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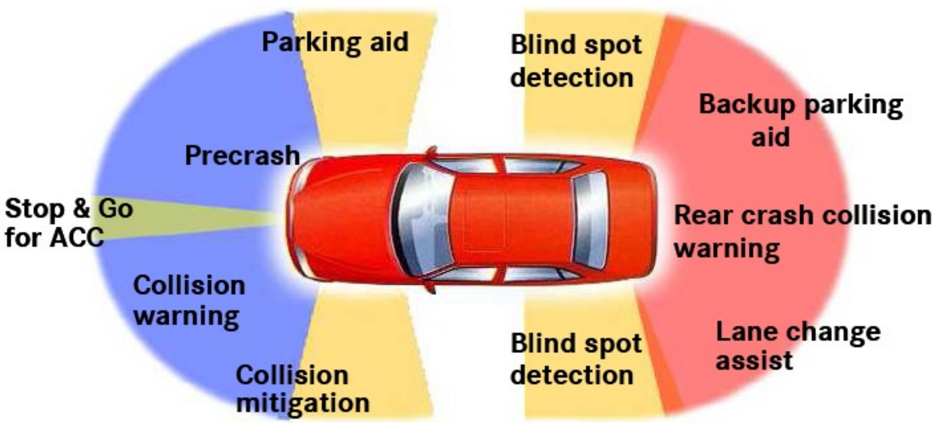
Wireless transfer of L1 track trigger data in ATLAS ID

R. Brenner (with help from S. Cheng and H. Kratz,Microwave Technology Group, Signals and Systems, Uppsala University)

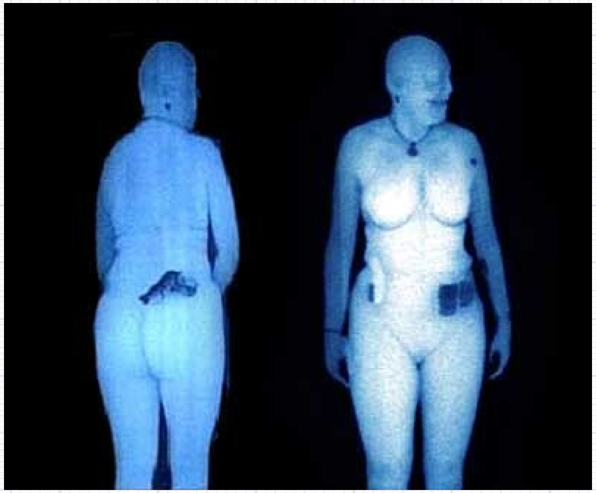
- Extremely High Frequency technology
- Motivation for wireless data transfer in the track trigger
- Simple idea
- Initial tests
- A more sophisticated idea
- Key technology development
- Conclusions

Extremely High Frequency (EHF) technology

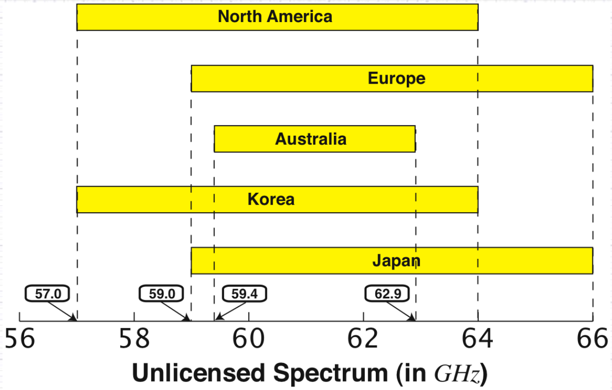
- 79 GHz- Automotive short range radar (SRR)

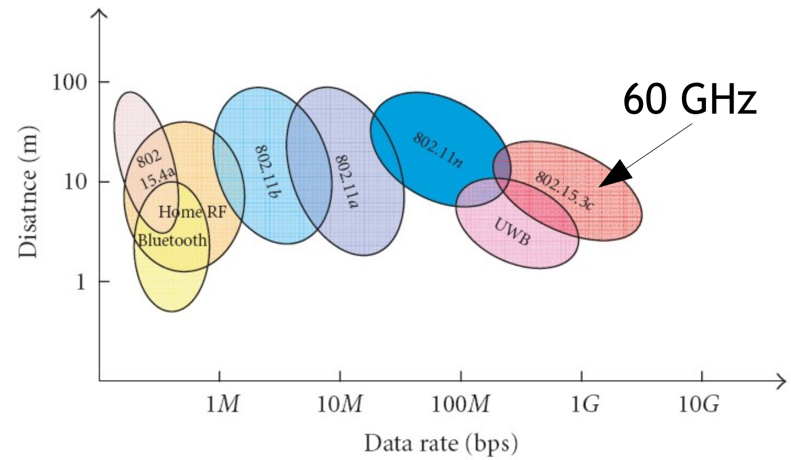


- ~95 GHz Security applications



- 60 GHz- WLAN applications





Why wireless

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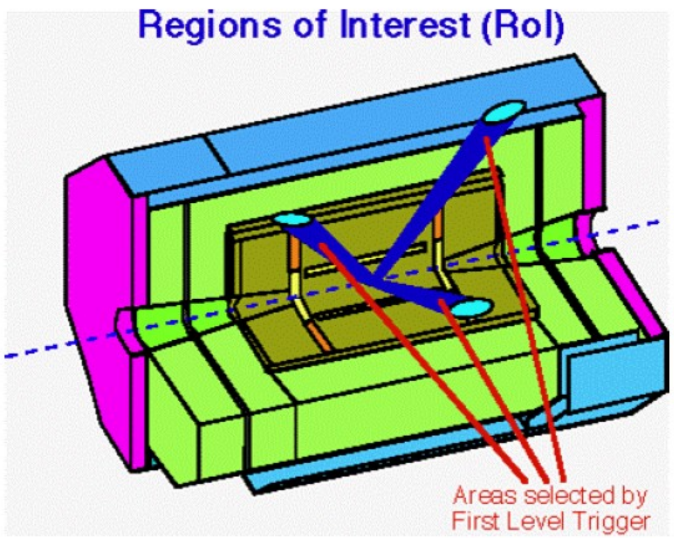
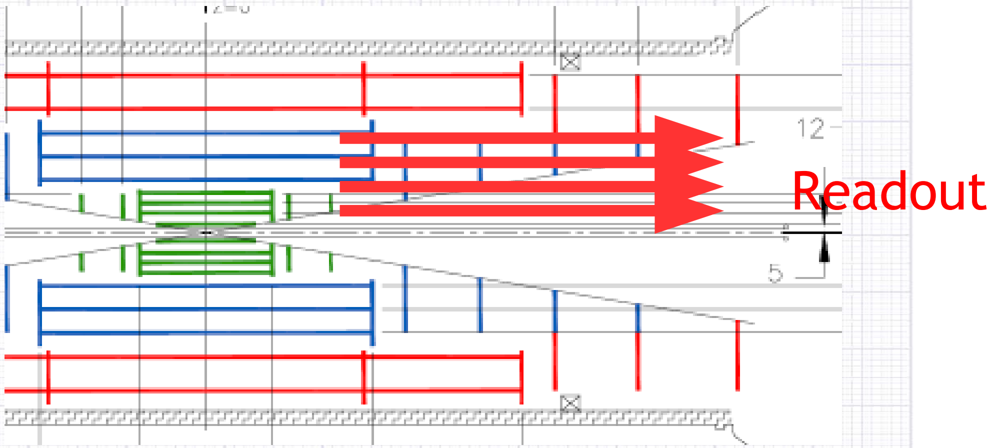
The present tracker readout architecture is not optimal for trigger... a fundamental difference



Physics events are triggerd in RoI that are conical regions radial from the interaction point in Φ and η



Axial tracker readout resulting in long paths, Long latency etc.

<u>Wireless transfer with millimeter wave:</u>

- Small and low mass components of materials already used in our trackers
- Low power
- Low cost
- High band width

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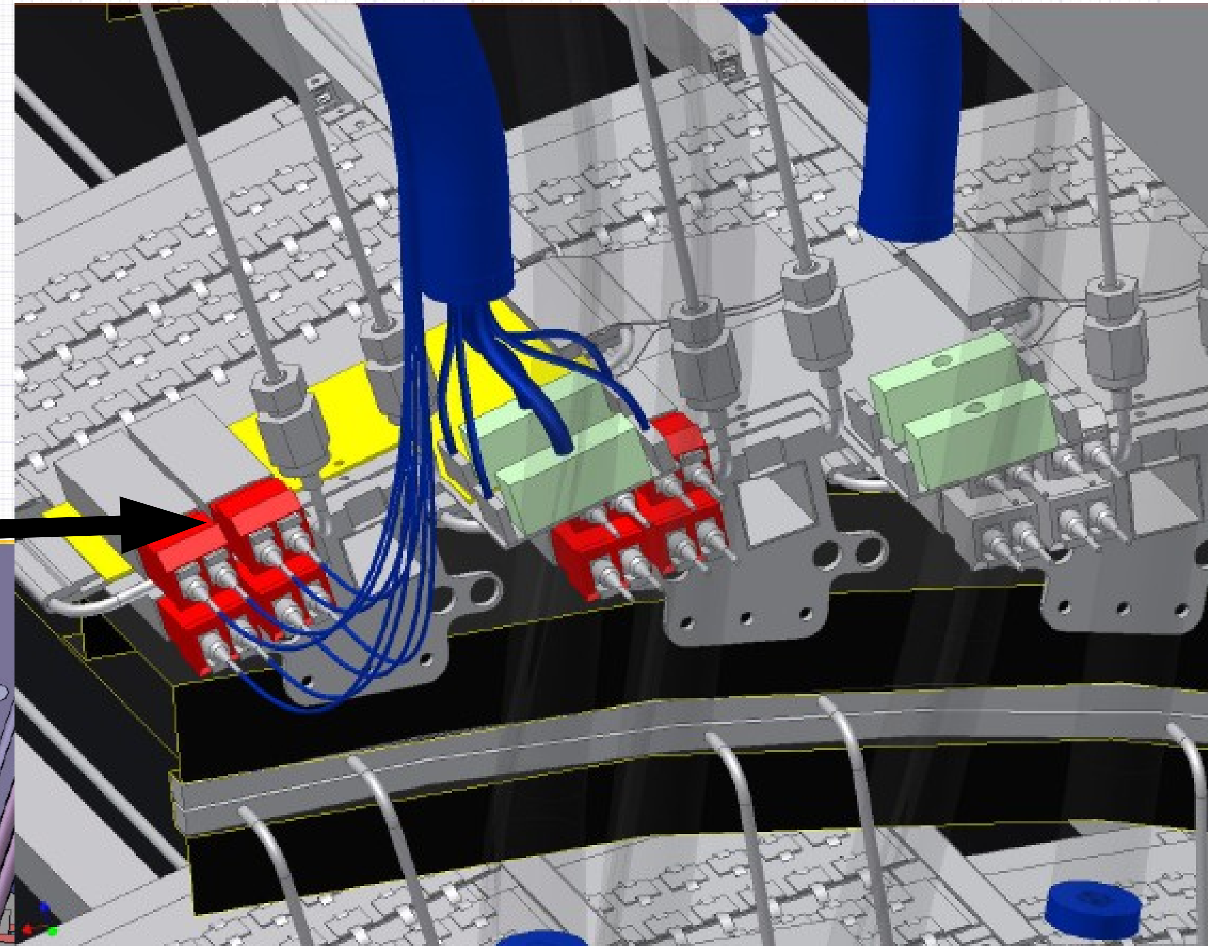
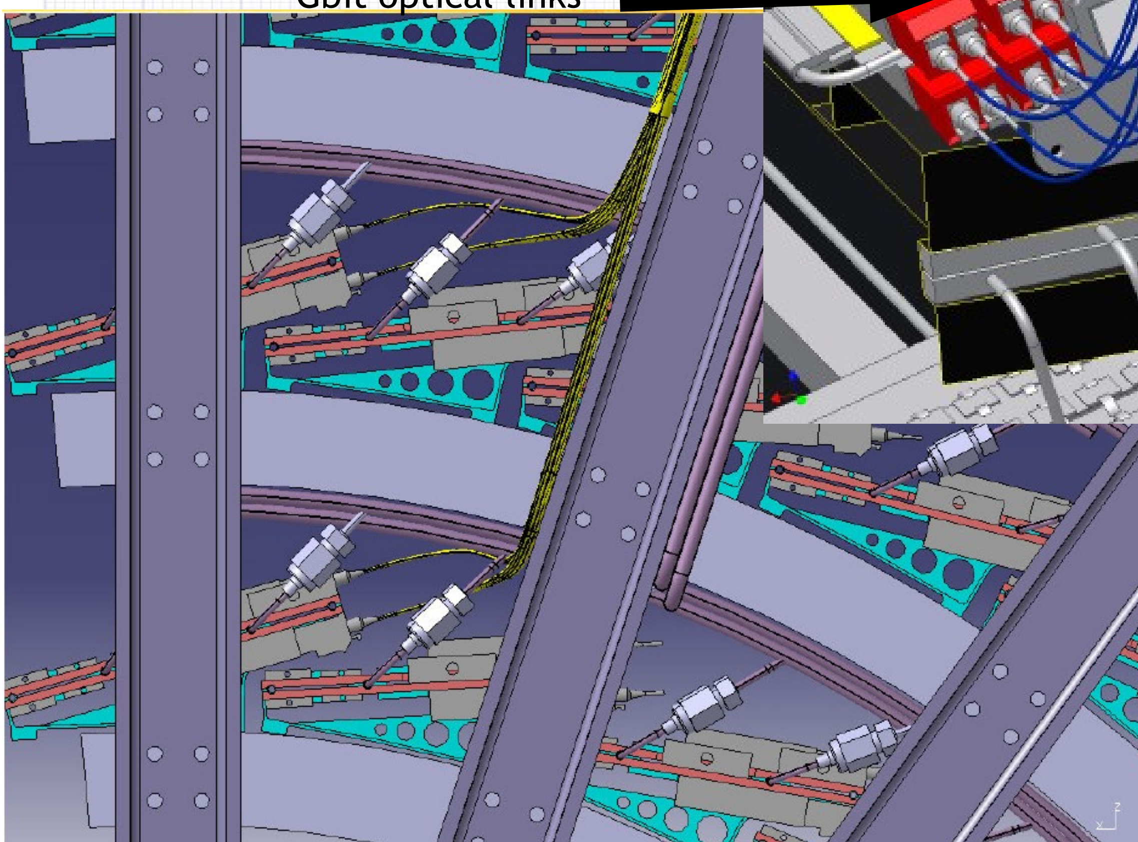
One could believe from this picture that increasing the number of services wouldn't be impossible

Gbit optical links





But don't believe in this drawing!
In real life this region will be totally crowded by services

Tracker p. 3

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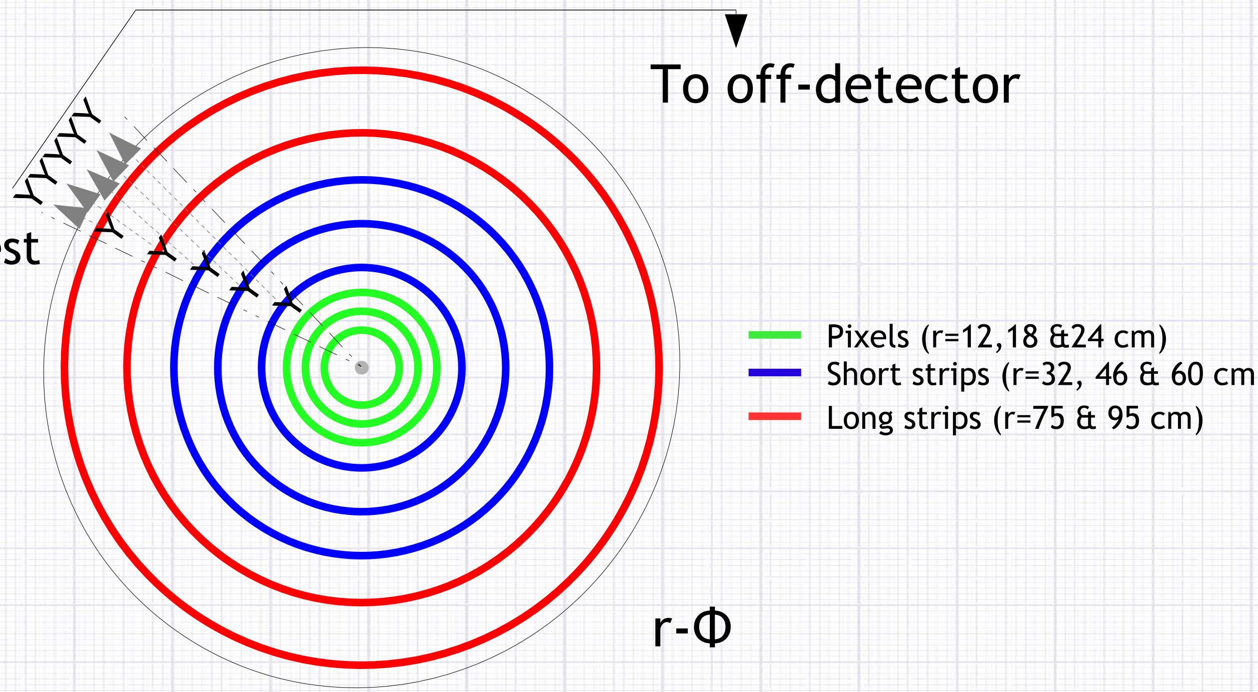
A simple idea....



...but not trivial to build on detector

- If all 1-2 hit clusters from strip layers only are read out for L1 trigger the required bandwidth is 50-100 Tb/s!
- The detectors is fortunately divided into a 20-50 kmodules and if each is provided with a link then the bandwidth/link < 5 Gb/s

Perhaps doable after all?

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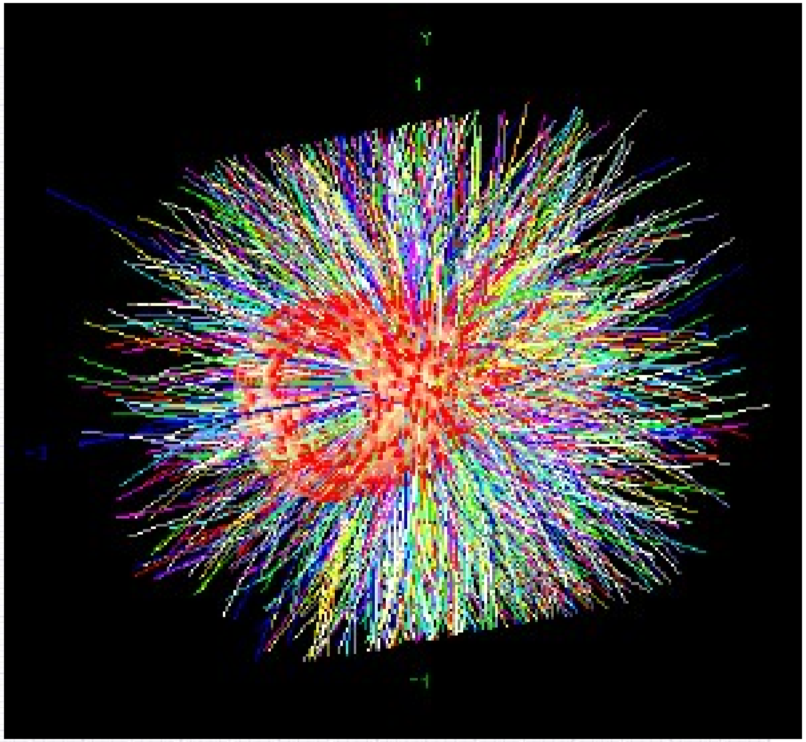
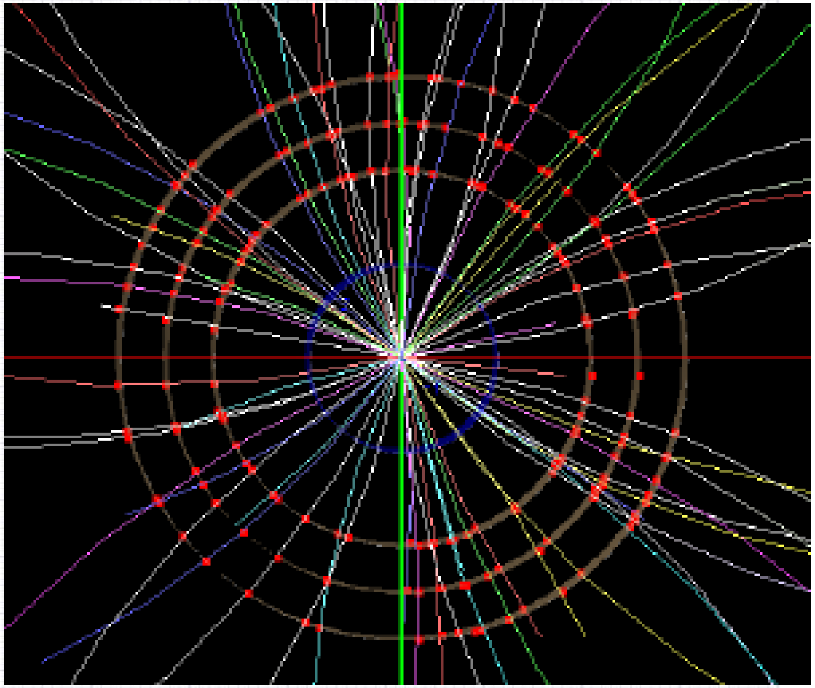
Off detector





Transfer L1 data from the cryostat wall to Content Addressable Memories (CAM) or Associative Memories (AM) for fast pattern recognition located in ATLAS cavern

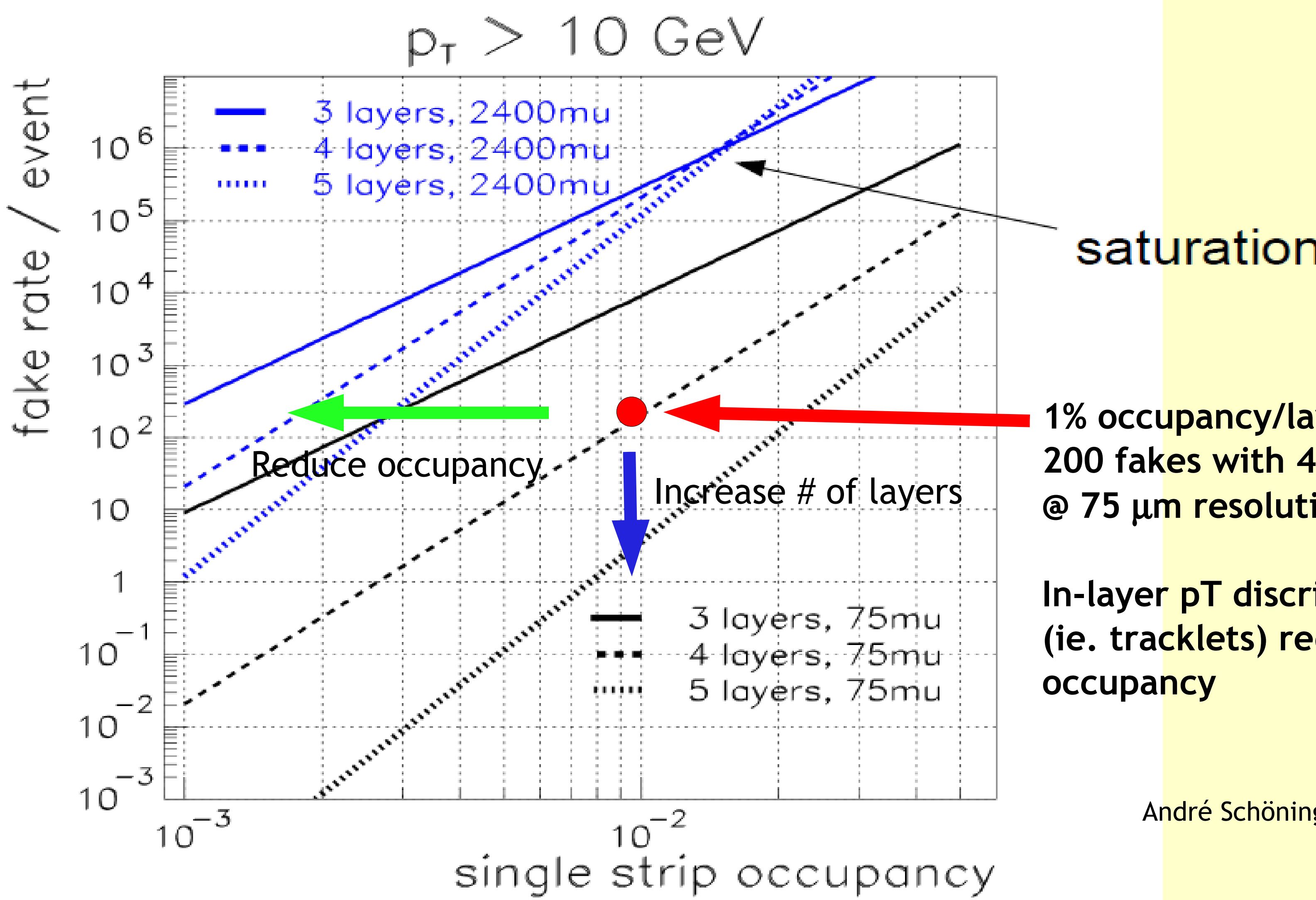
Ex. patterns for a geometry with three layers

- 80 μm pitch and reconstruction down to 1GeV pT: 70 Gpatterns
- 320 μm pitch and reconstruction down to 10 GeV pT: 500 Mpatterns

Simulation by Sebastian Schmitt (Univ. Heidelberg)

...not easy either

fakes vs. occupancy/resolution/layers



1% occupancy/layer -> 200 fakes with 4/4 layers @ 75 µm resolution!

In-layer pT discrimination (ie. tracklets) reduces occupancy

André Schöning

Fakes can be reduced by adding more layers in the trigger or by lowering the occupancy

Fakes vs. resources

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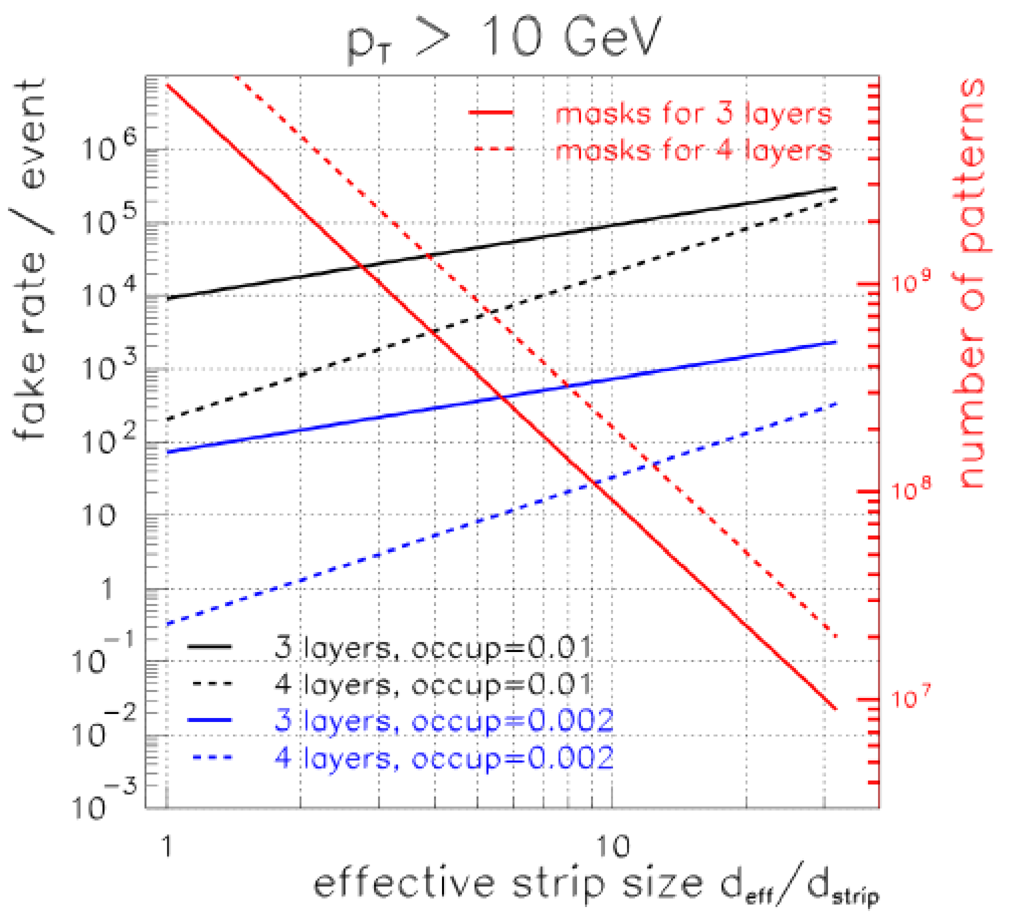


normalized to 75µm

total number of valid patterns

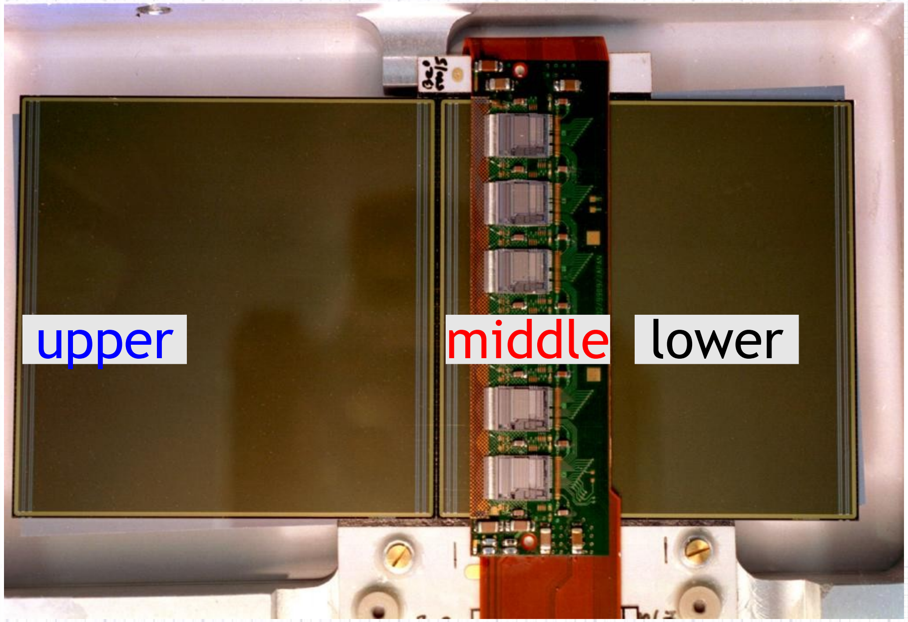
Lower occupancy is clearly favorable!

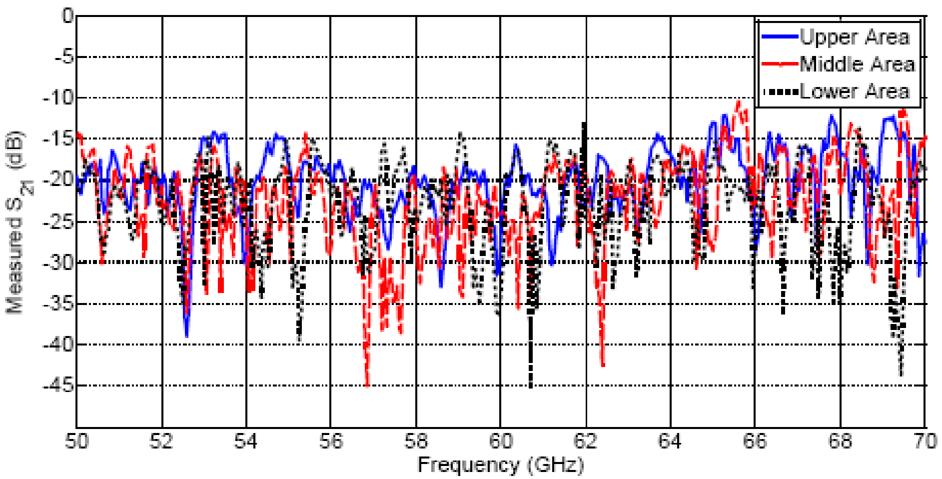
André Schöning

Lowering the pT threshold will the number of patterns

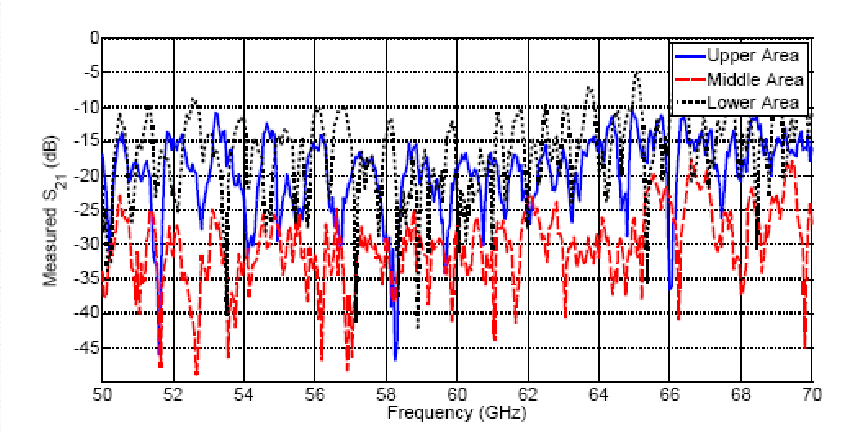
Initial tests at 60 GHz

- Degradation of module performance because of pick-up of 60 GHz not seen.
- Noise from LHC in 60 GHz band not likely because of frequencies in beam lower and the beam pipe shielding the detector
- Transmission of signals through a SCT barrel module.

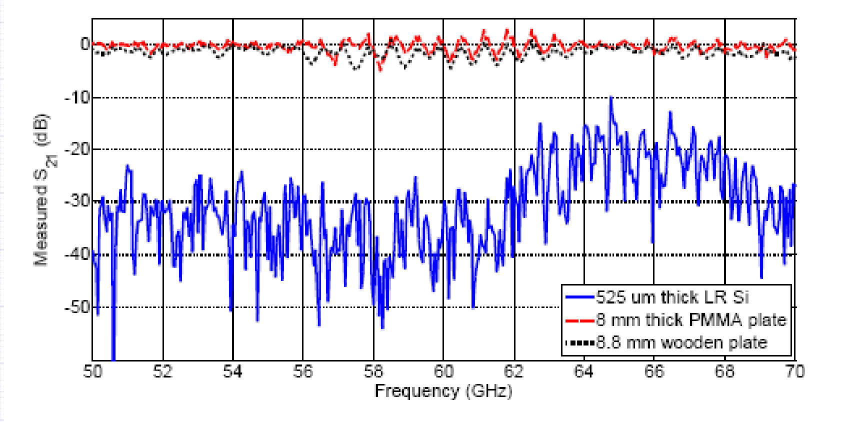




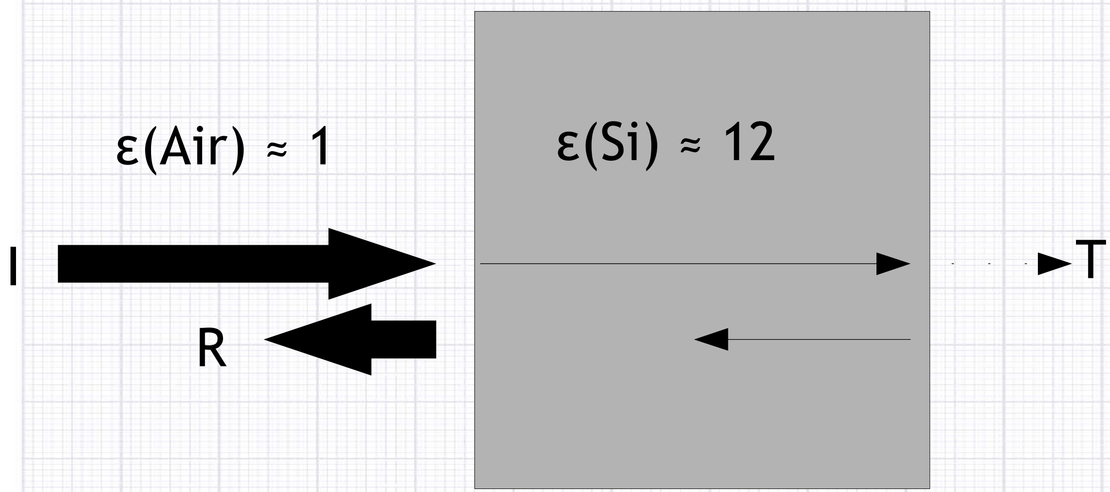
- The result shows it is almost impossible to send signals through a silicon module



Dummy module Si + AlO_2



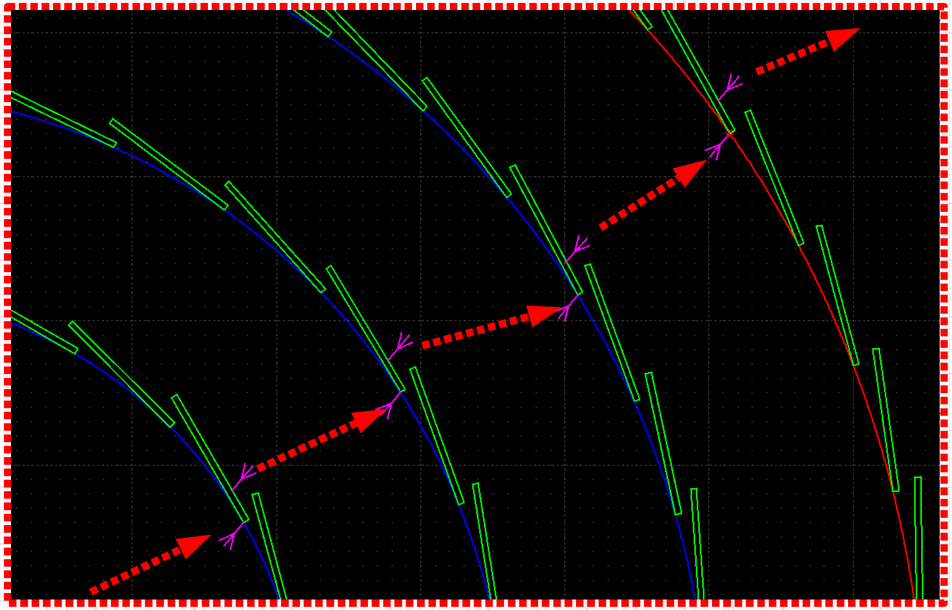
Various materials

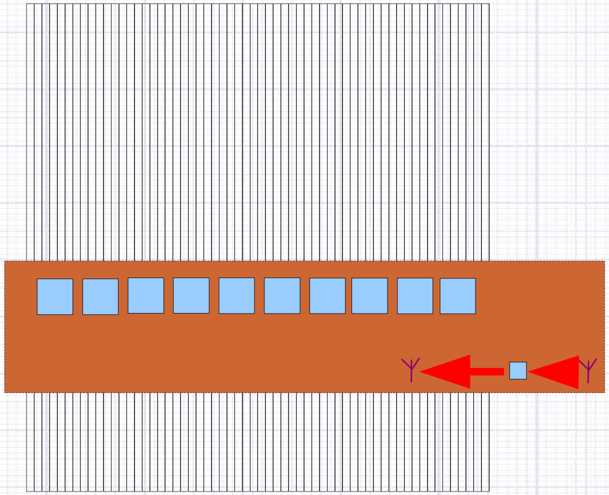


The reflection in silicon can be technically suppressed with adding material with suitable ε in the interfaces but the aluminum layers on both sides of the silicon is an obstacle that cannot be won

A more sophisticated design

- Take advantage from the fact that signals do not penetrate silicon sensors in the design of the wireless network because of no interference between layers
- Invent a new way to transfer L1 signals and at the same time reduce number of fakes.
- Use separate antennas for reception and transmission to avoid the screening problem





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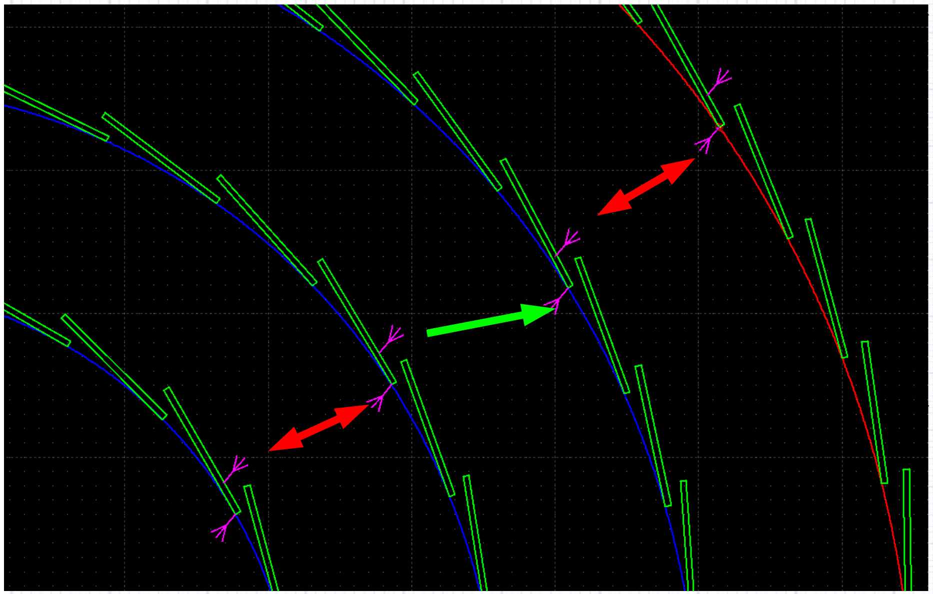
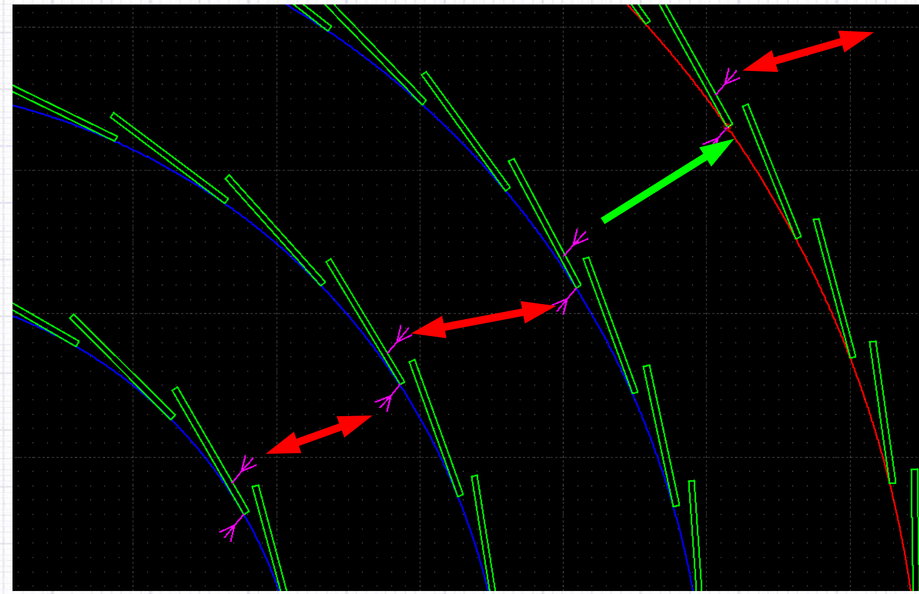
Reduction of fakes with correlation





Doublets **Triplets**

- Correlation between two layers or three.
    - Use only the axial strips on modules
    - Accept hits only in pT window >8GeV (2-3mm on next layer)
- Correlation between two sides of an axial-axial module

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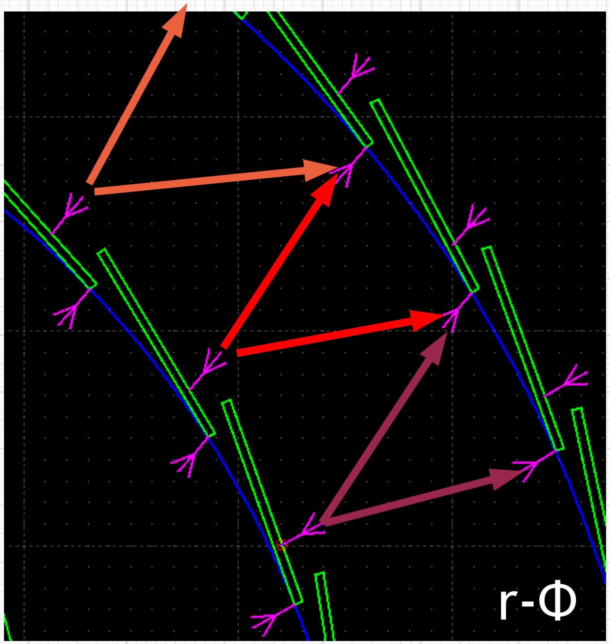
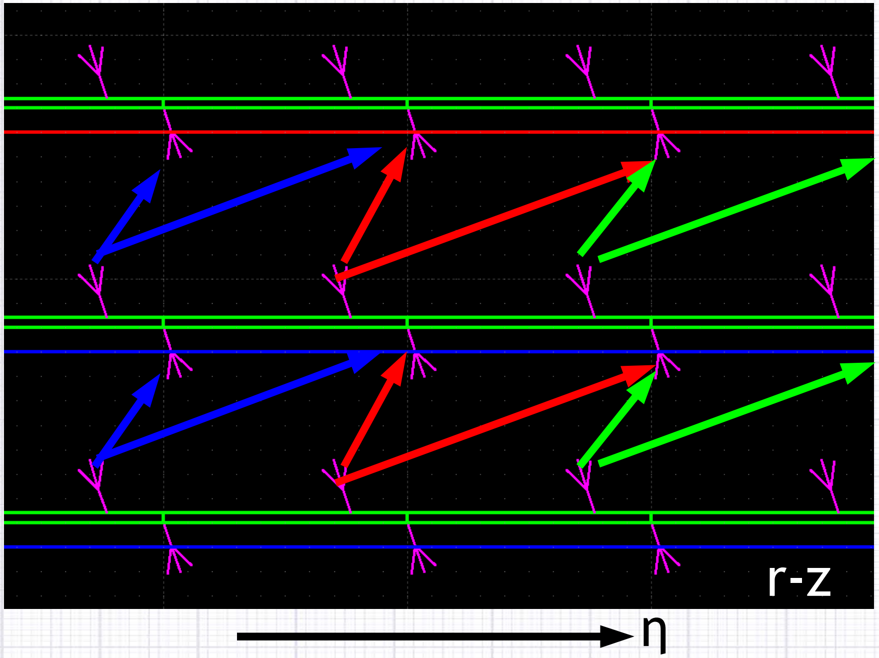
Multi-module data transfer

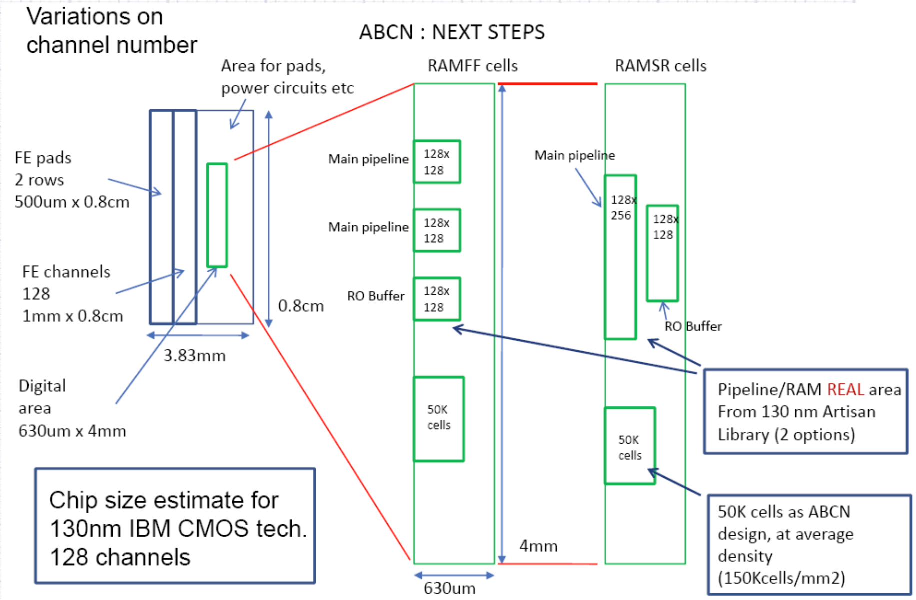




- Each module has to share data with 4-6 modules on the next layer
- Directive antenna technology important to get high gain (low power) and reduce interferences
- Perhaps a fully integrated scheme with chip-to-chip data transfer between layers (which would require chips on different layers facing each other.

Key technology development

- Integration of trigger in front-end ASIC and on detector module -> 130nm process leaves plenty of space for trigger on the ABCDnext
- Integration of wireless data transfer on module or FE chip using 3D assembly techniques
- Development of correlation logic and optimal data formatting



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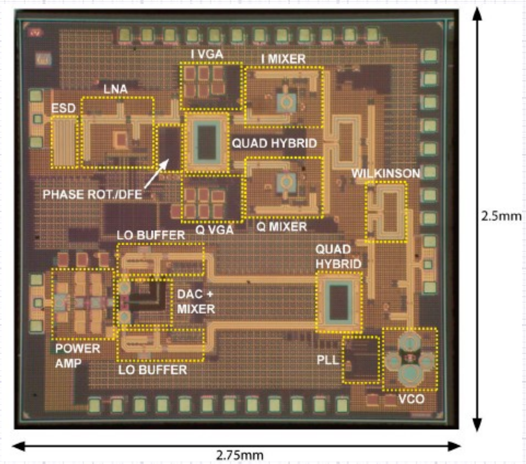
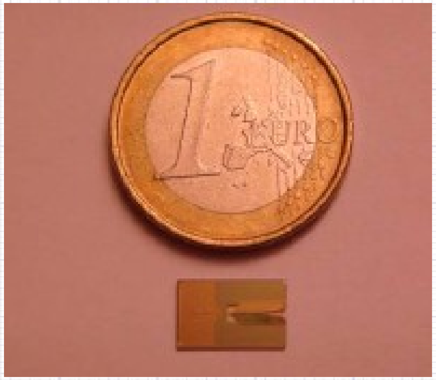
- Low power 60 GHz transceivers

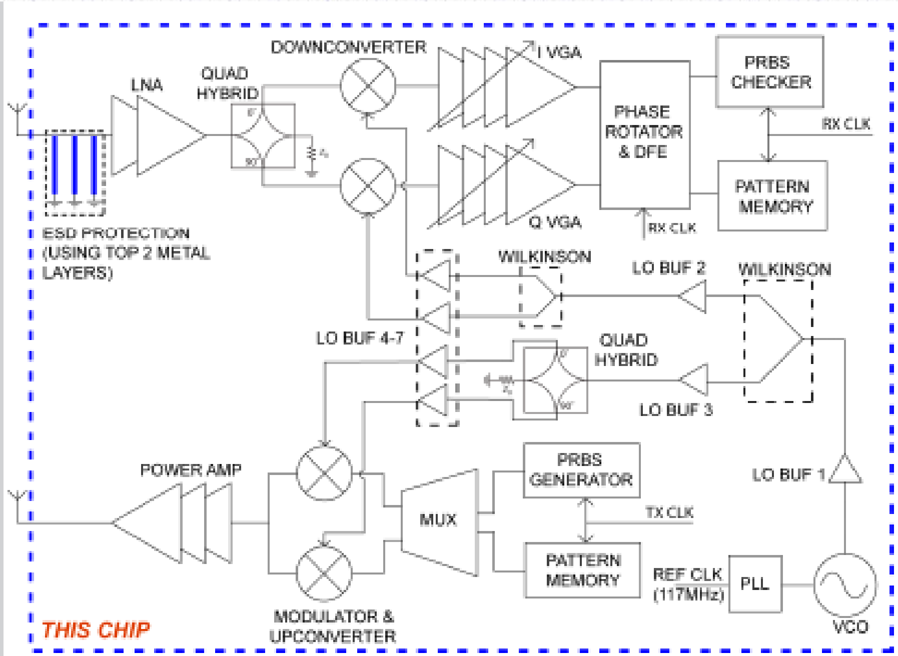


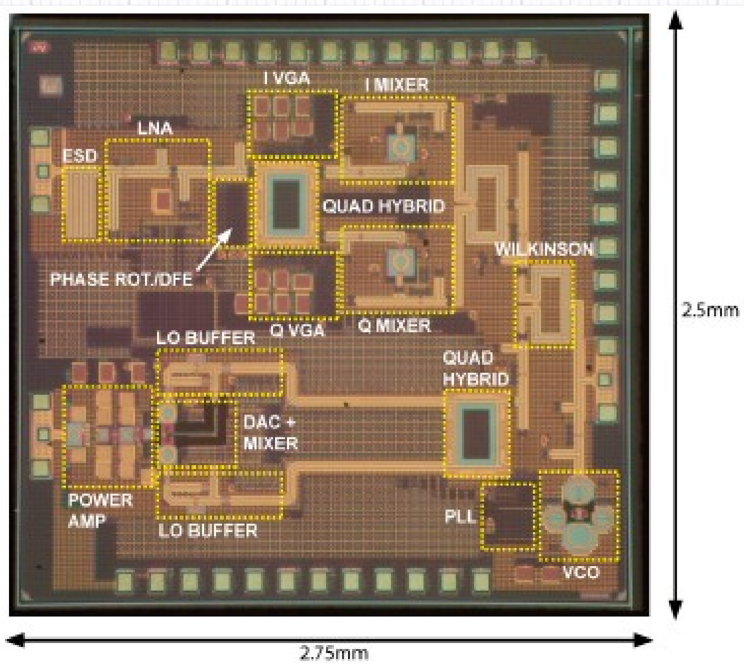
- Compact, low mass directional antennas for 60 GHz
  - Surface integrated waveguides (SIW) in kapton
  - MEMS antennas in silicon

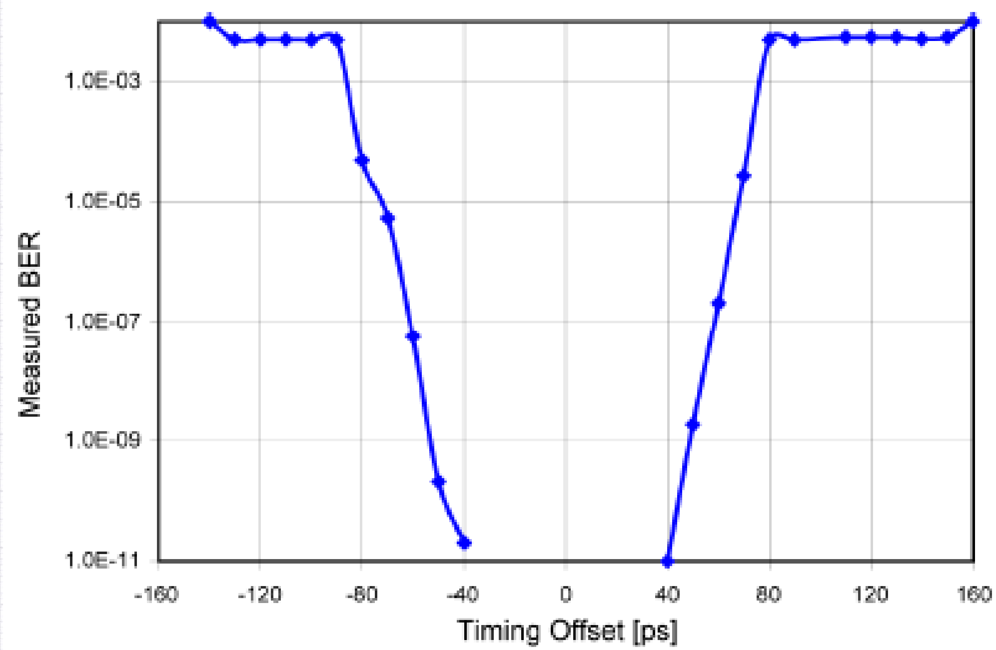


Berkeley Wireless Research Center (C. Marcu et al.), A 90nm CMOS Low-Power 60GHz Transceiver with Integrated Baseband Circuitry, prsented at ISSCC 2009

New version in 65 nm CMOS in process at ST Microelectronics



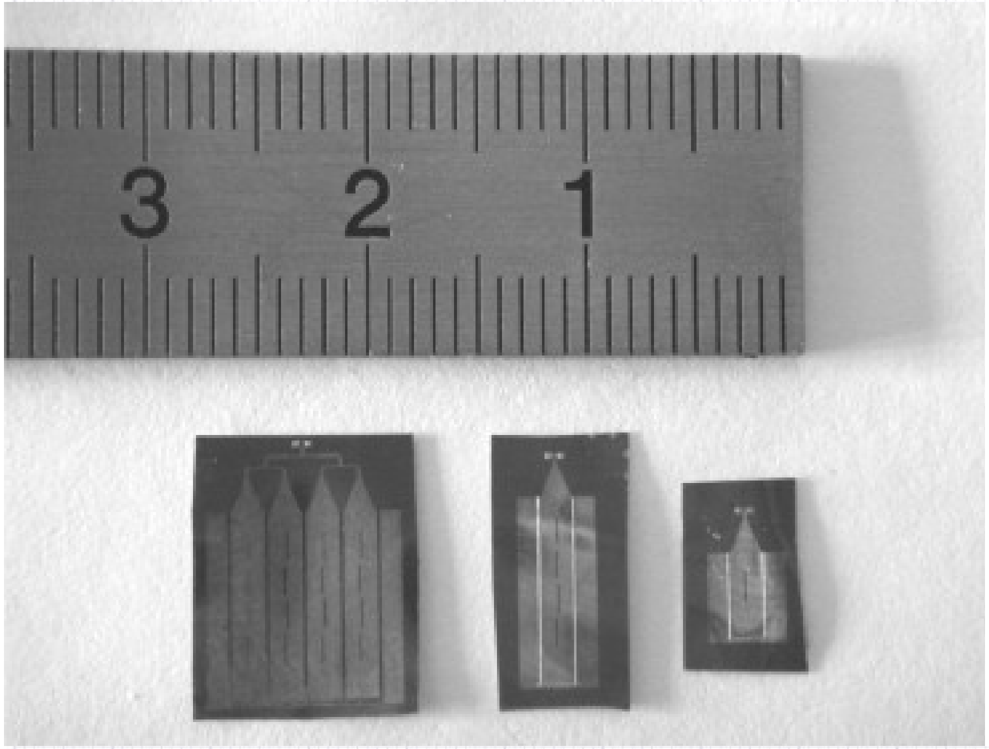


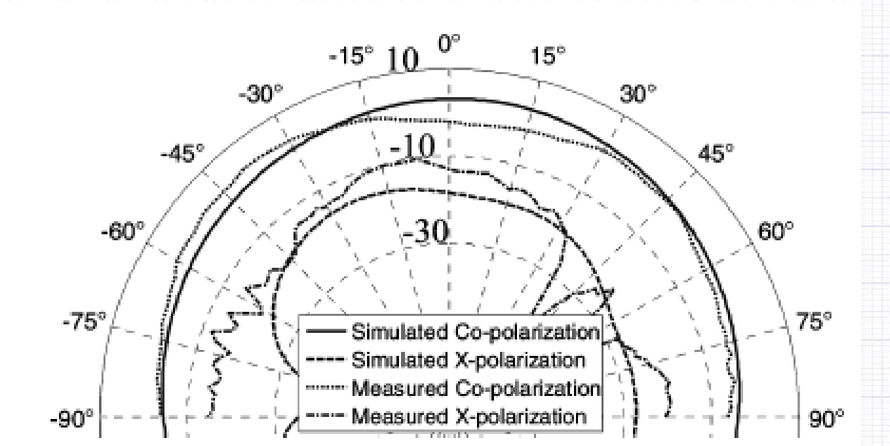


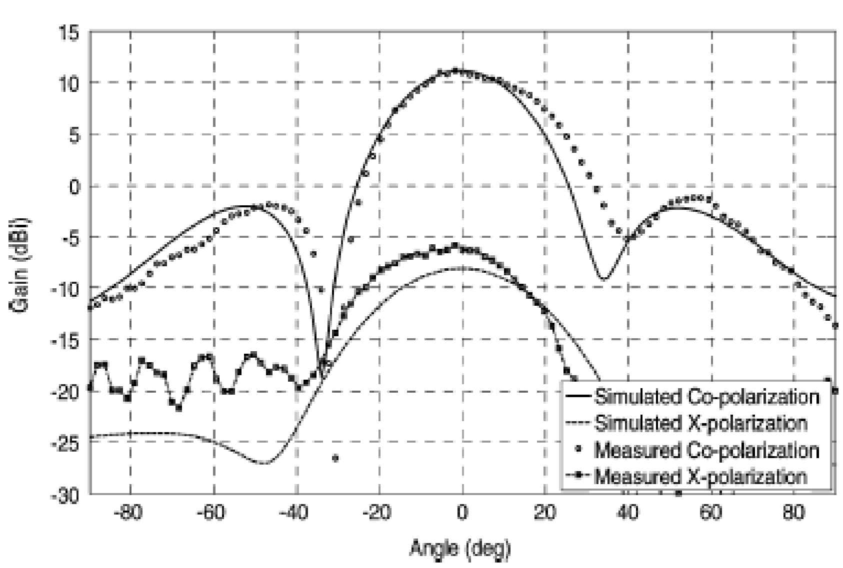
Surface Integrated Waveguides

Development at Uppsala University

- Mm array antennas processed on kapton foil



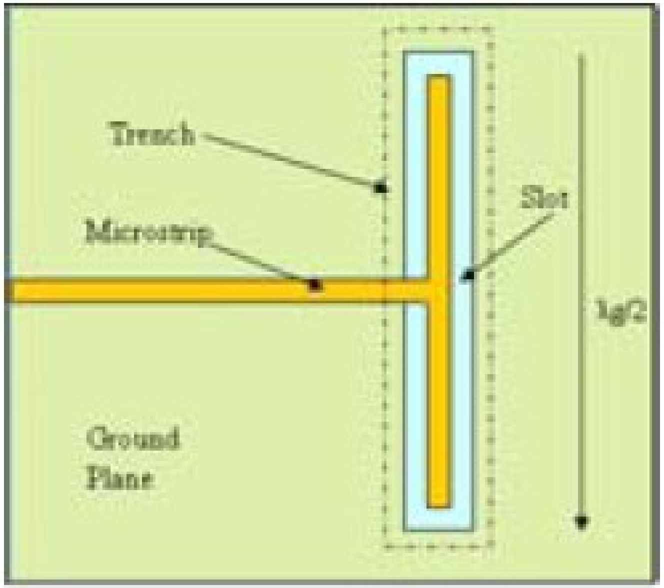


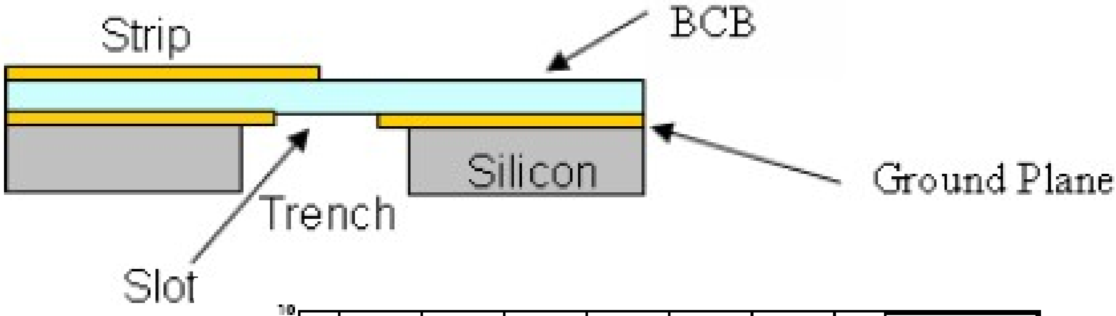


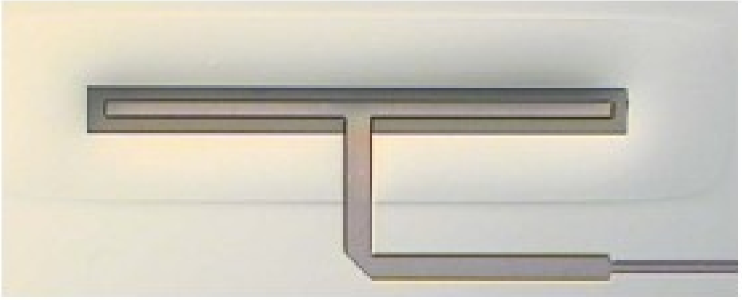
S. Sheng et al., IEEE TRANSACTIONS ON ANTENNAS AND PROPAGATION, VOL. 57, NO. 1, JANUARY 2009

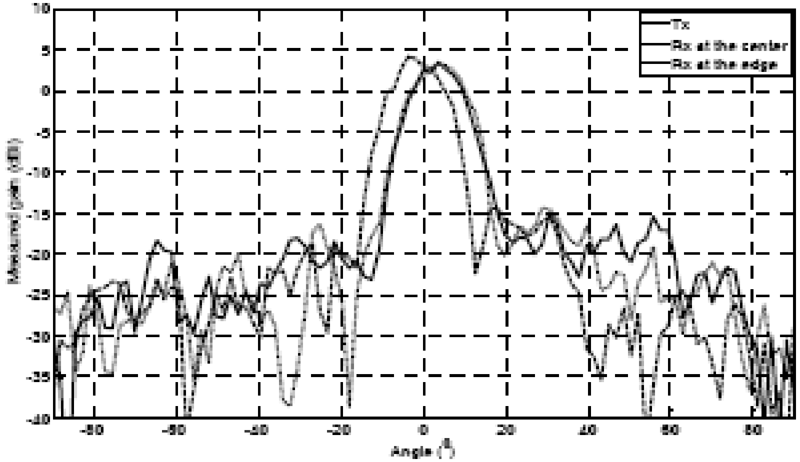
Integrated slot array antenna

Uppsala University & ACREO









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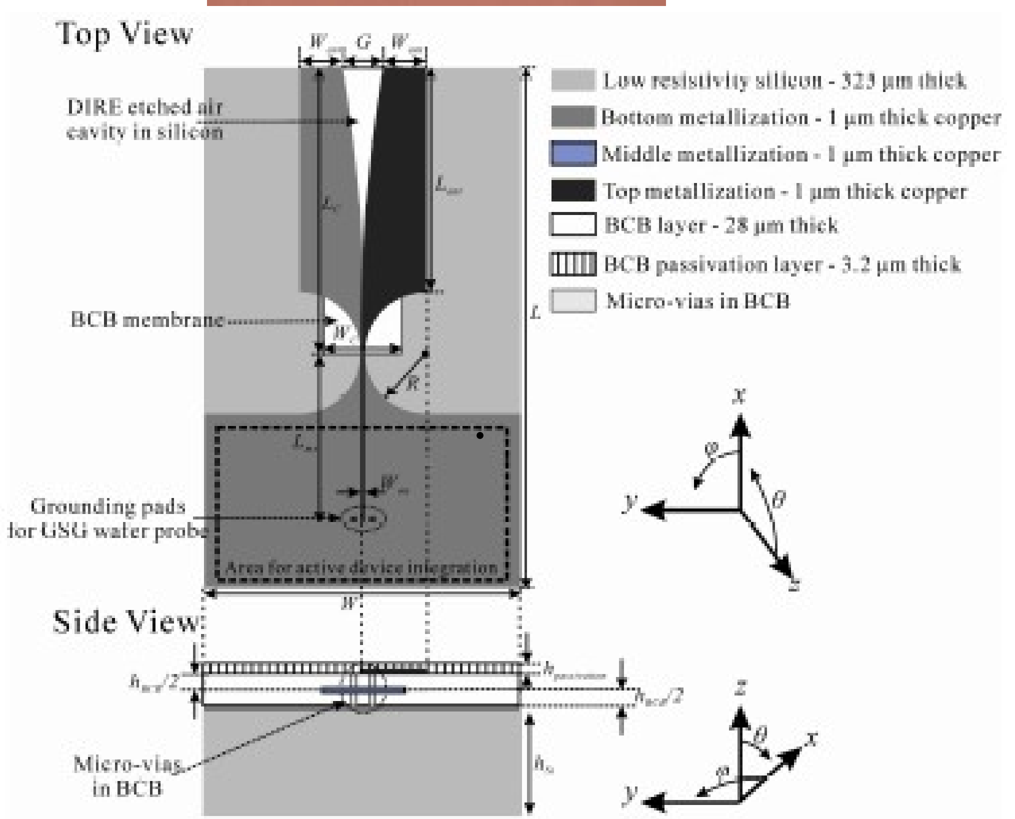
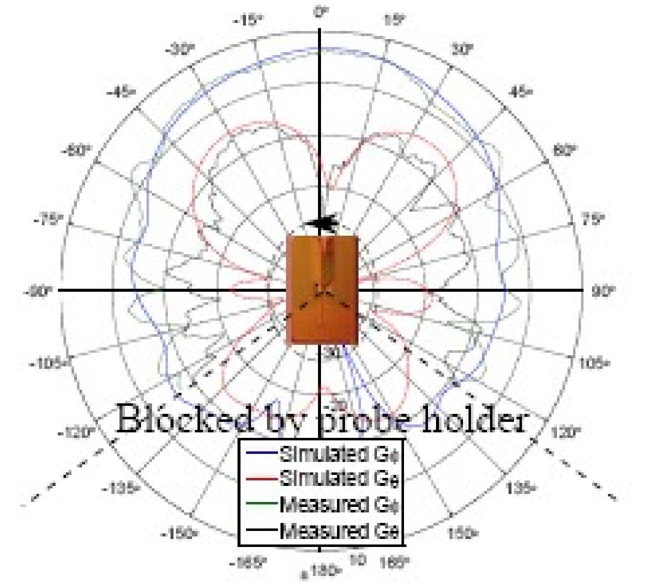
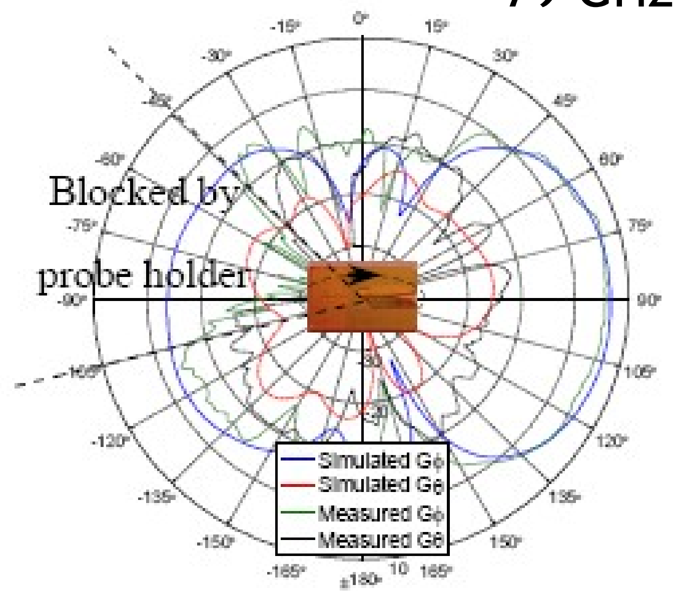
Tapered slot antenna

Uppsala University & ACREO





79 GHz



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Conclusions

- A new approach presented to use mm waves for transfer of L1 data in the tracker
- Large data bandwidth achievable with 60 GHz with little added power and material.
- Possibility to layer-to-layer, module-to-module and chip-to-chip communication
- Technology becoming available
- Technology is challenging and will need a lot of tests and studies. The system aspect of a wireless L1 trigger is also very challenging and will require expertise from the telecom field.