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Swiss contributions to LHC upgrades

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UNIVERSITÄT BERN

- SLHC machine scenario
- Detector upgrade issues
- Swiss contributions
  - Atlas (Geneva, Bern)
  - CMS(PSI)
- Conclusions

Swiss Institute of Particle Physics

LHC luminosity upgrade

LHC luminosity will increase in steps up to the design luminosity of 10^{34} cm^{-2} s^{-1}, ~ 100 fb^{-1}/year

after a few of years of running at design luminosity it will take very long to improve statistical errors significantly

European Strategy for Particle Physics

"… A subsequent major luminosity upgrade (SLHC), motivated by physics results and operation experience, will be enabled by focused R&D; *to this end, R&D for machine and detectors has to be vigorously pursued now and centrally organized towards a luminosity upgrade by around 2015.*"

increase luminosity by an order of magnitude, 10^{35} cm^{-2} s^{-1}, ~ 1000 fb^{-1}/year , studied for

Higgs couplings, heavy SUSY, new gauge bosons, rare decays, EWK precision measurements

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SLHC machine Scenarios

3 phases considered:

Phase 0: Push the machine to its maximum performance without hardware change
Luminosity of 2.3×10^{34} $cm^{-2}s^{-1}$. and ultimate energy 7.54 TeV (dipole field @ 9T)
Phase 1 (SLHC): Interaction Region (IR) quadrupoles life expectancy < 10 years
➔ Modify the insertion quadrupoles and their layout β^*
Phase 2: Rebuild the SPS with superconducting magnets, the transfer line to inject into LHC at 1 TeV and new 15T dipoles ➔ proton energy of 12.5 TeV

Parameters	LHC		SLHC (Phase1)	
	Nominal	Ultimate	Scenario 1	Scenario 2
Bunch spacing [ns]	25	25	25	50
Proton/bunch Nb[10^{11}]	1.15	1.7	1.7	4.9
β^* at IP1&5 [m]	0.55	0.5	0.08	0.25
Longitudinal profile	Gaussian	Gaussian	Gaussian	Flat
Rms bunch length σ_z[cm]	7.55	7.55	7.55	11.8
Peak luminosity [10^{34} $cm^{-2}s^{-1}$]	1	2.3	15.5	10.7
Effective luminosity (5h) [10^{34} $cm^{-2}s^{-1}$]	0.56	1.15	3.6	3.5
peak events per crossing	19	44	294	403
Comments			Crab + D0 (+ Q0)	Wire compen-sation

Baseline

Detector Issues (common to Atlas and CMS)

detectors were not designed for 10x LHC

consequences of higherluminosity most severe for the inner detectors (tracking):

- occupancy -> higher granularity + rate capability
- radiation damage -> new sensor materials/designs

boundary conditions

- detector performance must not degrade (material budget)
- much of the existing services must be reused (cables, fibres, cooling)

increased channel count -> power is a major issue
(low power designs, alternative powering schemes)

very little time for R&D for an upgrade near the middle/end of the next decade

ATLAS Upgrade

Due to increase of radiation level, pile-up, background each sub-detectors has to think of the consequences in term of detector performance, aging, radiation hardness!

Inner Detector (ID):

Completely new design and detectors – No TRT, more pixel and strips:

→ New detector and ASICs technologies to withstand the radiation level

→ Simulations drive optimal geometry (Strawman layers) and occupancies

LAr Calorimeter:

FCAL: To be replaced with smaller gap size and special cooling close to the beam pipe.
HEC: Cold electronics may have to be replaced (no need to get HEC wheels apart)
Others: More R&D require about the Ion buid-up

Tile Calorimeter:

Front-end electronics and Low Voltage Power Supplies

Muon System:

MDT: Chambers and readout electronics are radhard at LHC or can stand 10 times the max nominal flux but further studies need to be performed in SLHC environment

→ 2008: detail upgrade plan based on some tests and R&D

TGC: Thick GEMs can possibly replace forward chambers due to high occupancy.

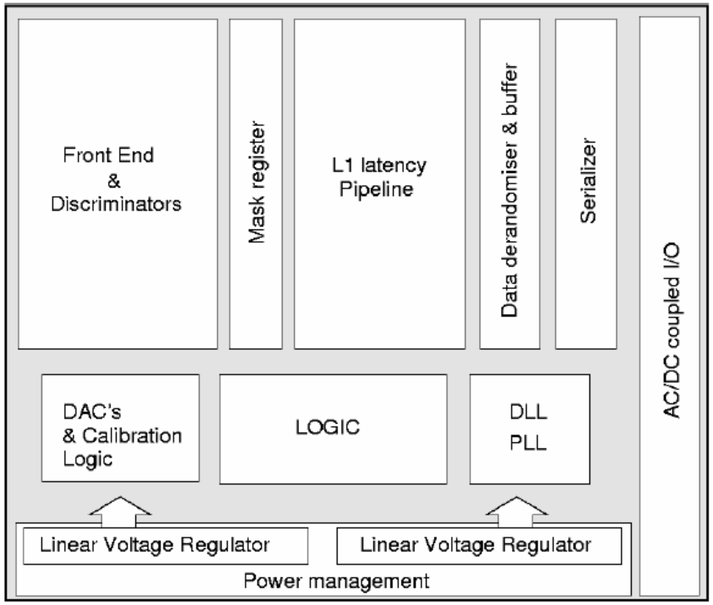
Electronics for Strips

Goal: Prepare a design of the FE ASIC in deep submicron radiation tolerant. Design and evaluation with 250 nm towards 130 nm technology

Minimum requirements:

- Implementation of an on-chip shunt regulation to allow any powering scheme (Serial or DC-DC)
- Increased data bandwidth of 160 Mb/s
- Front-end for two signal polarities, 3 to 12 cm long silicon strips
- Minimum power circuit techniques
- Delay adjustment for control and data signals
- Compatibility with existing ATLAS SCT DAQ ROD hardware
- Similar "core" functionality as for the present silicon strip tracker: signal amplification, discriminator, binary data storage for L1 latency, readout buffer with compression logic, and data serializer.

ABC-N Readout architecture



Design team:

- Daniel La Marra, Sebastien Pernecker, Geneva University
- Wladek Dabrowski, Krzysztof Swientek, AGH-Cracow
- Jan Kaplon, Karolina Poltorak, Francis Anghinolfi, CERN
- Mitch Newcomer, Pennsylvania University

Power Distribution

Services are clearly an issue for the material budget as well as for the system design

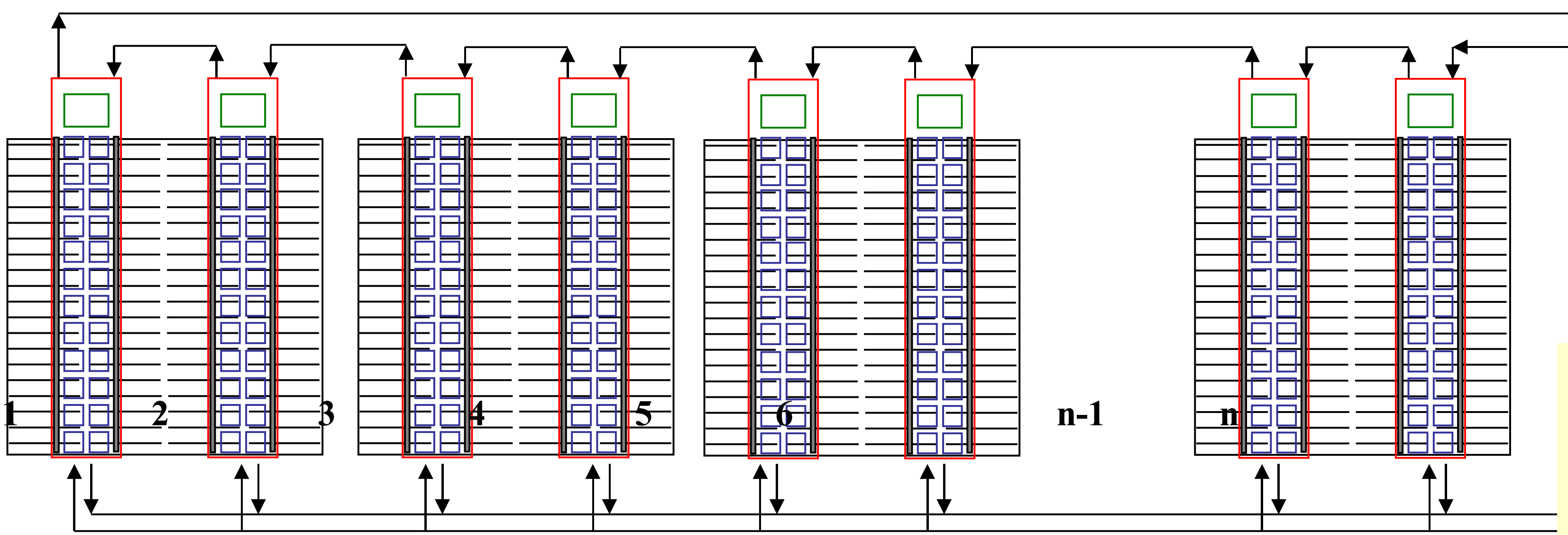
Tracker Upgrade should leave with the existing ID services and optimize the power distribution: Serial Powering or DC-DC (Individual Powering is abandoned)

SCT - 4mW/ch → 24 kW (excl. cable losses)

Strip Upgrade - 2mW/ch → 90 kW only for FE (45 Mch)

Short-Strip Super-Module configuration

n is hybrid number = 20; V_H(0.13μm)=1.2V



SP
$I_{PS}=I_H=4.2A$
$V_{PS}=nV_{ABCN}=24V$

PP
$g= GAIN_{DC-DC}=20$
$I_{PS}=n/g.I_H=2A$
$V_{PS}=gV_{ABCN}=24\ V$

NB: Here only 2 cables/SM needed but for IP it would be 40 cables

UniGe Involvements

Asics: Digital architecture & simulation: pipeline, derandomizer, Data Compression Logic, Readout Logic and Control; Check after place and route!

→ 250nm submission January 2008

→ 130nm design from January 2008

Detectors: 135 sensors of size10X10cm^2 ordered to Hamamatsu

UniGe ordered 15 sensors: 12 p-stop and 3 p-spray

Sensor characterization will be made and compared with other institutes

Module Concept: UniGe investigated 2 concepts module directly mounted on barrel or mounted on an intermediate local support!

→UniGe operates 3D Thermal FEA to evaluate and optimize the design

→Strategy is to make prototype modules in 2008 with above detectors and Asics

DCS: Involvement in the strategy and decision for the detector safety. DCS will be part of the system design to optimize the service and resource issues.

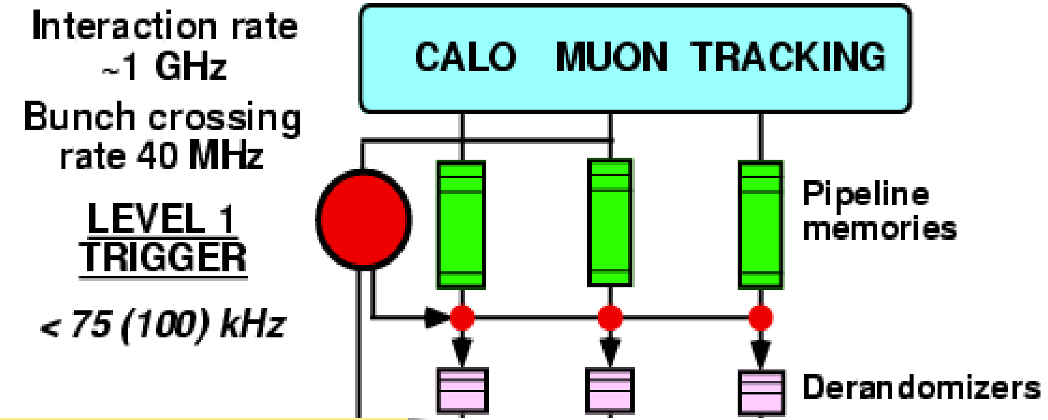
Mechanical Engineering: Involvement in the structure and service design.

Probable participation in B-layer pixel replacement (2012)

14/09/2007

LVL1 Trigger

ATLAS LVL1 trigger uses calorimeter trigger towers and muon trigger chambers



LVL1 Calo trigger

Hard jets stay hard jets, even when surrounded with 500 (soft) pile-up events

Raising thresholds to keep trigger rate acceptable

- *High-Pt physics not affected*

LVL1 Muon trigger

At SLHC, cavern background (neutrons) and K^0_L decays will increase and give raise to higher fake muon rate at LVL1.

ATLAS profits from an air core toroid, i.e. no iron and only little multiple scattering of muons.

Muon trigger rate not expected to become dominated by fakes.

ATLAS LVL2 trigger to reduce fake muons (Local Muon track reconstruction and match with ID track)

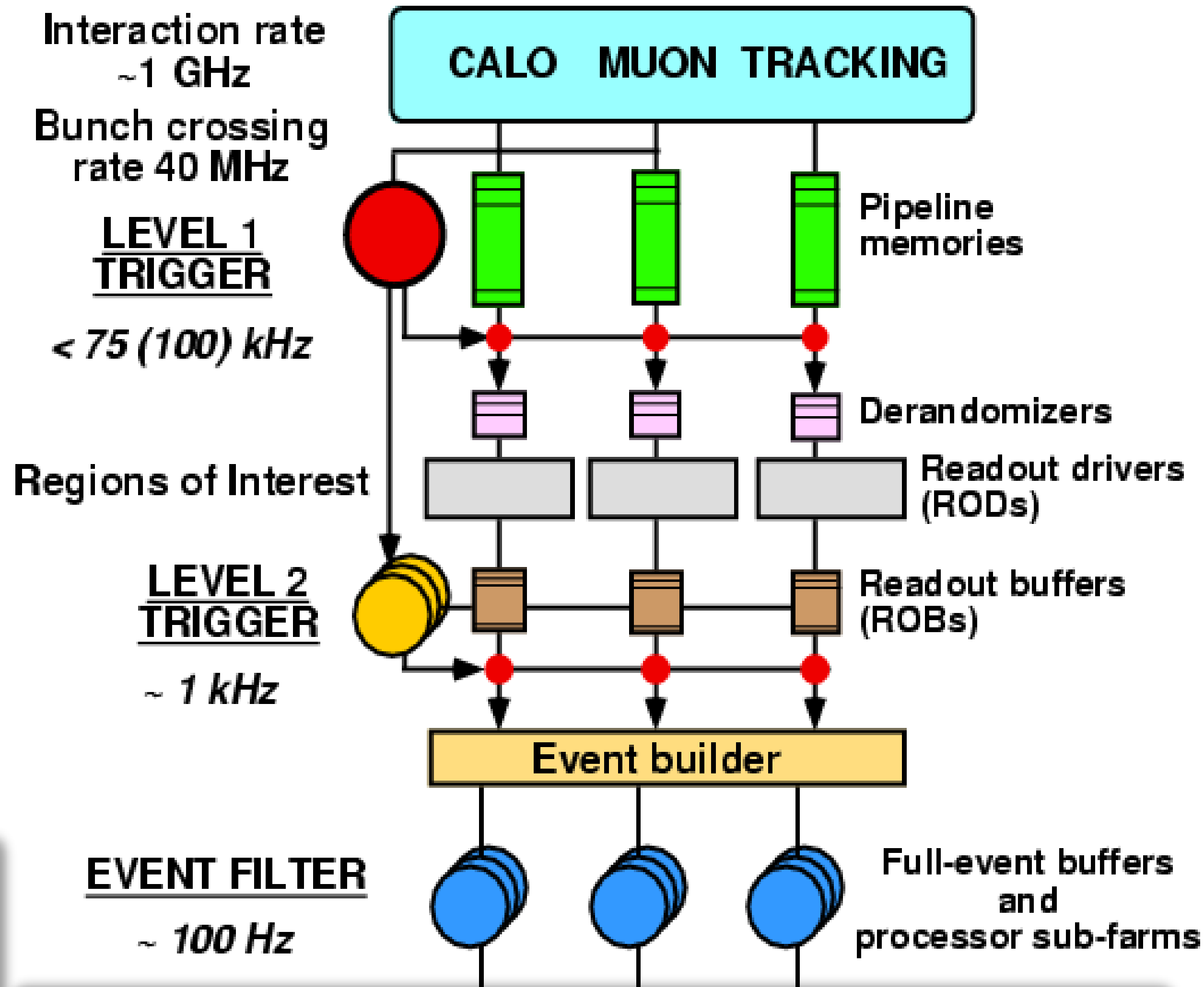
LVL2 Trigger and Event Filter

LVL2 Trigger:

local reconstruction of data within **Regions of Interest** as defined by LVL1

Possible to increase bandwidth out of Readout buffers

Can profit from faster CPUs available at time of SLHC



Event Builder and Event Filter:

Possible to increase bandwidth out of Readout buffers

Remote Farm: Studying whether Event Filter Farms could be located remote (even transcontinental)

CMS upgrades

The CMS upgrade for SLHC is mostly a tracker upgrade

- complete re-design
- pixel layers will need higher rate capability and radiation hardness
- inner strip layers will become pixel detectors
- outer strips will become shorter
- the tracker will have to contribute to the L1 trigger

PSI pixel group will contribute to pixel developments for SLHC

EOI March 2007

CERN/LHCC 2006-xxx
CMS EOI xxx
dd month 2006

CMS

Expression of Interest in the

SLHC

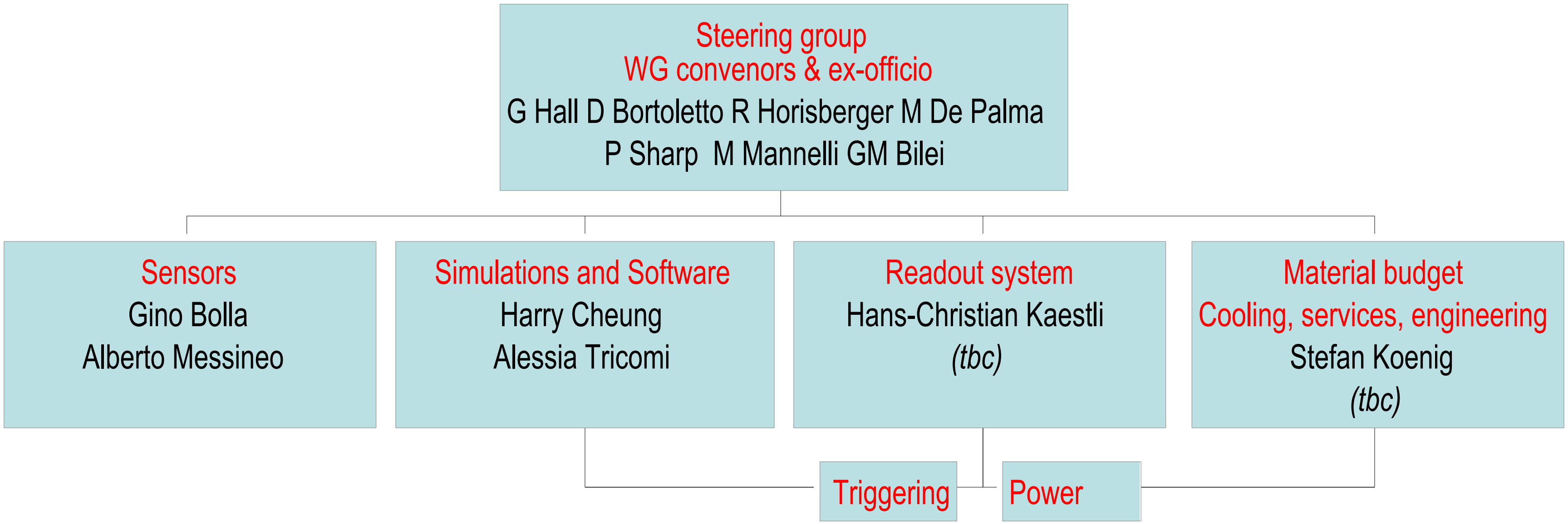
CMS xxx Projects ... update below !!!		
CMS Spokesperson	Michel Della Negra, CERN	Michel.Della.Negra@cern.ch
CMS Technical Coordinator	Austin Ball, CERN	Austin.Ball@cern.ch
CMS Collaboration Board Chair	Lorenzo Foà, Pisa	Lorenzo.Foa@cern.ch

PSI pixel group activities/projects

construction of of (LHC) CMS pixel detector still ongoing

SLHC contributions

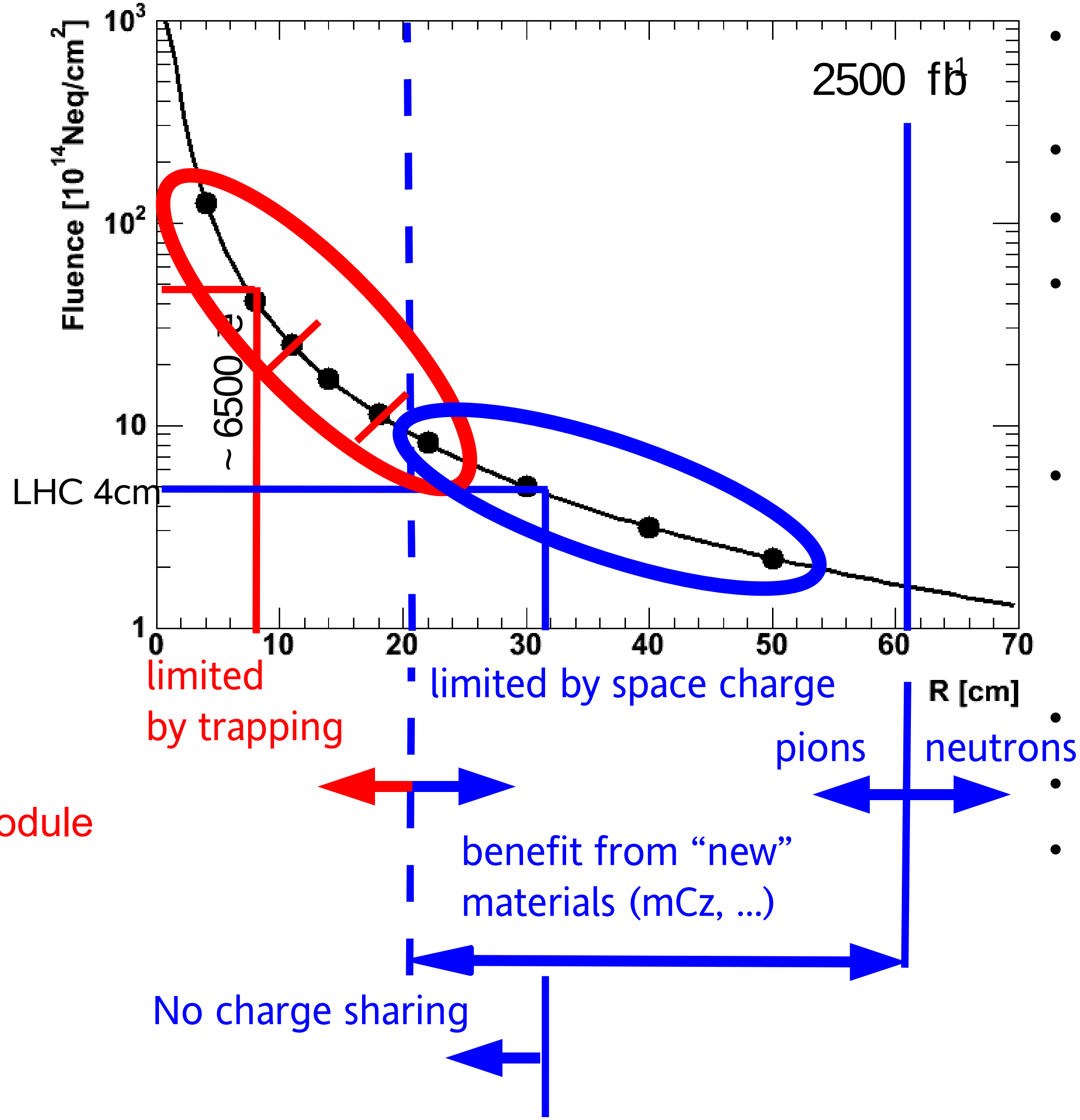
- sensor development
- SLHC upgrade workshops
- upgrade working groups



Sensor options for SLHC tracking

4cm < r < ~25 cm

- hybrid pixels
- pitch in rϕ ~ 50μm
- large ROCs
  - poss. in 0.13?
- Price reduction of bump bonding ??
  - r > 11cm affordable ??
- n-side readout
- p-material ?
  - single sided processing
  - cost
  - problematic module design
- FZ, DOFZ or Cz ?
- Replace 4cm layer frequently

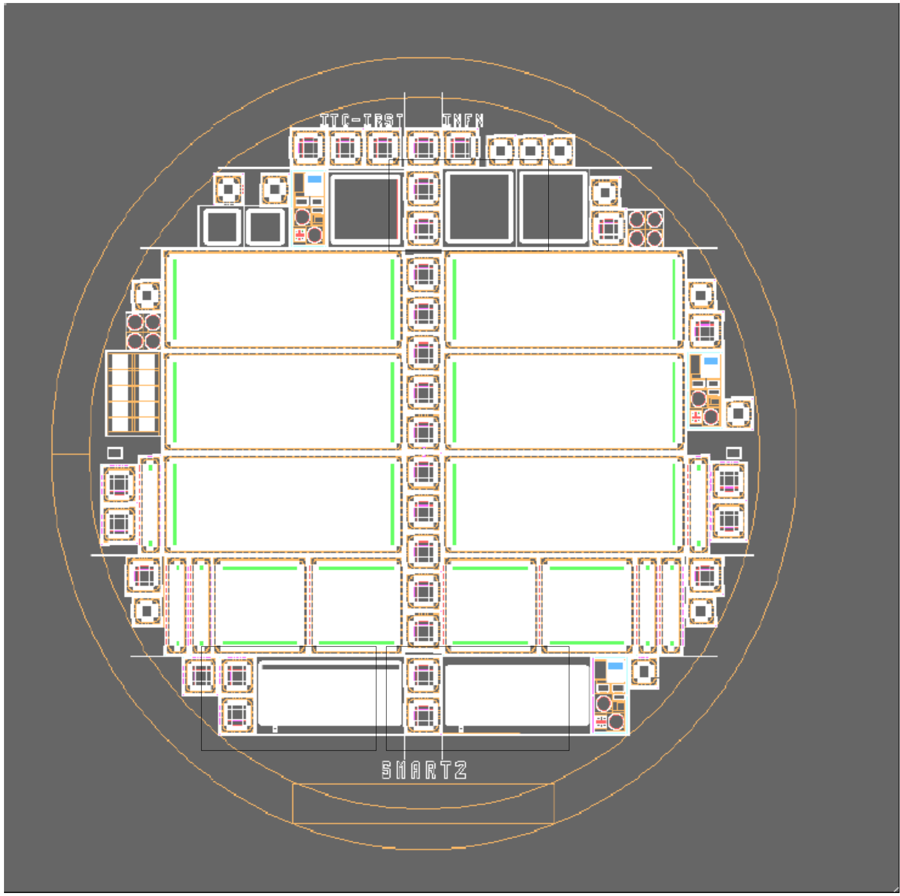


25cm < r < ~50 cm

- hybrid pixels with 1-to-1 coverage
- pitch in rϕ ~ 100μm
- pitch in z ~ 1mm
- large ROCs
  - 0.25
  - low power
- Price reduction of bump bonding ??
  - bump pitch >200μm
  - done by industry
- n-side readout
- p-material
- DOFZ or Cz ?

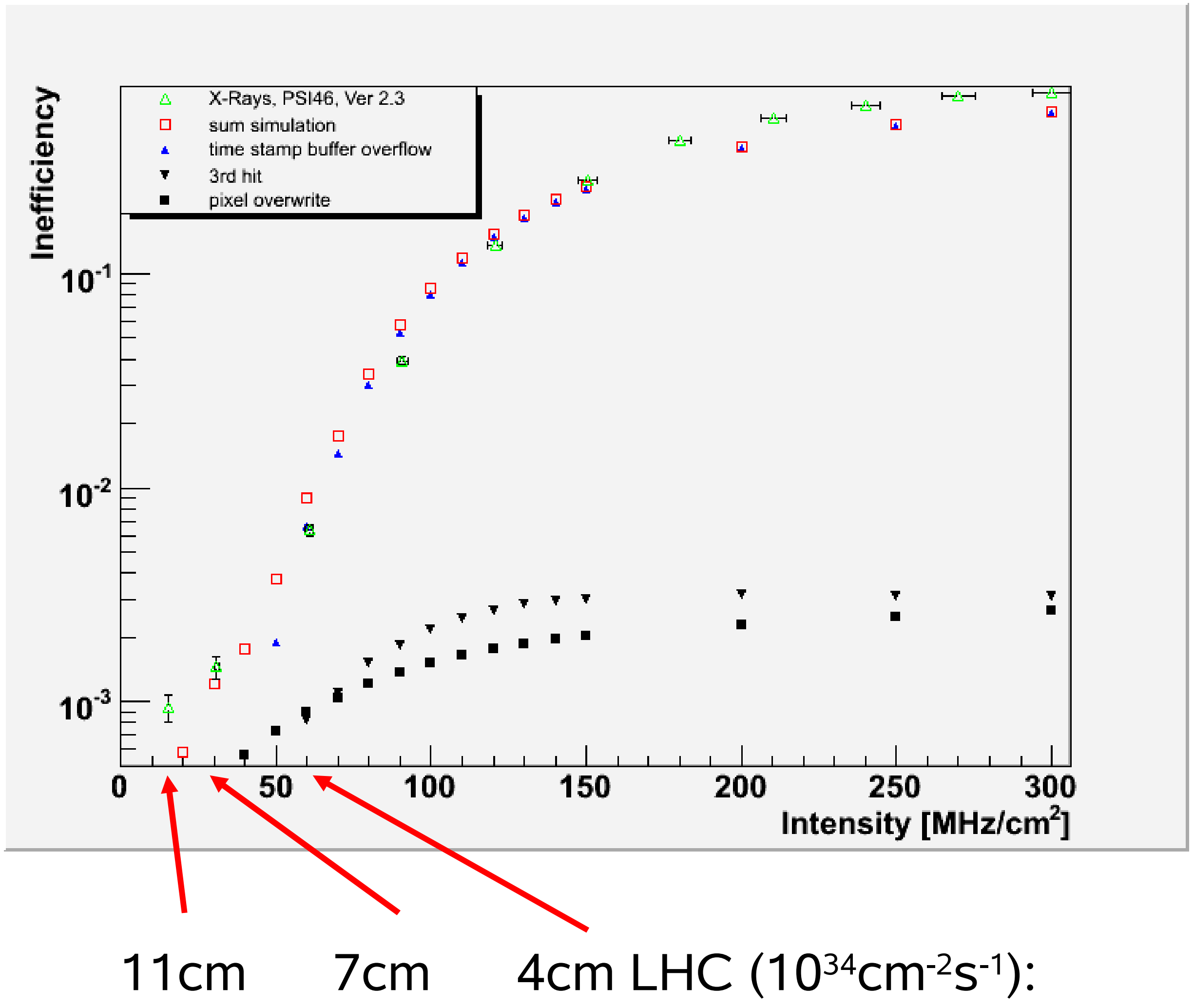
Sensor Submissions

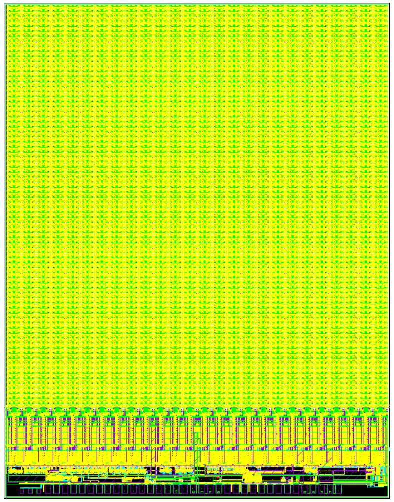
- RD50 has submitted several n-in-p mask sets which contain pixel sensors compatible with the CMS ROC
  - CNM Barcelona: 2006 (mCz, epi, FZ)
    - first sensors delivered
  - IRST Trento
    - 2006/7: RD50/Smart 3 (end of this year)
      - 2 pixel sensors
    - 2006/7: 3D (beginning 2008 ?)
      - pixel sensors fitting to CMS ROC
      - sensors for capacitance determination
  - Micron: 2006 150mm wafers
    2 pixel sensors
    - first sensors delivered
    - IV testing ongoing
    - single die bumping planned for this autumn
    - ready for last PS irradiation period 07?



High rate tests of Pixel ROC

- X-ray box, up to 300 Mhz/cm^2
- Steep rise of inefficiency due to buffer limitations
  well described by simulation
- suitable for LHC, improvements needed for inner layers SLHC
- small design changes sufficient for intermediate radii
  more work for innermost radius





PSI pixel projects/collaborations

- FP7 "Infrastructure", collaboration with CERN and others
  swiss members are UniGe, ETHZ, PSI
  PSI: on-chip DC-DC conversion

- sensor development, RD50
  Applied for Marie-Curie Training Network (FP7)
  1 PhD-student (sensor development) and 1 Post-Doc (development of 0.13 um chip)

- PIRE (Partnership in International Research and Education) with 5 US Universities
  "Collaborative Research on Advanced Pixel Silicon Detectors for the CMS Detector"
  funding approved by NSF this year, $2.5M over 5 years,
  1 Postdoc at PSI + varying number students
  improvement of existing pixel readout chip for a possible intermediate upgrade

Summary/Conclusions

- an upgrade of the LHC to increase the integrated Luminosity by an order of magnitude is is currently under study (but not an approved project)
  luminosity increase likely to proceed in stepwise
- in addition to machine upgrades this will require substantial detector upgrades particularly of the inner detectors of Atlas and CMS
- little time for R&D for an upgrade in ~10 years
- CMS and Atlas have expressed interest and begun preparations
- R&D has started involving UniGe, UniBe, ETHZ and PSI
- PSI has played a key role for the present CMS pixel detector and will contribute to an CMS tracker upgrade