-1} ($\sim 100\mathrm{fb}^{-1}/\mathrm{year}$)	
∼2022	**Phase 2: High-luminosity (HL) LHC: new focusing magnets and Crab cavities for high luminosity with levelling**	Pixel replacement; HEC RO electronics; sMDT installation, RO electronics, L1 muon trigger
	Run 4: $\mathcal{L} \sim 5 \cdot 10^{34}\mathrm{cm}^{-2}\mathrm{s}^{-1}$, collect data until $\geq 3000\mathrm{fb}^{-1}$	
∼2030	**End of data taking**	

SCT Phase 0: Insertable B-Layer (IBL) installation



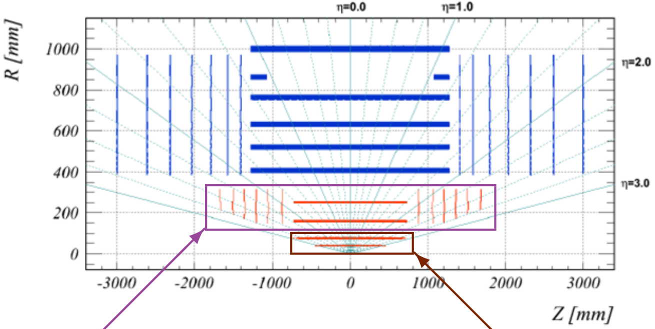
- The major ATLAS upgrade during 2013/14 LHC shutdown
- An additional pixel layer with an advanced technology to maintain and improve the pixel detector performance at higher luminosities
- Closer to the interaction point (only 3.3cm)

Schedule (completions)

- May 2013: module, stave, and off-detector production
- August 2013: stave loading on new beam pipe
- December 2013: final system tests and commissioning on surface
- June 2014: installation in pit, commissioning and sign-off for closure

MPP contributes on all aspects of IBL module QA: defining procedures, testing, rating and software development for commissioning and calibration

Phase 2: full pixel system replacement with 4 or 5 layers

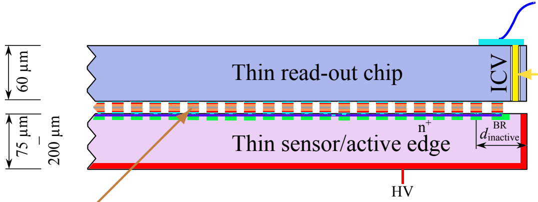


Outer layers (r=10-30cm): $5 \cdot 10^{15} \mathrm{n/cm^2}$

- up to 10 $\mathrm{m^2}$ pixel surface
- cost-effective n-in-p pixel sensors
- thickness 150-300 μm

Inner layers (r=3-10cm): $2 \cdot 10^{16} \mathrm{n/cm^2}$

- thin planar pixel sensors
- thickness 75-150 μm
- vertical integration, active edges



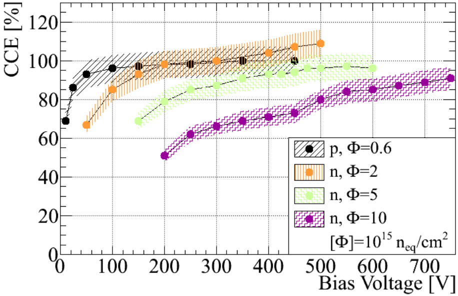
Solid Liquid Interdiffusion (SLID):

- CuSn soldering
- alternative to bump-bonding

Through Silicon Vias (TSV):

- Signals and services brought across the read-out chip
- no need of chip to extend beyond the sensor

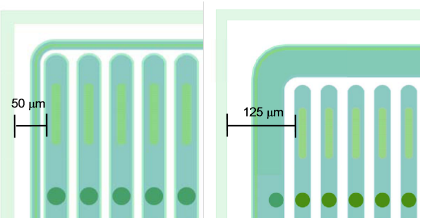
$\Rightarrow$ more compact pixel module

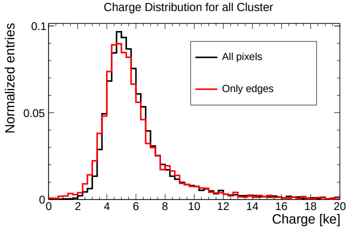


$\leftarrow$ SLID module with 75μm HLL sensor:

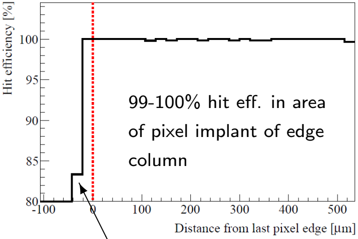
- shown is charge collection efficiency normalized to unirradiated value
- tested successfully up to $10^{16}\mathrm{n}/\mathrm{cm}^2$

- ATLAS: 1mm guard ring around pixels for breakdown protection and E-field smoothing $\Rightarrow$ inactive area
- Alternative: active edge pixels through implanted side walls
- MPP-HLL design with active edge of 125μm and 50μm (250μm used for IBL)
- Produced at VTT in Finland with 100μm thick sensors





Edge pixels exhibit same charge collection properties as central ones

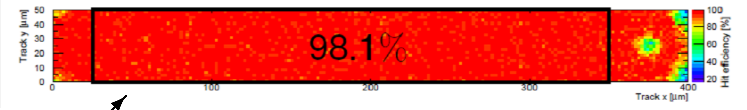


83% hit eff. in area between last pixel implant and active edge

SCT Phase 2: n-in-p sensor technology (outer layers)

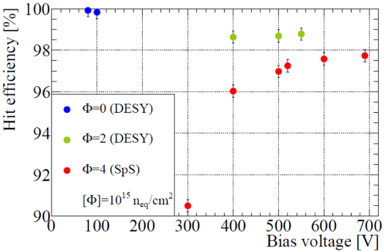
- cost-effective through single-side processing

Test beam results:

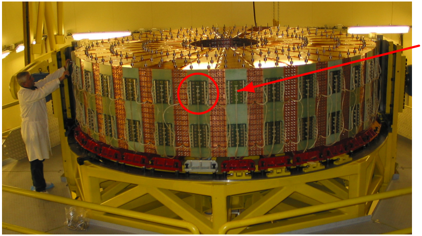


FE-I3 chip (current ATLAS readout chip):
hit efficiency at $V_{\text{bias}} = 600\,V$
for $\Phi = 10^{16}\text{n/cm}^2$

FE-I4 chip (new IBL chip):
hit efficiency vs. bias voltage



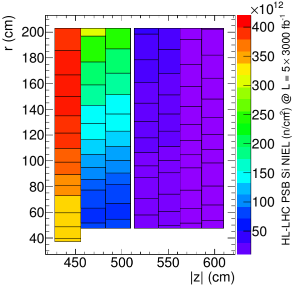
MPP group demonstrated feasibility of n-in-p technology for outer pixel layers



- HEC readout electronics are mounted on outer circumference of HEC wheels, inside liquid Argon cryostat, in high radiation area
- Radiation hardness tested for ten years under LHC conditions

Expected radiation levels for 10 years of operation of HL-LHC, including a safety factor of 5:

- NIEL: 4.1$\cdot 10^{14}$ $\mathrm{n/cm^2}$
- Hadrons ($E_{\mathrm{had}} > 20\mathrm{MeV}$): 5.1$\cdot 10^{13}$ $\mathrm{h/cm^2}$
- TID: 6.2 kGy

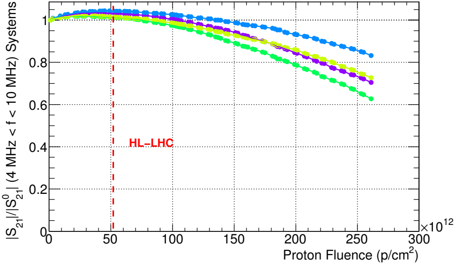


1 MeV neutron equivalent NIEL dose

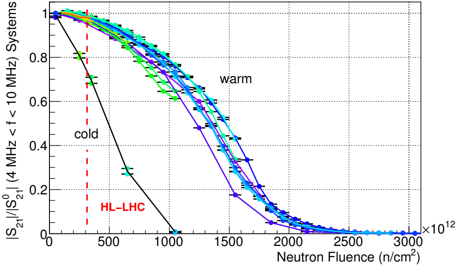
Extensive test beam program by MPP group:

- Hadrons ($E_{\mathrm{had}} > 20\mathrm{MeV}$): 200 MeV proton beam from PIF at P.-Scherrer-Inst., CH
- NIEL: neutron beam from $\mathrm{D_2O(p,xn)}$ reaction from FNF at Nat. Phys. Inst., Rez, CZ

proton



neutron

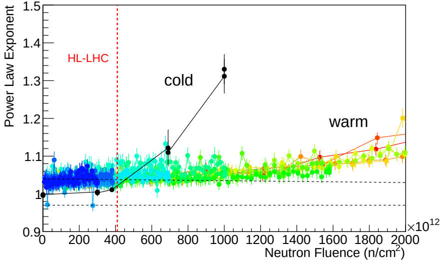


In-situ measurement of HEC cold amplifiers at RT during irradiation:

- Several boards placed along the beam
- Plotted is normalized gain parameter
- In general, protons cause more damage
- Neutrons are dominant factor due to higher abundance

Performance degradation in cold significantly worse!

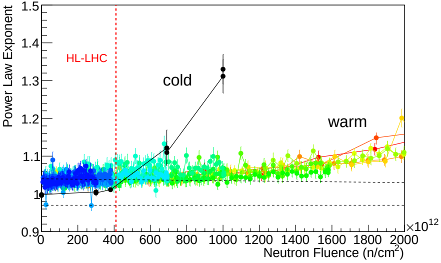
HEC cold amplifiers: linearity



Measurement of a set of typical input and corresponding output pulses during irradiation to analyze linearity of HEC response:

Non-linearities in cold significantly worse!

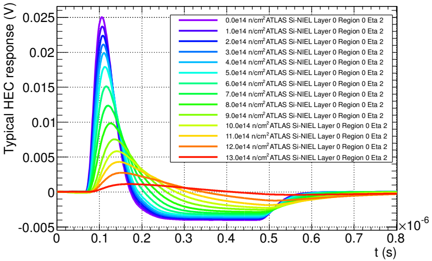
HEC cold amplifiers: linearity; Impact on HEC response



Measurement of a set of typical input and corresponding output pulses during irradiation to analyze linearity of HEC response:

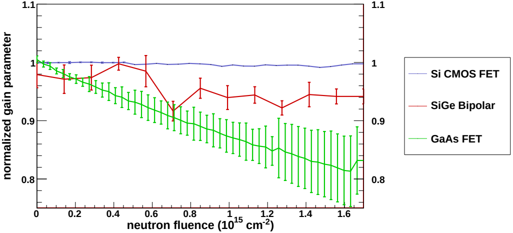
Non-linearities in cold significantly worse!

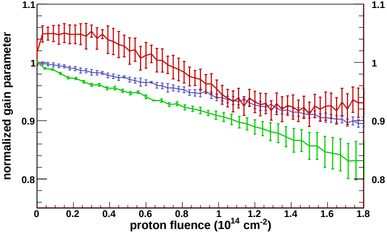
- Detailed simulations to evaluate impact of gain degradation and spread, impedence mismatch, and non-linearities, on HEC response to a typical triangular input current pulse
- Study of the effects of these degraded pulse shapes on physics performance ... ongoing analysis
- Simulation and analysis of transistor models to identify material parameters responsible for radiation damage



HEC cold amplifiers: alternative technologies

In-situ measurement of currrent (GaAs FET) and alternative (Si CMOS FET, SiGe Bipolar) transistor technologies under irradiation:



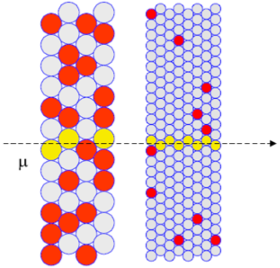


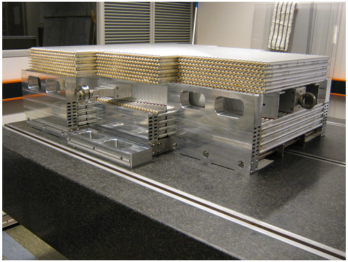
- Alternative technologies more radiation hard than current GaAs technology
- SiGe Bipolar transistors require stabilization of operation point
  $\rightarrow$ Si CMOS FET technology of choice
- Goal: first full amplifier design submission by 2013

MDT: new small-diameter drift tube (sMDT) chambers

Reduce drift tube diameter from 30mm to 15mm:

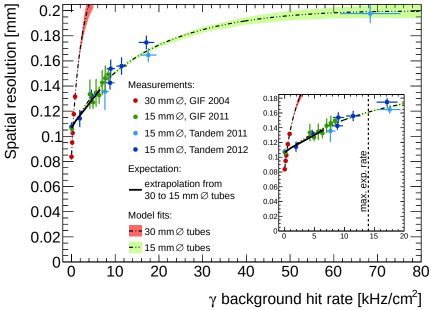
- 7.6 × lower occupancy
- 4.5 × shorter deadtime
- 8.6 × less gain loss due to space charge
- drift velocity independent of electric field and space charge fluctuations
- up to twice the number of layers



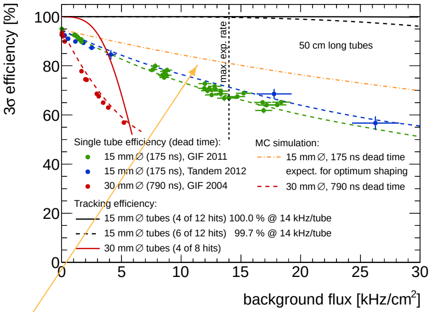


Development and production by MPP group only!

Irradiation tests performed with γ irradiation (CERN) and proton irradiation (Munich Tandem accelerator):
Excellent performance up to very high rates far exceeding the maximum requirements for HL-LHC (14 $\mathrm{kHz/cm^2}$ background flux)



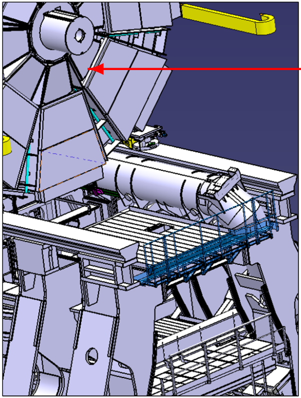
Single tube resolution

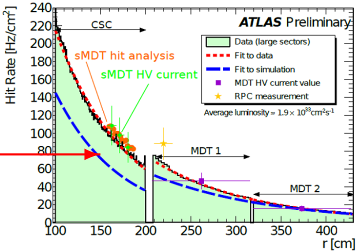


Single tube tracking efficiency (hit on track within 3σ resolution)

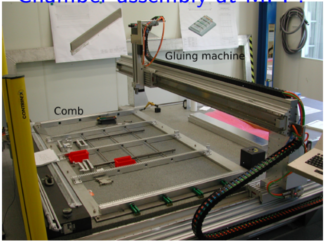
Room for further improvement with new read-out electronics under development

Measurement of background rates in highest rate region (inner bore of small wheel):





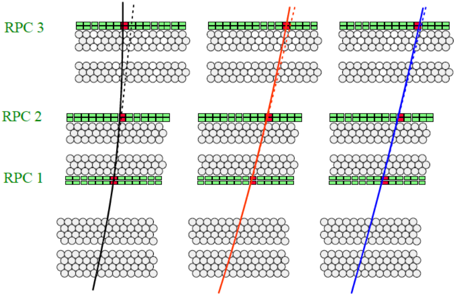
Chamber assembly at MPP:



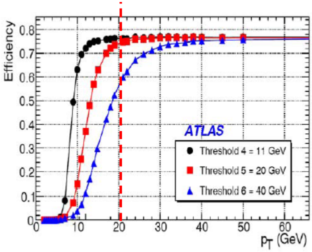
- Phase 0: installation of four sMTD chambers (on rails) in middle barrel to close acceptance gap
- Phase 2: replacement of MDT chambers under consideration

To keep L1 muon trigger rate from low-energy muons at acceptable level, sharpening of the trigger thresholds and higher momentum resolution are required

The current L1 muon trigger system has insufficient spatial resolution to sufficiently discriminate muons above 20 GeV



p_T: 10 GeV 20 GeV 40 GeV



Proposal by MPP group:

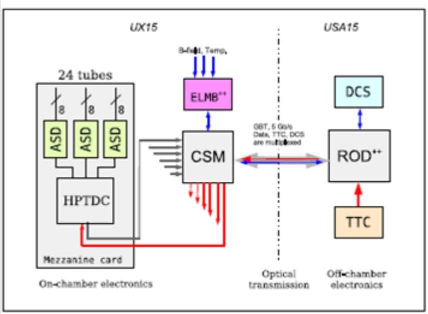
- Use region of interest defined by current trigger chambers (RPCs in barrel, TGCs in endcaps) as seed for fast track segment finder in MDT multilayers
- Requires modification of MDT frontend electronics

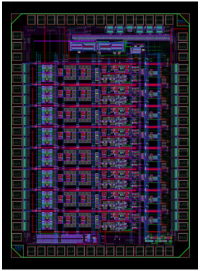
MDT Phase 2: new readout electronics

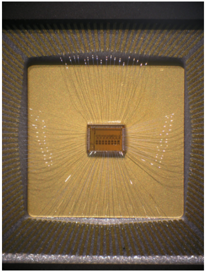
Independent of L1 muon trigger proposal, current MDT readout electronics need to be replaced in Phase 2 to prepare for higher rates

New (s)MDT readout electronics chain under development by MPP group with

- new ASD and TDC chips
- implementation of L1 trigger algorithms







New prototype MDT ASD chip produced in radiation hard IBM 130nm CMOS technology

- needs further optimization for high rates / short deadtime
- new chip designer urgently needed

Thank you!

OTP class 1 tasks

Class 1 by Funding Agency

As of June 1st 2010, Weekend and Night shifts count with a weight of 1.31, while Day and Evening shifts count with a weight of 0.66

	2012												2013		2012-13	2012-13	2012-13
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	Alloc	Req	Alloc/Req
Argentina							7.9	9.8	7.9	11.8	7.9				45	36	124%
Armenia															0	4	0%
Australia			4.6	4.0	29.6	24.9									63	88	72%
Austria															0	12	0%
Azerbaijan															0	9	0%
Brazil				7.9	10.5	5.9						11.8	5.9	5.9	48	56	86%
Canada		2.6	22.4	25.6	68.2	59.1	57.2	55.2	51.8	25.0	15.7	5.9	19.1	23.0	431	386	111%
CERN	29.0	36.9	39.0	46.5	23.1	27.9	30.3	43.4	41.8	37.6	31.2	17.1	23.7	9.2	437	579	75%
Chile					11.2	8.6					5.2				25	27	93%
China			7.9	11.8		3.9		26.9	10.5	14.4	20.4	8.5	11.8		116	101	115%
Colombia			2.6				19.7								22	21	104%
Czech Republic	3.1		28.9	6.6	6.6	25.2	8.5	21.7	21.6	19.0	32.2	16.4	8.6	7.9	206	228	90%
Denmark			8.5	4.6		3.9	20.4	3.3	6.6		7.9	3.9	11.8	4.6	76	73	104%
France - CEA			4.0	4.6	3.9	7.2	2.6	11.8	32.2	2.6	2.0	5.9	10.5	1.3	89	144	61%
France - IN2P3	9.2		30.3	41.6	46.4	29.0	37.6	53.6	62.2	53.7	41.4	33.5	35.5	7.2	481	581	83%
Georgia				7.9	3.9										12	25	48%
Germany - BMBF	7.0	7.2	98.9	110.9	112.7	116.7	69.6	123.9	99.8	89.4	74.6	47.9	65.7	17.7	1042	1154	90%
Germany - DESY			11.1	10.5	7.2		17.1	5.9	20.3	21.7	24.3	6.6	41.3	15.1	181	176	103%
Germany - MPI		7.2	6.6	32.2	23.7	16.4	32.8	5.2	26.3	21.0	26.9	9.2	11.2	7.2	226	173	130%
Greece			13.2	7.9	2.6	2.6	23.7	4.0	30.2	4.0		3.3	2.6	3.3	97	108	90%
Israel			13.1	13.8	21.7	30.3	25.6	25.0	4.0	14.5	7.2			7.9	163	153	106%
Italy	0.7	2.0	38.1	73.6	77.5	79.5	82.1	62.4	67.6	99.2	84.7	25.6	46.6	20.3	760	793	96%
Japan			19.0	5.3	21.8	13.8	15.1	25.7	26.2	22.3	29.5	30.2	30.8	14.4	254	421	60%
Morocco			13.8								3.3	5.3	5.3		28	48	57%
Netherlands			9.8	13.8	7.2	15.8	17.7	15.1	5.9	15.8	10.5	0.7	17.8	2.6	133	184	72%
Norway			2.0	1.3	6.6	11.2	4.0	7.9	6.6	10.5	9.8	5.2	19.7		85	101	84%
Poland	1.3			9.8		5.9	17.7	7.2	11.8	8.5	22.3	3.9	9.9		99	118	84%
Portugal	10.5	4.6	20.3	42.7	22.4	25.6	19.0	15.1	20.3	9.9	17.1	15.1	25.6	3.9	252	95	265%

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