Trends and synergies in solid state tracking R&D

Executive Summary of the session

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Sensors @ HL-LHC

- Extensive R&D campaigns happened in all experiments.
  Baselines defined with options to follow up.
  - For ATLAS and CMS - Outer Tracker well defined
    - **Common ATLAS & CMS Market Survey** for Outer Tracker for AC-coupled sensors
  - More studies necessary for inner pixel
    - Some common ATLAS/CMS wafer submissions planned

	Strips/strixel baseline	Pixel outer layers baseline / options	Pixel inner layers baseline / options	Special
ALICE	MAPS (Monolithic Active Pixels)			
ATLAS	• **n-in-p planar** FZ 300µm thick AC-coupled • and/or HV-CMOS	• **n-in-p** (n) **planar** • and/or HR/HV-CMOS	• **n-in-n planar** 100-200µm active thickness • and/or HR/HV-CMOS • and/or **3D** • and/or diamonds	With ~700m² needs to be factored in the global orders
CMS	• **n-in-p planar** FZ 200µm *active* thickness AC- and DC-coupled • and/or MCz (pref) • and/or 300 µm	• **n-in-p planar** 100-200µm active thickness	• **n-in-p planar** 100-200µm active thickness • and/or **3D** sensors	**HGCAL** • p-in-n planar DC-coupled large PAD sensors 100-300µm active thickness (deep diffused) • Or n-in-p (deep diffused)
LHCb	UT **planar n-in-p** • or p-in-n	VELO **planar n-in-p** • or n-in-n		

Pixel Sensors – Challenges and Synergies

- Evaluation which sensor technology will withstand the radiation at the innermost pixel layer(s).
  - ***Diamond*?** **3D?** **Planar** (would be wonderful because it is simple)?
    - By the way – for planar voltage helps!
    - Is 3D compatible with the small pitch (ratio column radius vs. column depth)
    - Are diamonds available? Is polarization a problem?
- Pitch of 25 μm (baseline is ~50x50 μm^2 or 25x100 μm^2)
  - BB on small sensor pitch 25 μm to demonstrated reliably within industry
    - Cell size? Probably not a problem!
  - Cell isolation? Breakdown voltage?
  - Bias grid – how to? Do we need one?
- Solution for sparking with n-in-p sensors
  - Industry solution? In-house?
- Is there a limit on physical sensor thickness to be assembled with acceptable yield?
  - Bow and bump bonding??

Synergies ATLAS & CMS

Synergies ATLAS & CMS & LHCb

NB.: Main R&D for strip/strixel layers done – common MS ATLAS&CMS in preparation

Not an HL-LHC baseline

HR/HV-CMOS

- HR/HV-CMOS is a very appealing and interesting technology.
  - It could solve lots of issues, especially in case of a full monolithic approach
  - Ideas are being evaluated to use it to replace the standard **pixel and/or strip** sensors at lower cost still together with standard CMOS chips
    - 'Standard' CMOS process (but HV) instead of dedicated process
    - Gluing replaces high cost bump bonding in pixel case

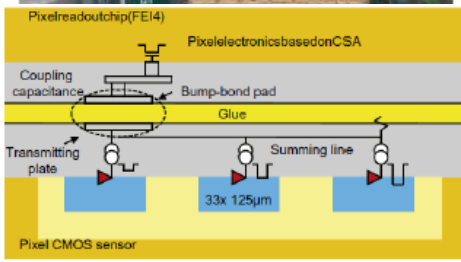
- Unfortunately it has not been consequently picked up by a dedicated R&D collaboration some years ago.

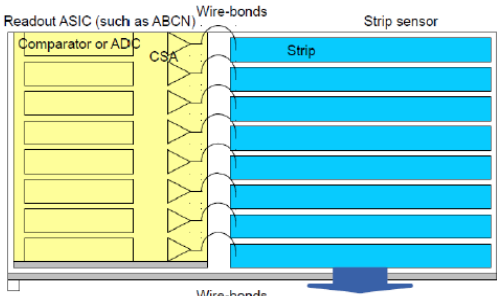
- Can the technology be matured in time for HL-LHC?
  - R&D!
  - System changes?
  - Power?
- Potential cost savings to be demonstrated
  - Taking the whole system into account

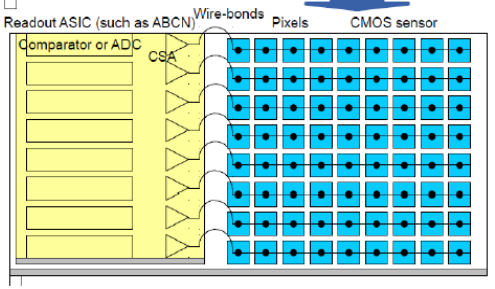
- ALICE: MAPS is a natural bet for ALICE with the less stringent requirement on radiation tolerance and readout frequency
  - Nice monolithic light weight approach

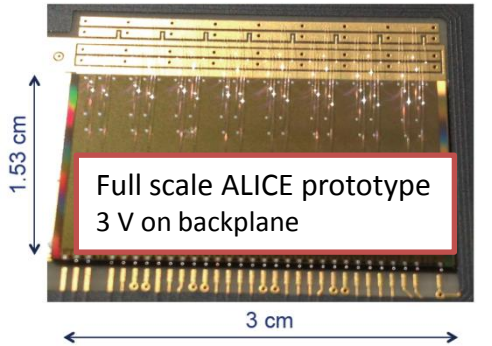
ALICE baseline

HV-CMOS demonstrator

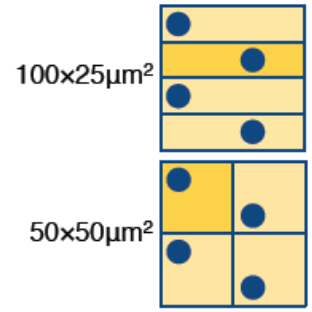








Pixel Electronics



- CMS & ATLAS have the 'same' requirements → **RD53**
  - Radiation tolerance, complicated digital logic
    - Buffering, readout rate, SEUs, ON/OFF of chip cells to match sensor cells
  - Less synergies with LHCb - although many similar challenges
  - No real synergies with ALICE
- In addition, urgent increase of effort necessary
  - on electrical links
  - on powering

	Bump pitch μm	Pixel size μm	Trigger rate	Readout	Mass / layer % X0
ALICE	Mono-lithic	30 x 30	1/30 μs	All data w/rolling shutter or priority encoder	~0.3 (*)
LHC-b	55 x 55	55 x 55	40 MHz	All data	~0.5 (*)
ATLAS	50 x 50 50x100	50 x 50 or 25 x 100 50 x 100	1 MHz	Triggered time stamp	~1.0
CMS	50 x 50 100x100	50 x 50 or 25 x 100 100 x 100	1 MHz	Triggered time stamp	~1.0

(*) At smallest radius. Goes up with radius

Share Challenges

We really appreciate RD50&RD53 and the common platforms they provide!!

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