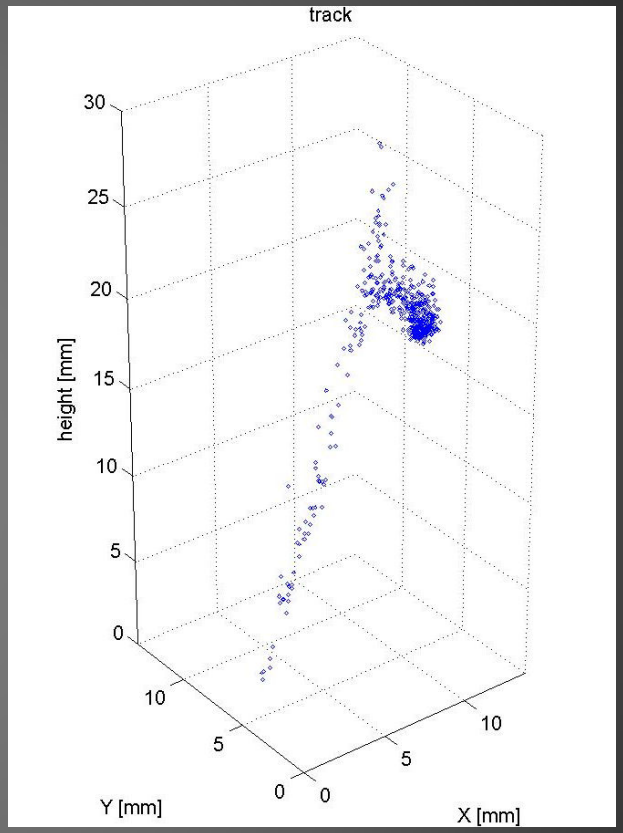
Data Compression and LVL1 track triggering by means of Digital Signal Processing in GridPix/Gossip FE pixel chips



- Introduction GridPix/Gossip
- GridPix as LVL 1 trigger in ATLAS
- IfLink
- Conclusions

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[1] Nikhef

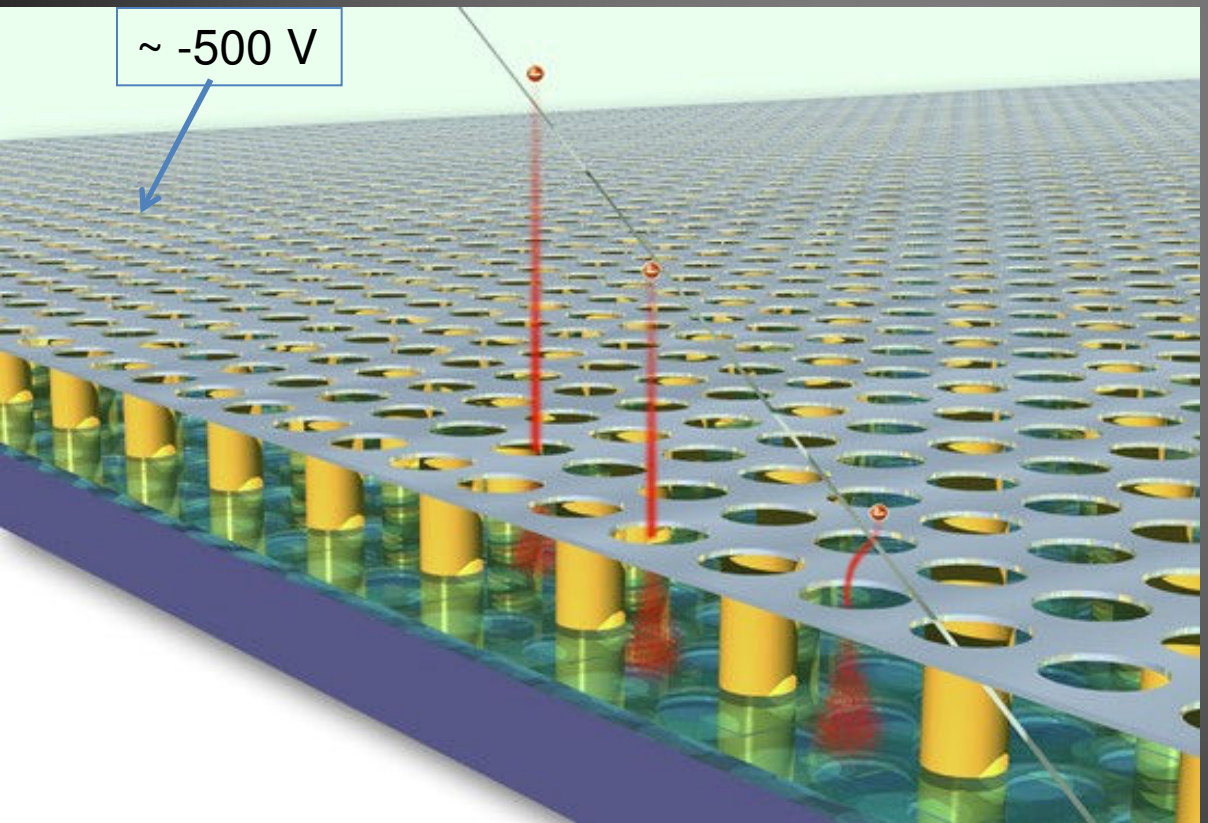
[2] Radboud University, Nijmegen

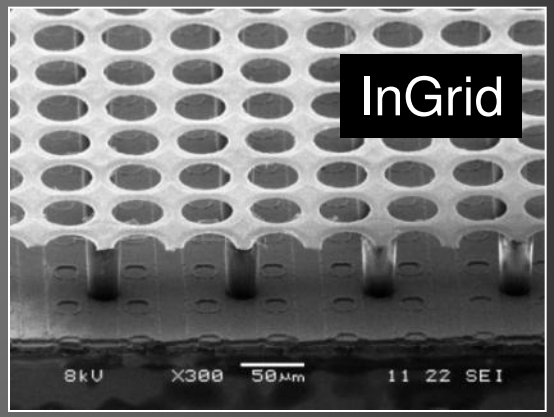
[3] CERN

WIT 2010, Berkeley, CA, USA
Feb 3, 2010

Functioning GridPix/Gossip

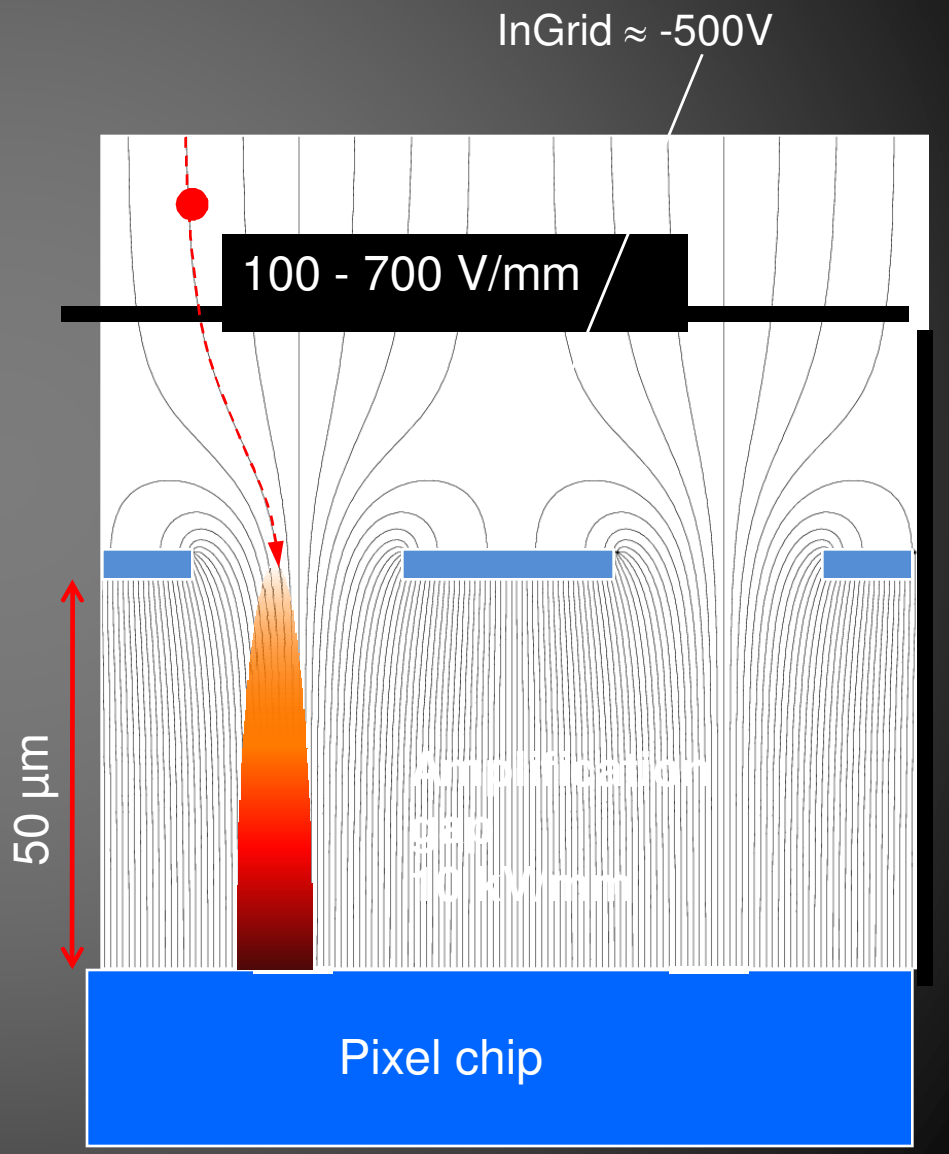
- Gaseous Pixel detector using a pixel chip
  - Using gas as a detecting medium
- Electron from traversing particle drifts towards Micromegas grid and is focused into one of the holes
- Thereafter a gas avalanche is induced ending at the anode pad of the pixel chip



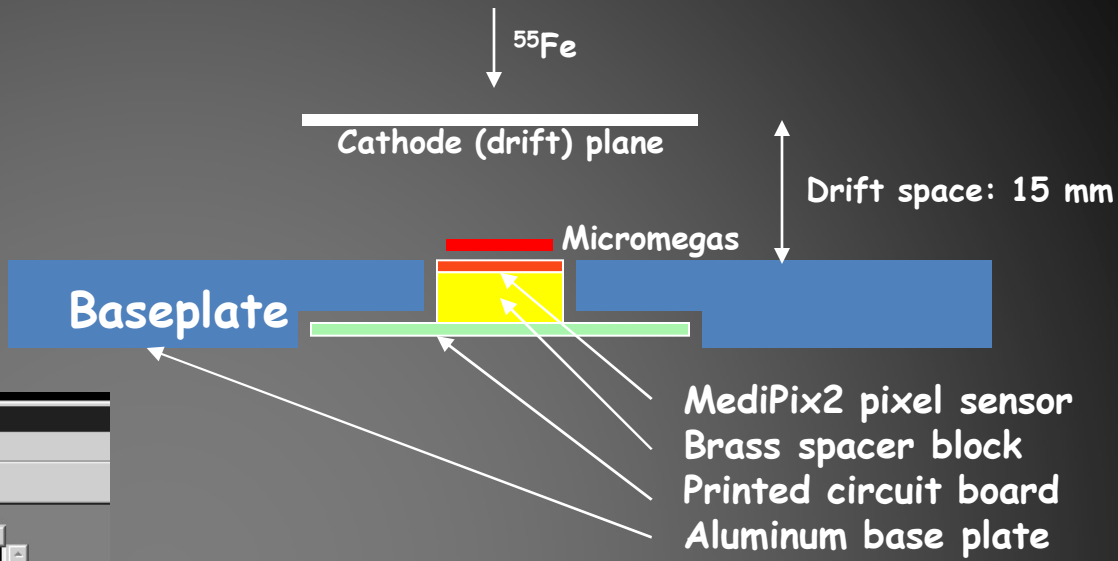


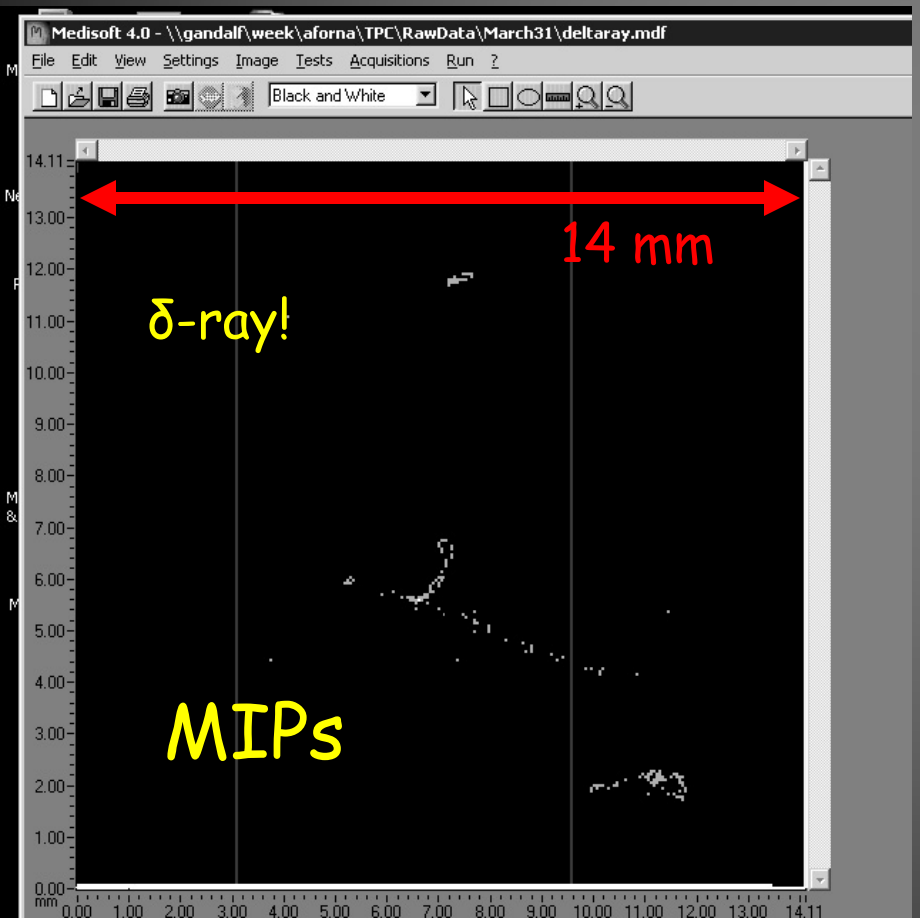
Field configuration of GridPix/Gossip

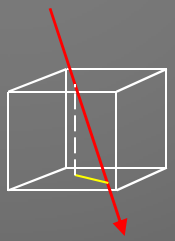
- Drift field 100 -700 V/mm
- High amplification field under grid to induce gas avalanche
  - ~ 10 kV/mm
- Micromegas holes centred on pads pixel chip
- Avalanche broadened by diffusion to 15 – 20 µm

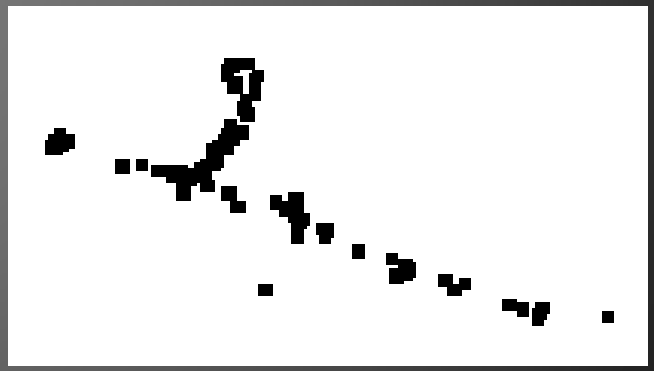


April 2004 Micromegas + MediPix 2 NIKHEF/Saclay/Univ. Twente:

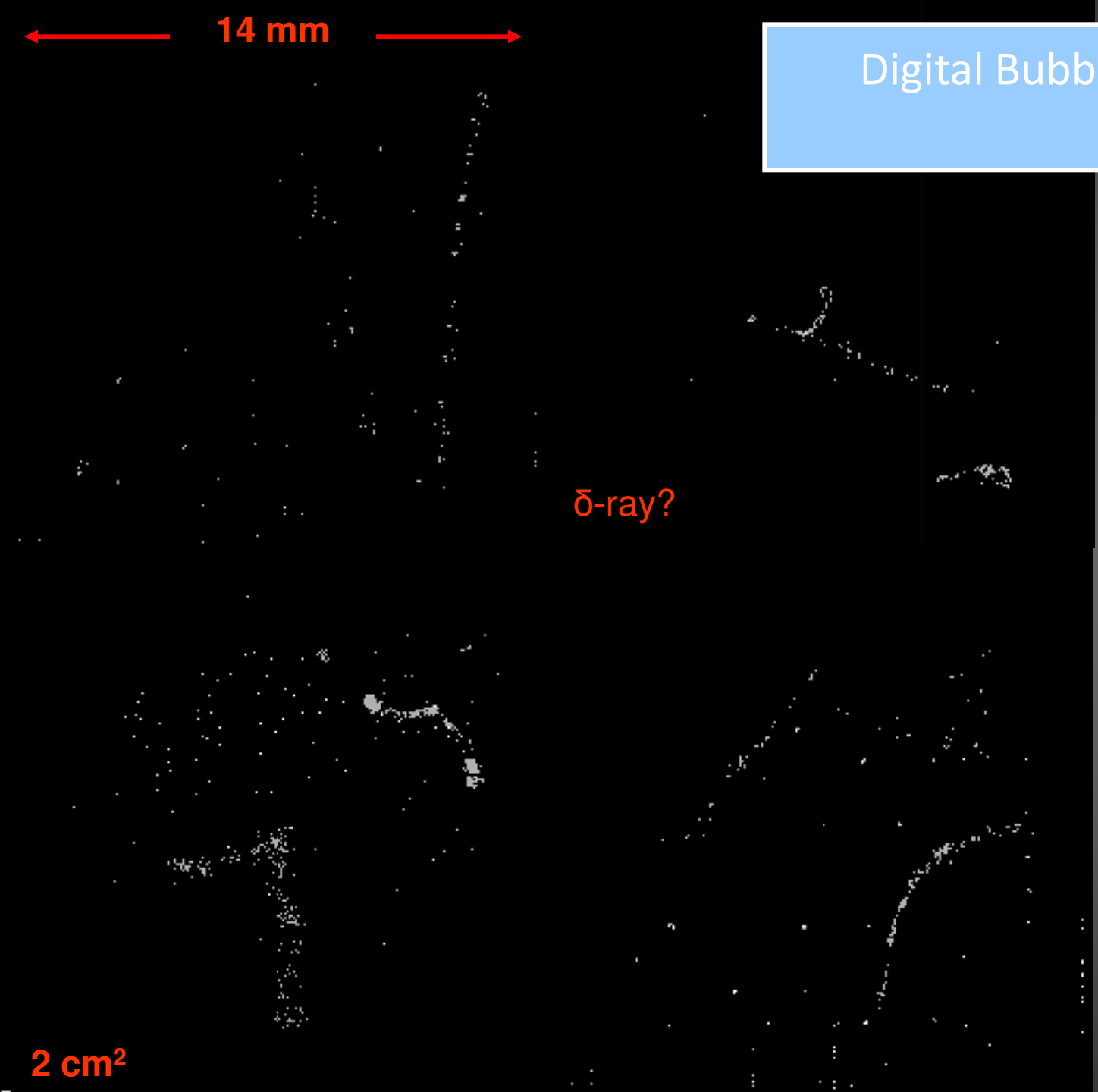








He/Isobutane
80/20
Modified MediPix



Digital Bubble Chamber-like picture Gallery

- Particles:

  Cosmics

- Gas Mixture

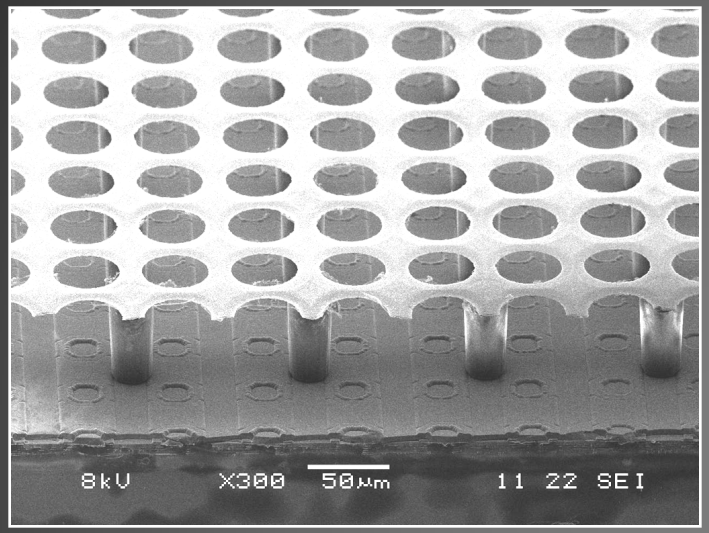
  He iC_4H_{10} 80/20

- No trigger

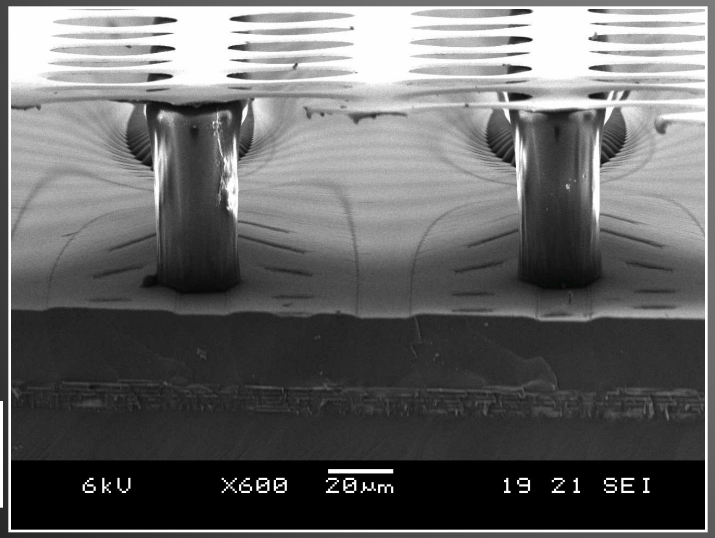
  Time & luck

Full post-processing of a TimePix

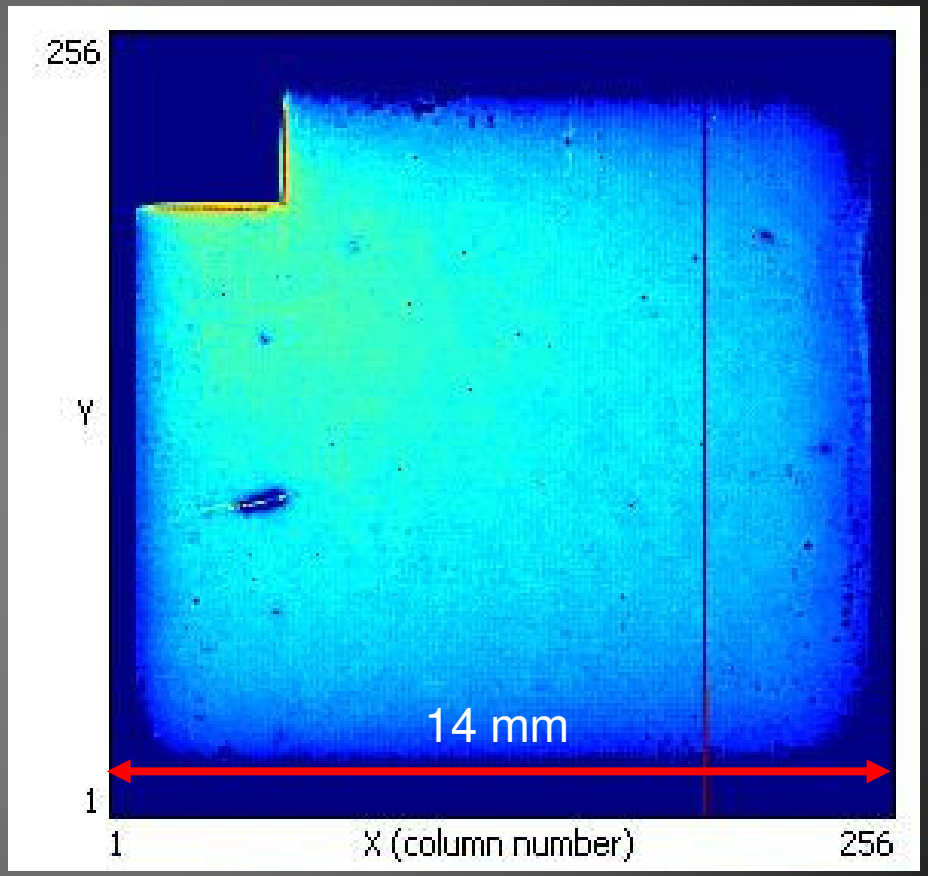
- Timepix chip + SiProt + Ingrid:



MESA+



IMT Neuchatel

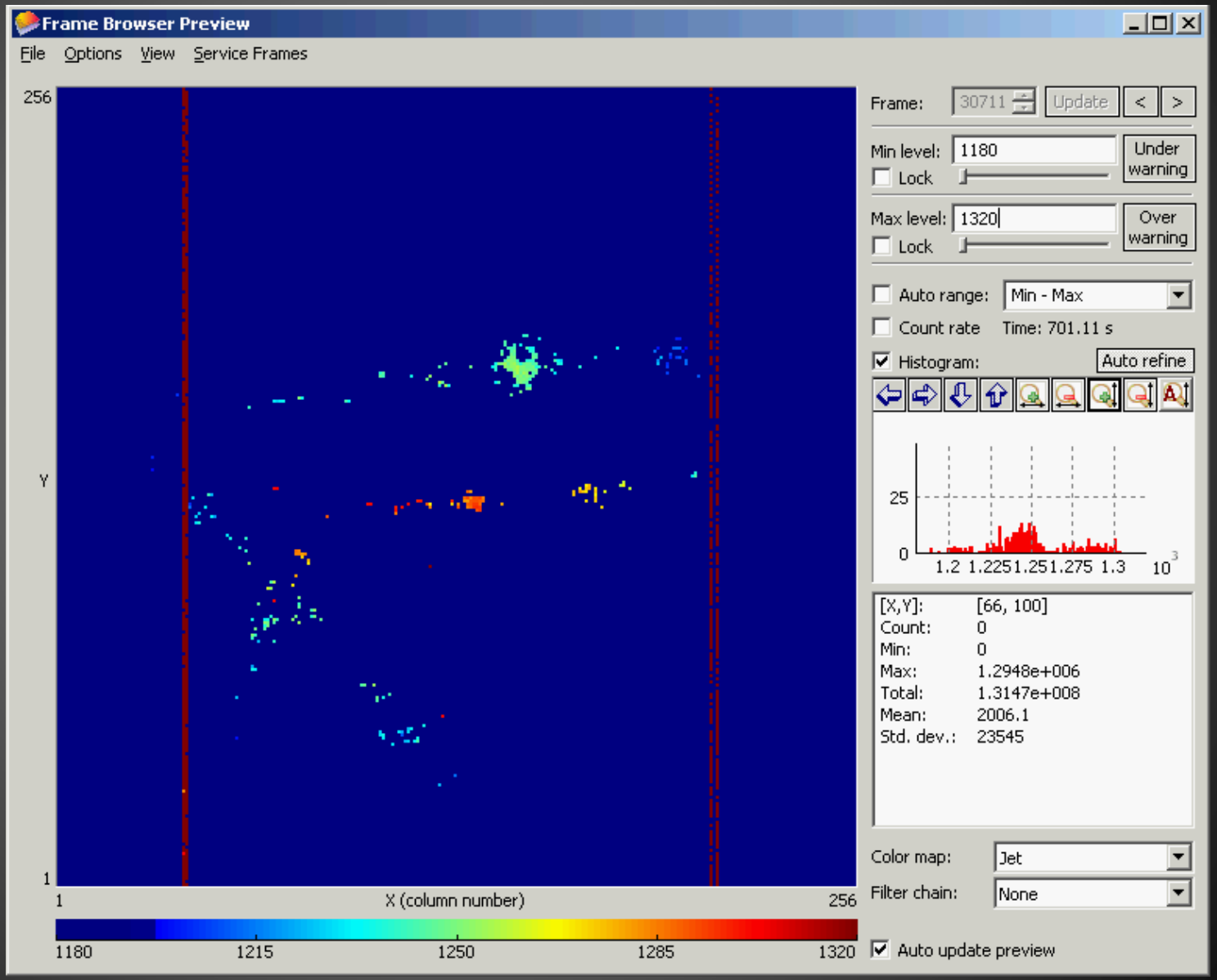


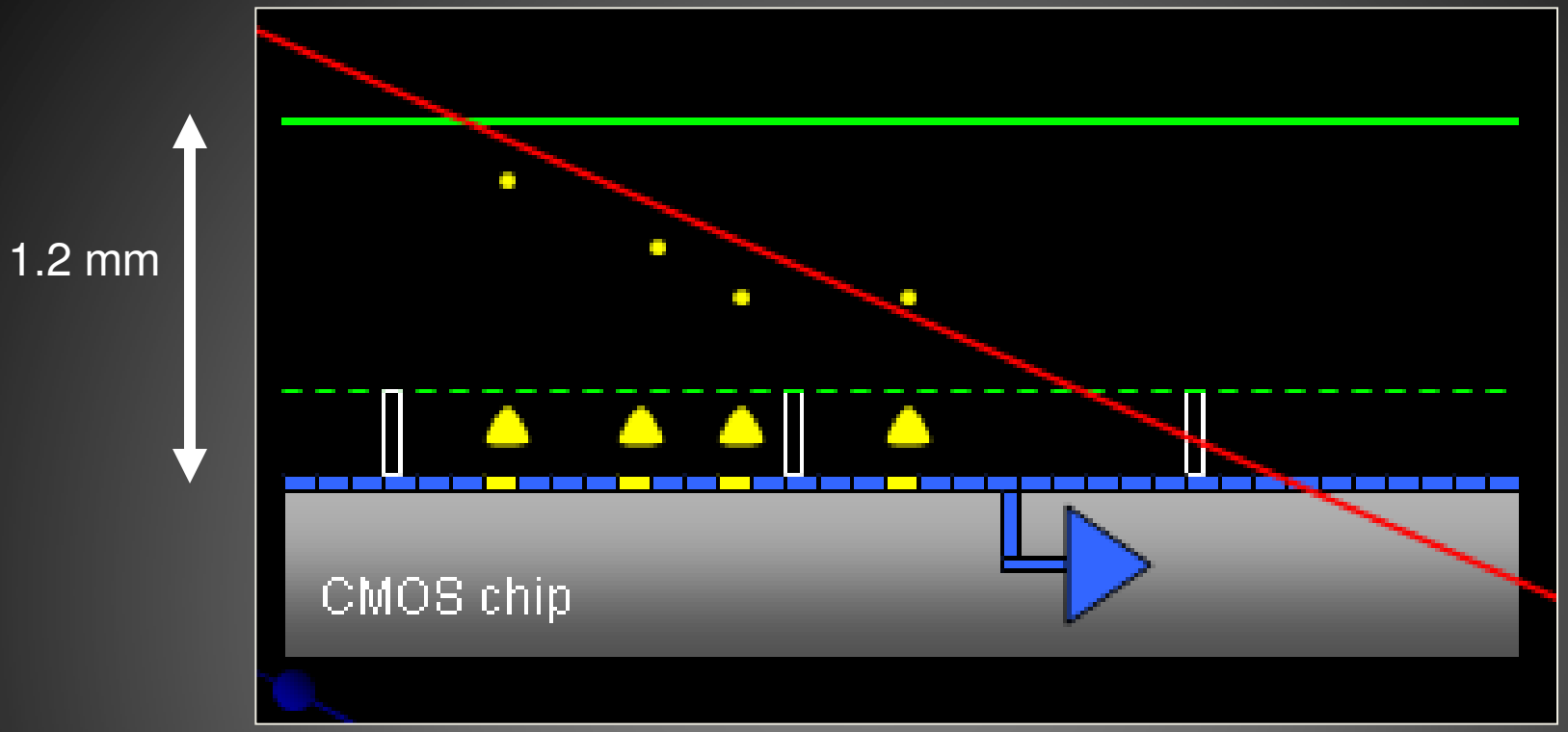
"Uniform"

Charge mode

Cosmic rays in Argon

Time mode

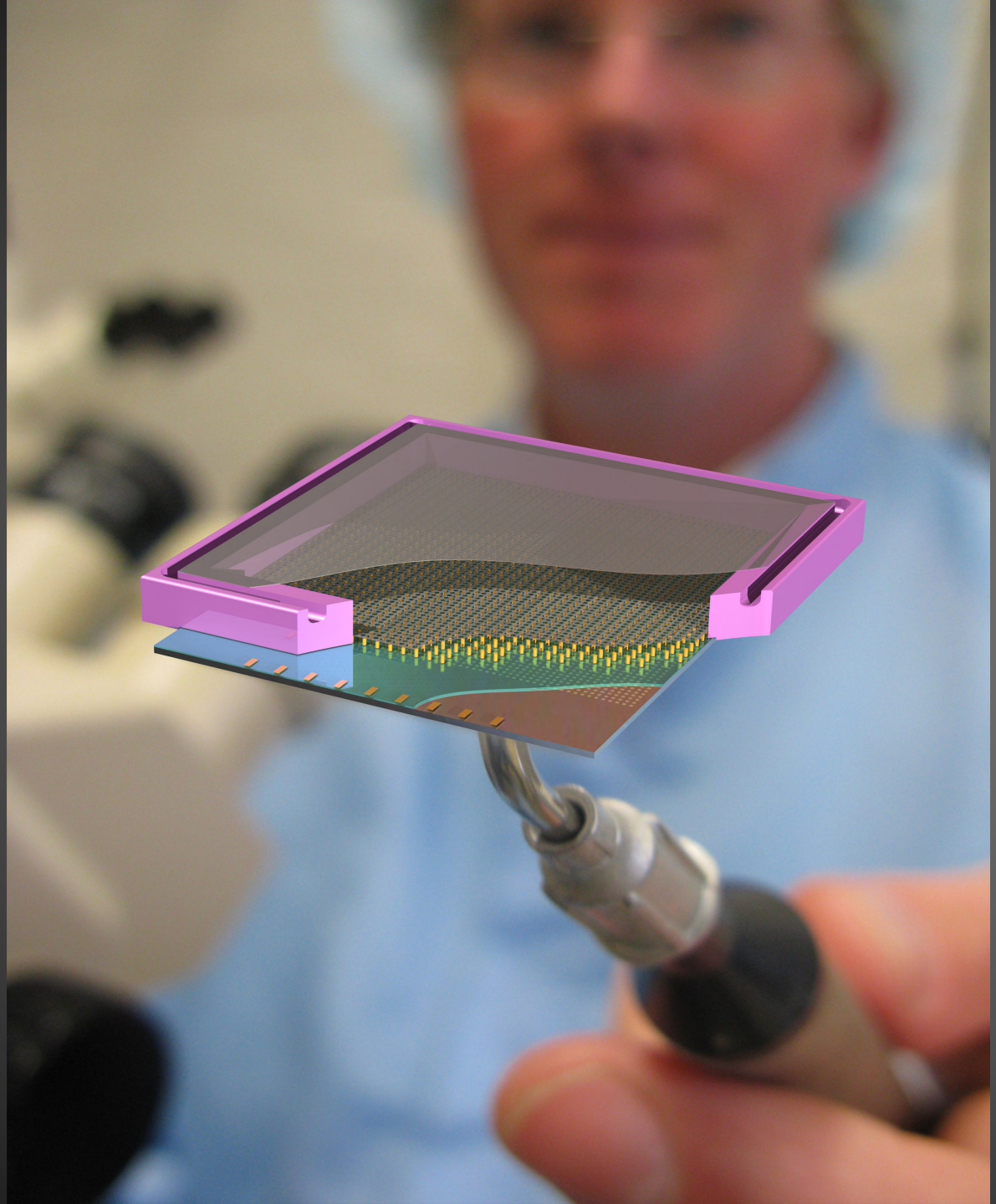




Gas On Slimmed SIlicon Pixels

Gossip: replacement of Si tracker

Essential: thin gas layer (1.2 mm)



Gas instead of Si

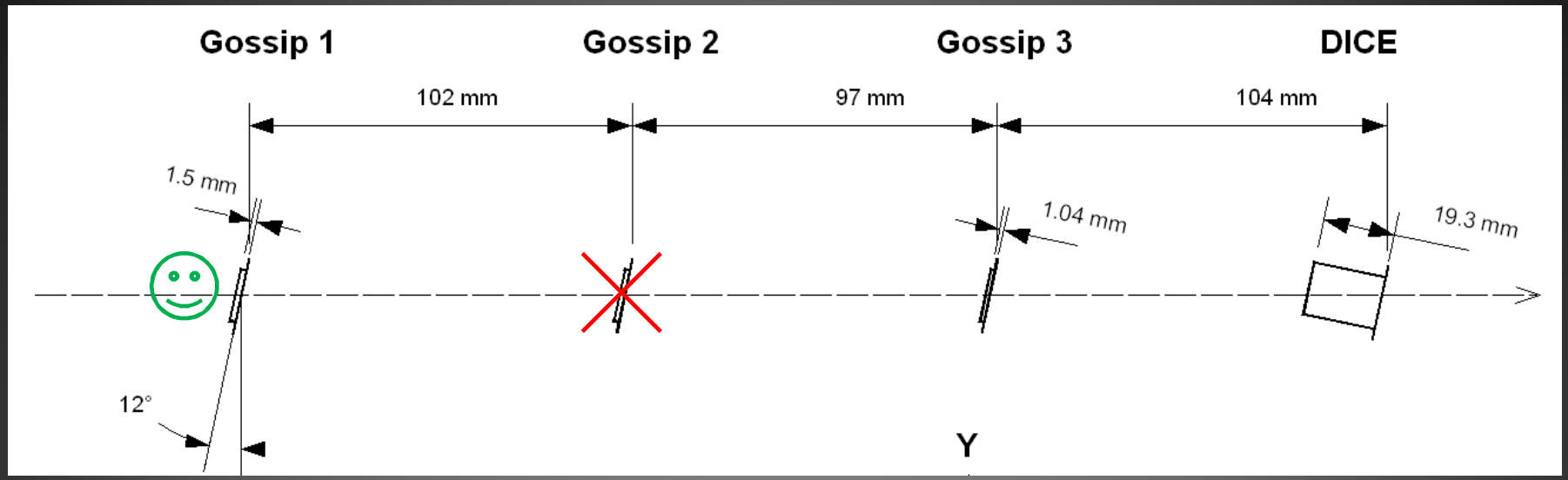
Pro:

- no radiation damage in sensor: gas is exchanged
- modest pixel (analog) input circuitry: low power, little space
- no bias current: simple input circuit
- low detector material budget: 0.06 % radiation length/layer
  typical: Si foil. New mechanical concepts
- low power dissipation : little FE power (2 μW/pixel); no bias dissipation
- operates at room temperature (but other temperatures are OK)
- less sensitive for neutron and X-ray background
- 3D track info *per layer* if drift time is measured
- gas is cheap (and *very* cheap wrt. Si sensors!), and light

Con:

- Gaseous chamber: discharges (sparks): destroy CMOS chip
- gas-filled proportional chamber: 'chamber ageing'
- Needs gas flow
- Parallax error: 1 ns drift time measurement may be required
- diffusion of (drifting) electrons in gas limit spatial resolution

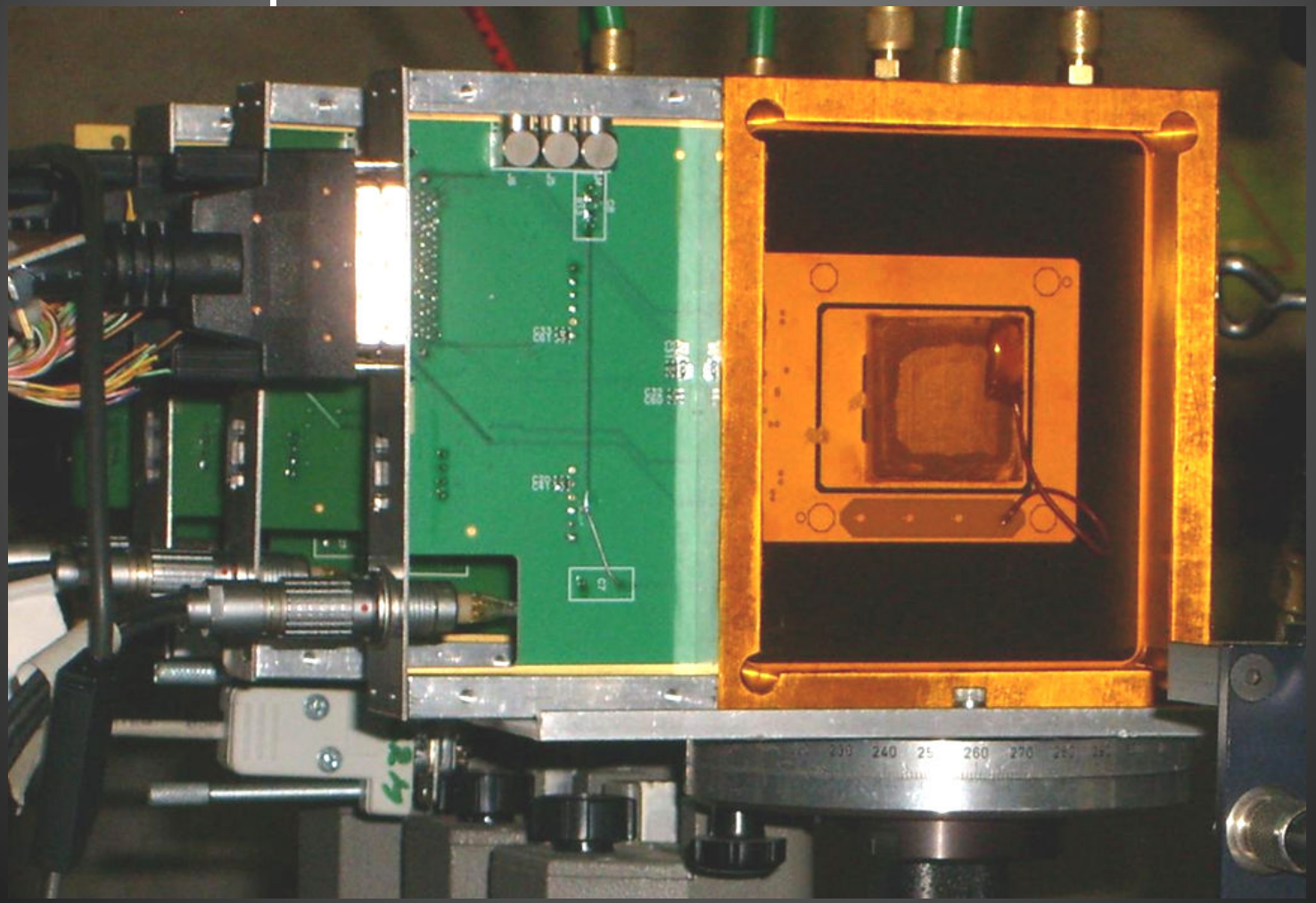
Test beam experiment using DME/CO_2



- Beam T10 (6 GeV π) at PS
- 4 detectors ~ 10 cm apart under 12 - 14° in Y and perpendicular in X
- HV problems (sparking)
  - Gossip 1: gas gap 1.5 mm, good single electron efficiency, protected with **GlobTop**
  - Gossip 2: not useful (HV problems)
  - Gossip 3: gas gap 1.04 mm, very small single electron efficiency (~ 16%)
  - DICE: gas gap 19.4 mm, single electron efficiency ~ 38%, but good for tracking
- Gas CO_2/DME 50/50

Testbeam setup in T10 (East hall)

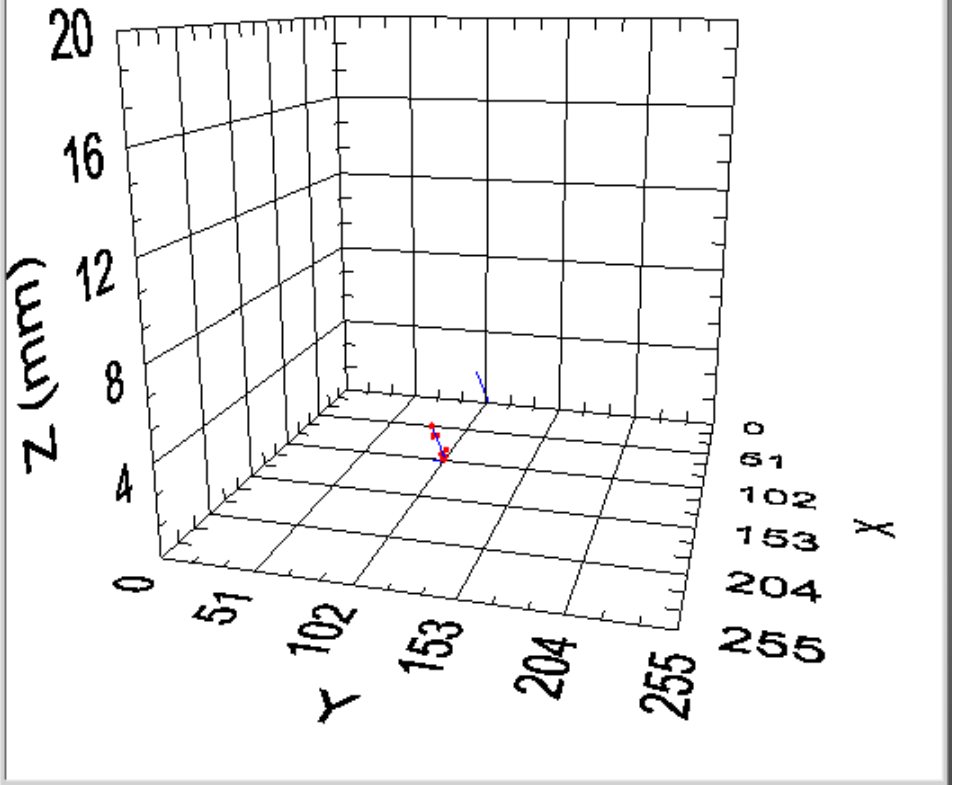
- 3 Gossips and one GridPix
- ~ 10 cm apart



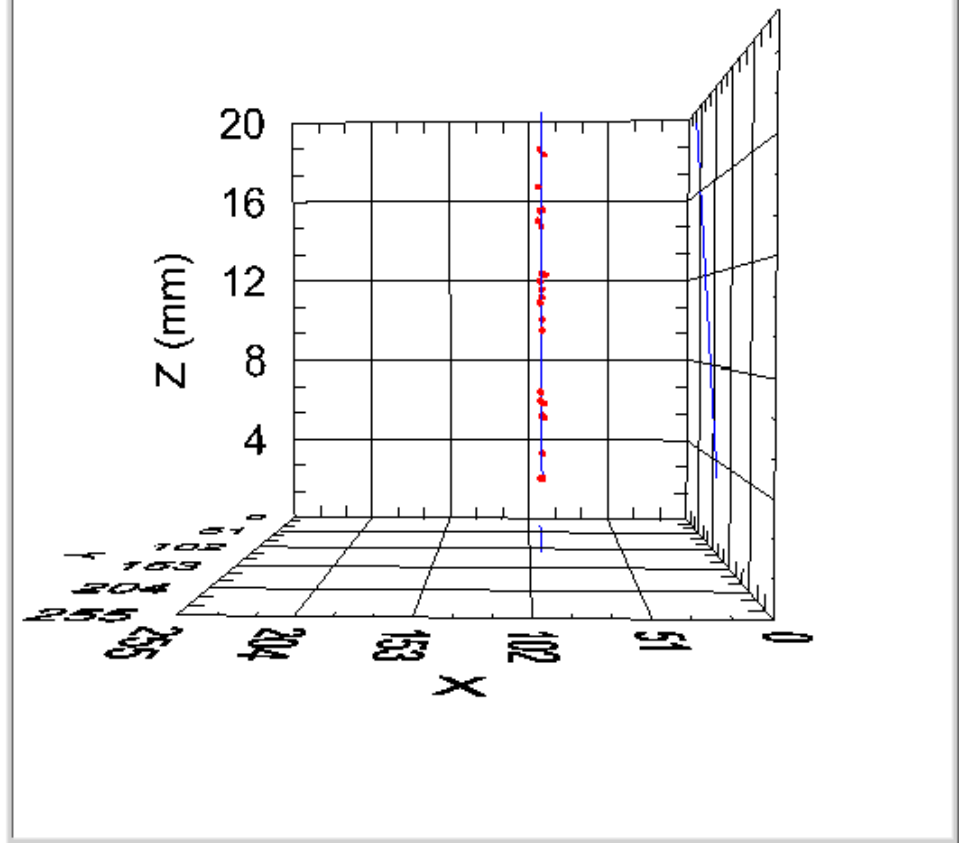
Example of events in Gossip 1 and DICE

- Pixel chip on X-Y plane

Gossip 1
1.5 mm gap



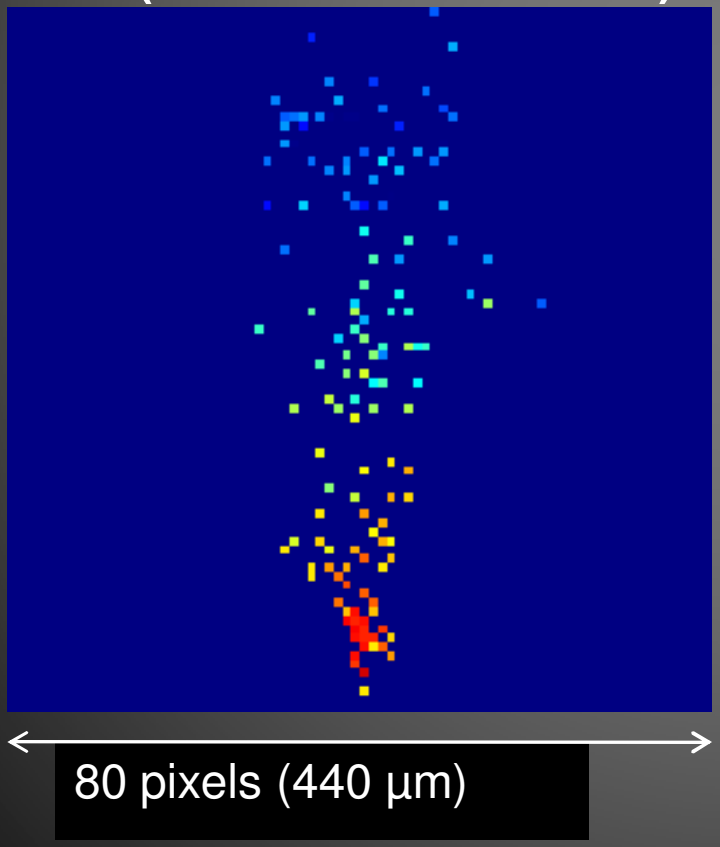
TimePix



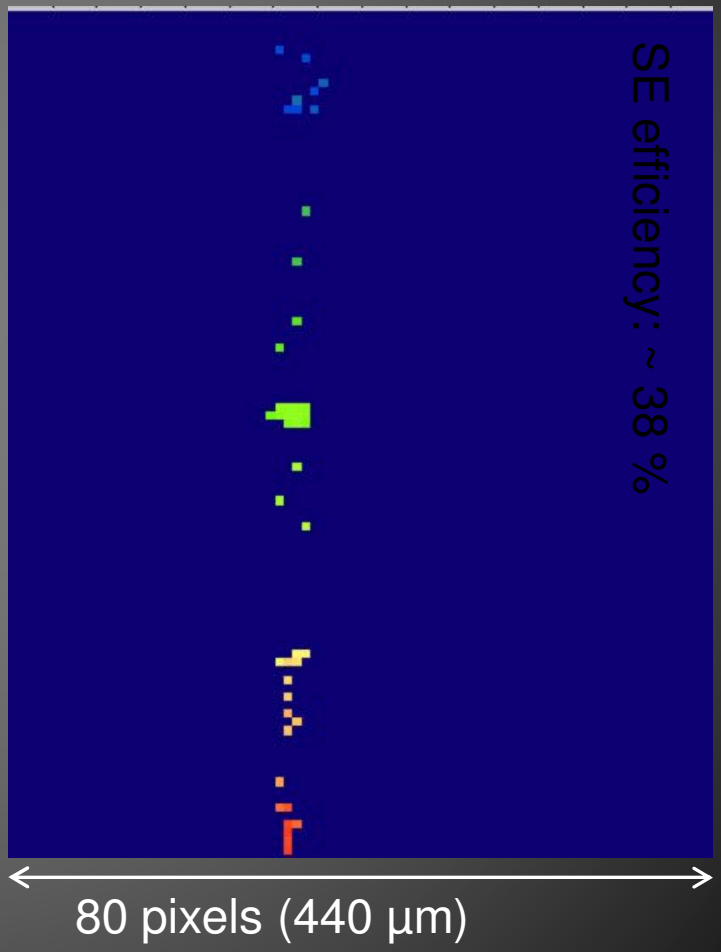
Comparing DME/CO_2 with Ar/iC_4H_{10}

- Projected slanting tracks
- Measured in DICE detector: drift distance 19.3 mm
- Very low diffusion for CO_2/DME

Ar/iC_4H_{10} 80/20
(June 2009 testbeam)



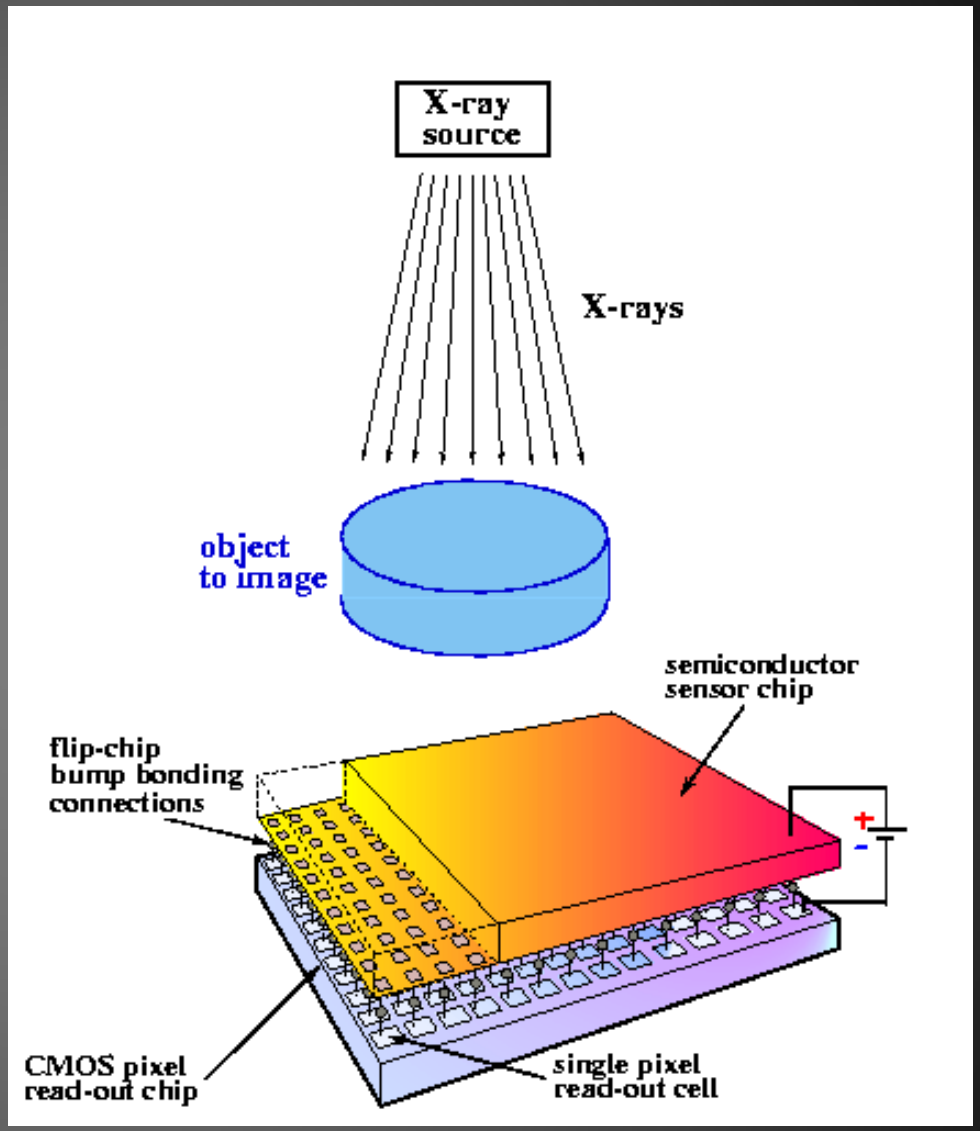
CO_2/DME 50/50



The MediPix2 pixel CMOS chip

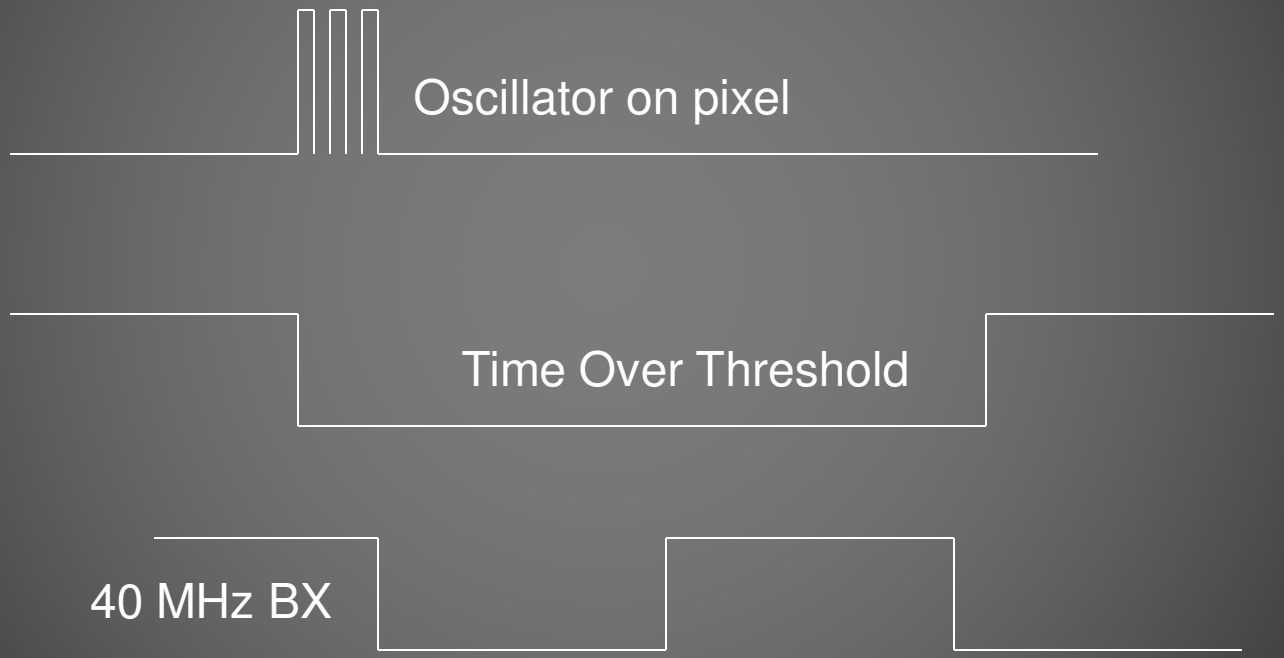
256 x 256 pixels
pixel: 55 x 55 μm^2
per pixel:
- preamp
- shaper
- 2 discr.
- Thresh. DAQ
- 14 bit counter

- enable counting
- stop counting
- readout image frame
- reset



We apply the 'naked' MediPix2 chip without X-ray convertor!

1 ns TDC per pixel

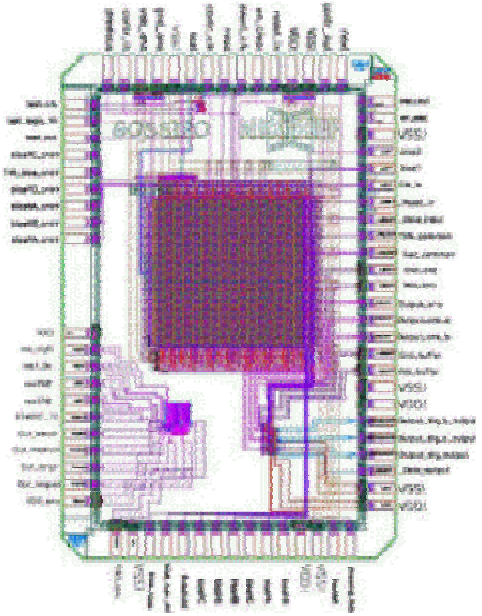


TimePix-2

Gossipo-2 MPW

600 MHz osc
in each pixel

Low-noise,
low power analog
input



Medipix-1

Medipix-2 — 250 nm technology

TimePix

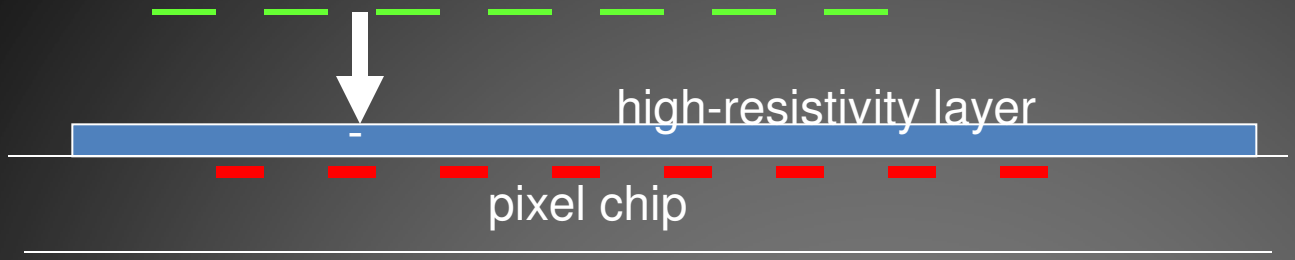
Medipix-3 — 130 nm technology

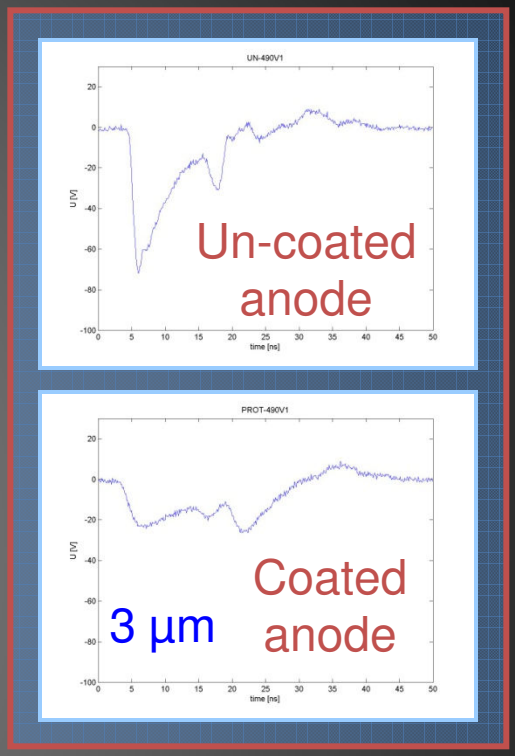
TimePix-2

TimePix-2:

- TDC per pixel: σ = 1 ns
- 'ADC' per pixel: TimeOverThreshold
- noise: 80 e- eq.
- discharge protection circuit
- fast (trigger enabled) readout

Essentially ALL info on primary electrons in gas is extracted!





SiProt protection against:

- hot spark plasma
- Too large charge in pixel circuitry [principle of RPCs]
  - local reduction of E-field: quenching
  - widening discharge funnel: signal dilution
  - increased distance of 'influention'

SiProt: a low T deposited hydrogenated amorphous silicon (aSi:H) layer

Up to 50 µm thick films, ~10^{11} Ω.cm

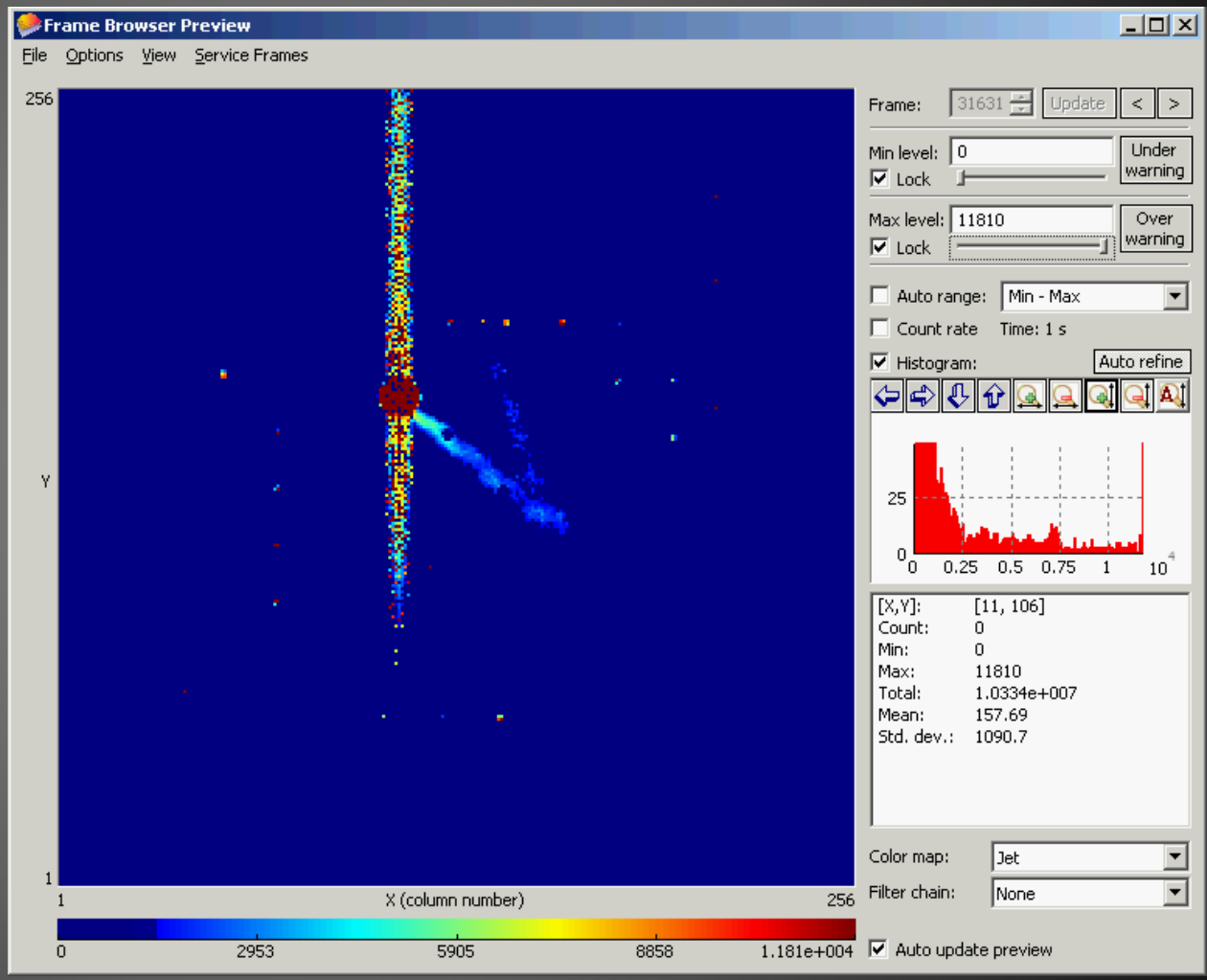
… discharges are observed !

For the 1st time: image of discharges are being recorded

Round-shaped pattern of some 100 overflow pixels

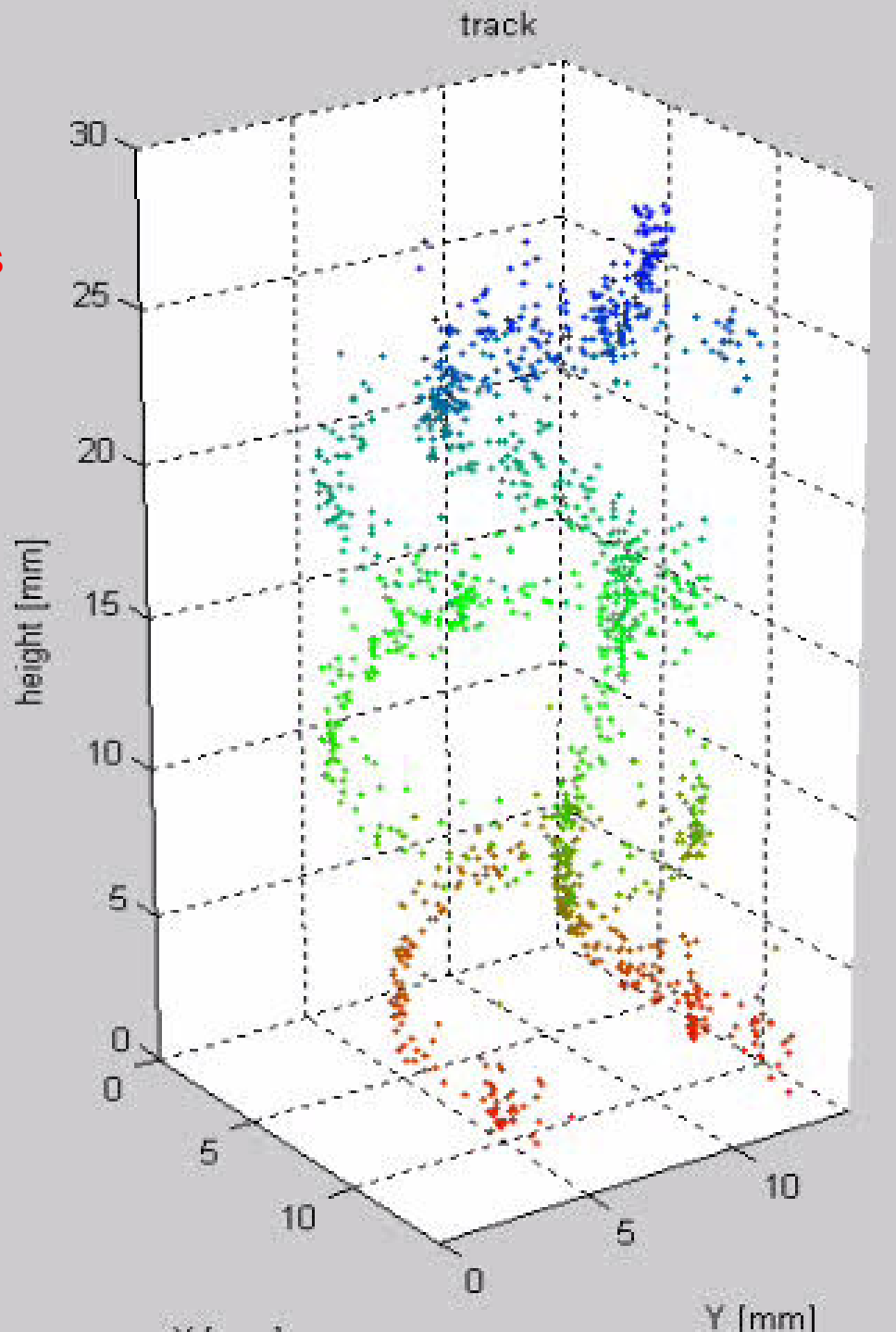
Perturbations in the concerned column pixels
- Threshold
- Power

Chip keeps working

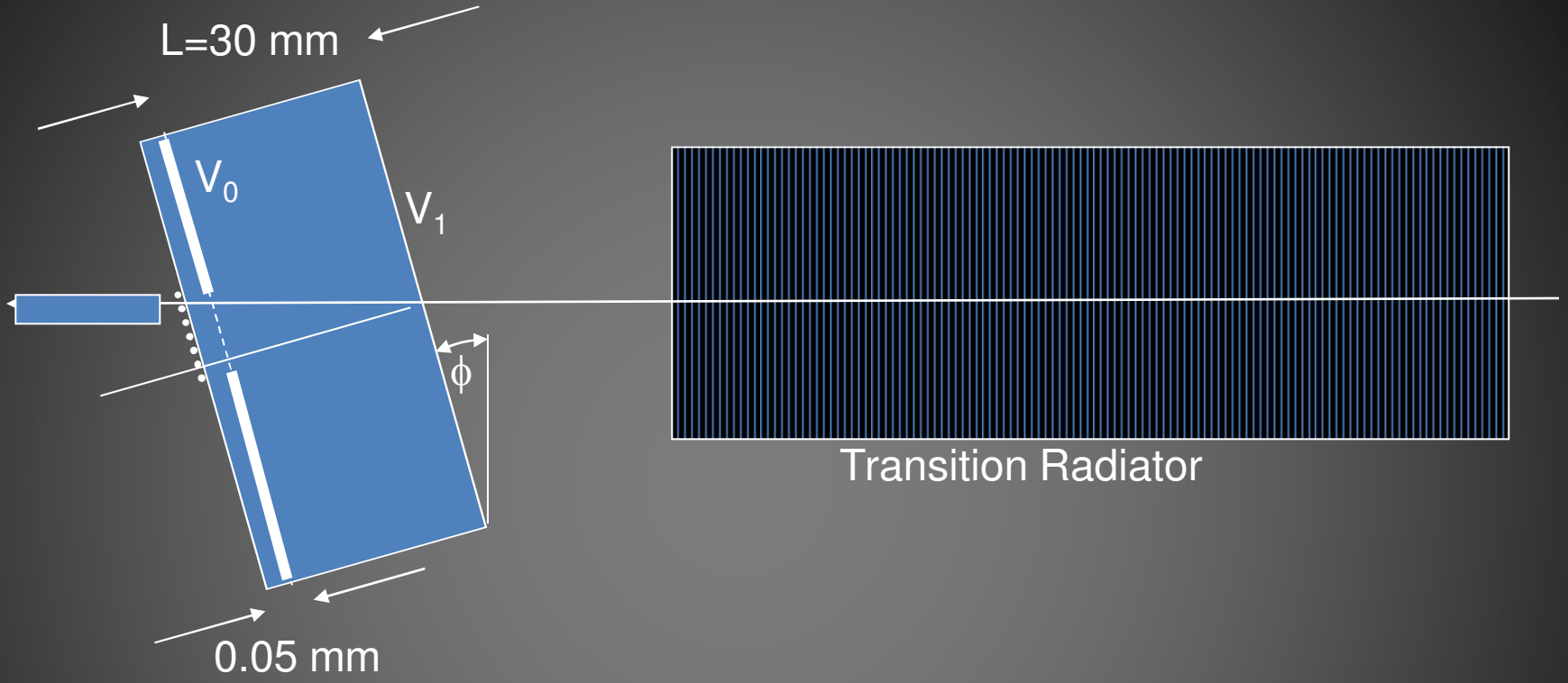


Tracks of two β's from 90Sr

B = 0.2 T



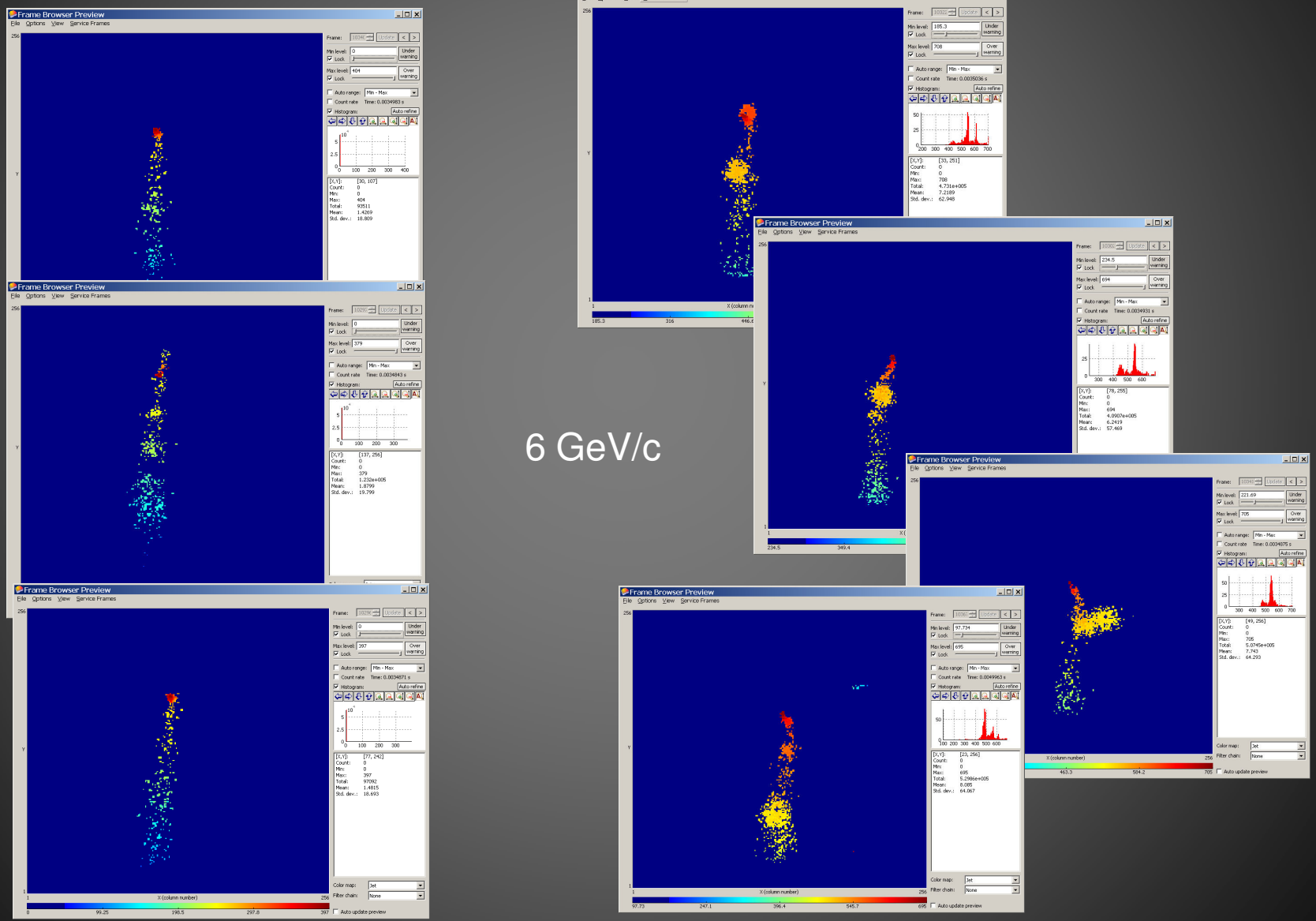
Testbeam Nov 5 – 12, 2007
PS/T9: electrons and pions, 1 – 15 GeV/c



Anatoli Romaniouk, Serguei Morozov, Serguei Konovalov
Martin Fransen, Fred Hartjes, Max Chefdeville, Victor Blanco Carballo

Particle Identification

Samples pions (left) and electrons (right)



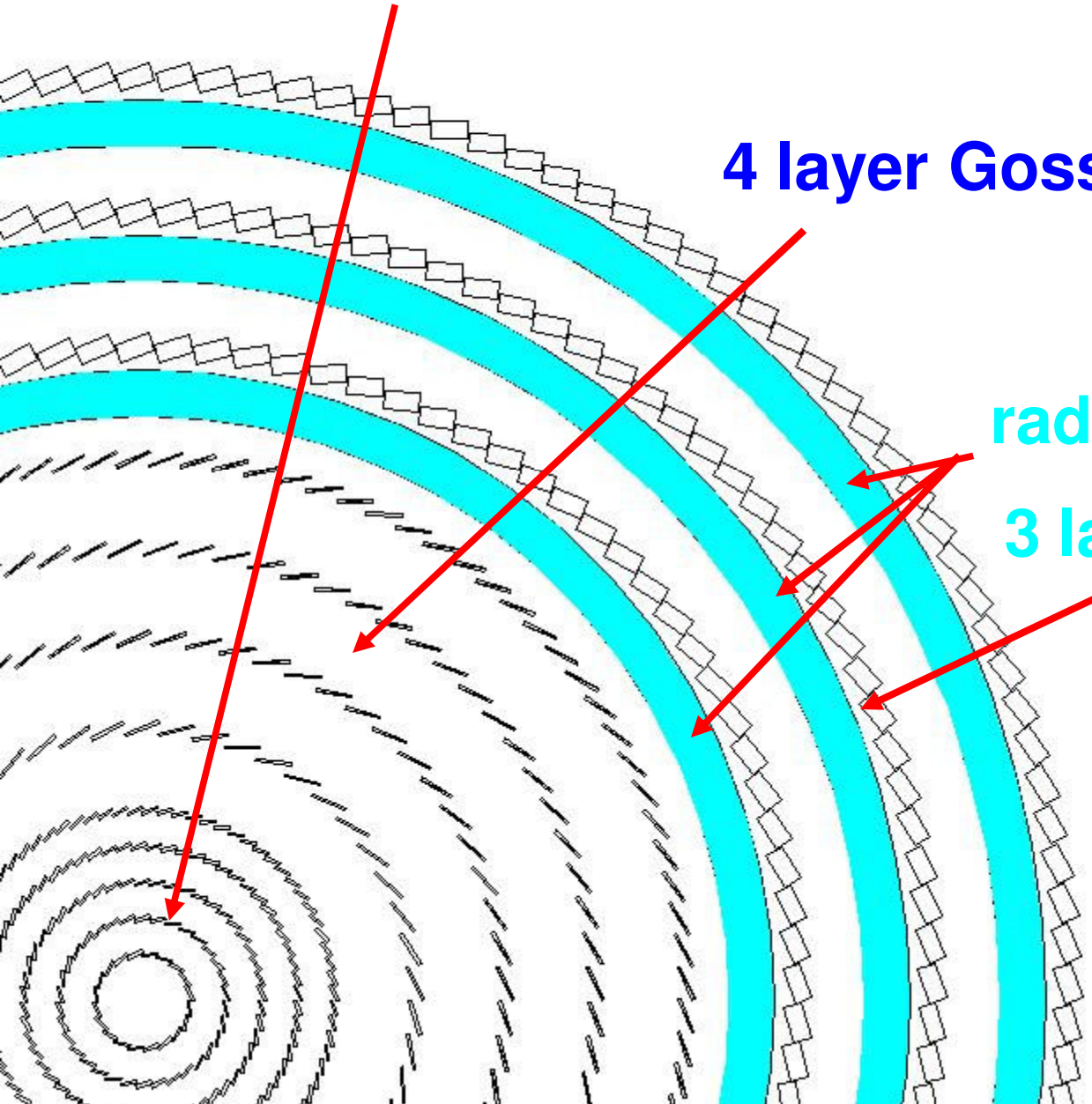
Status of GridPix/Gossip

- Priority 1: Chip destruction must be stopped

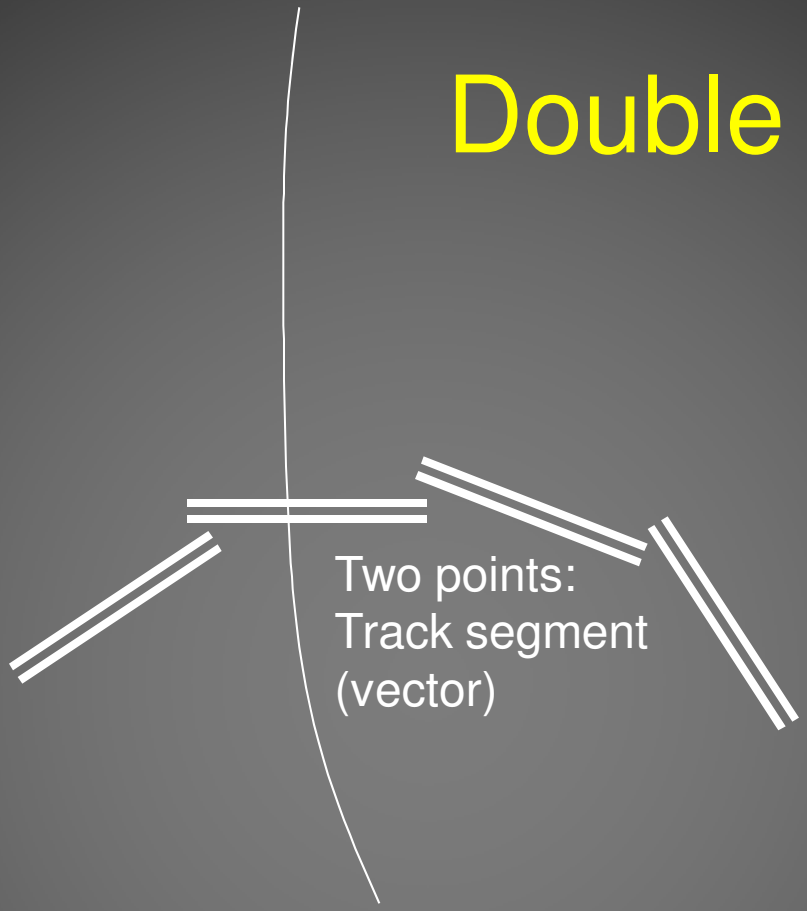
- low-cost mass production to be demonstrated (SMC in Edinburgh, UK, and IZM Berlin, Germany)

- Review by ATLAS Upgrade commission coming Monday, Tuesday

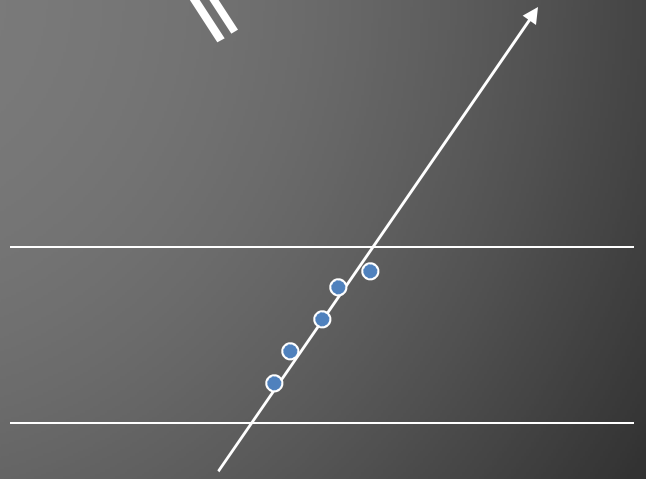
ATLAS & sLHC


5 (double) layer Gossip Pixel
4 layer Gossip Strixel
radiator
3 layers GridPix LVL1/

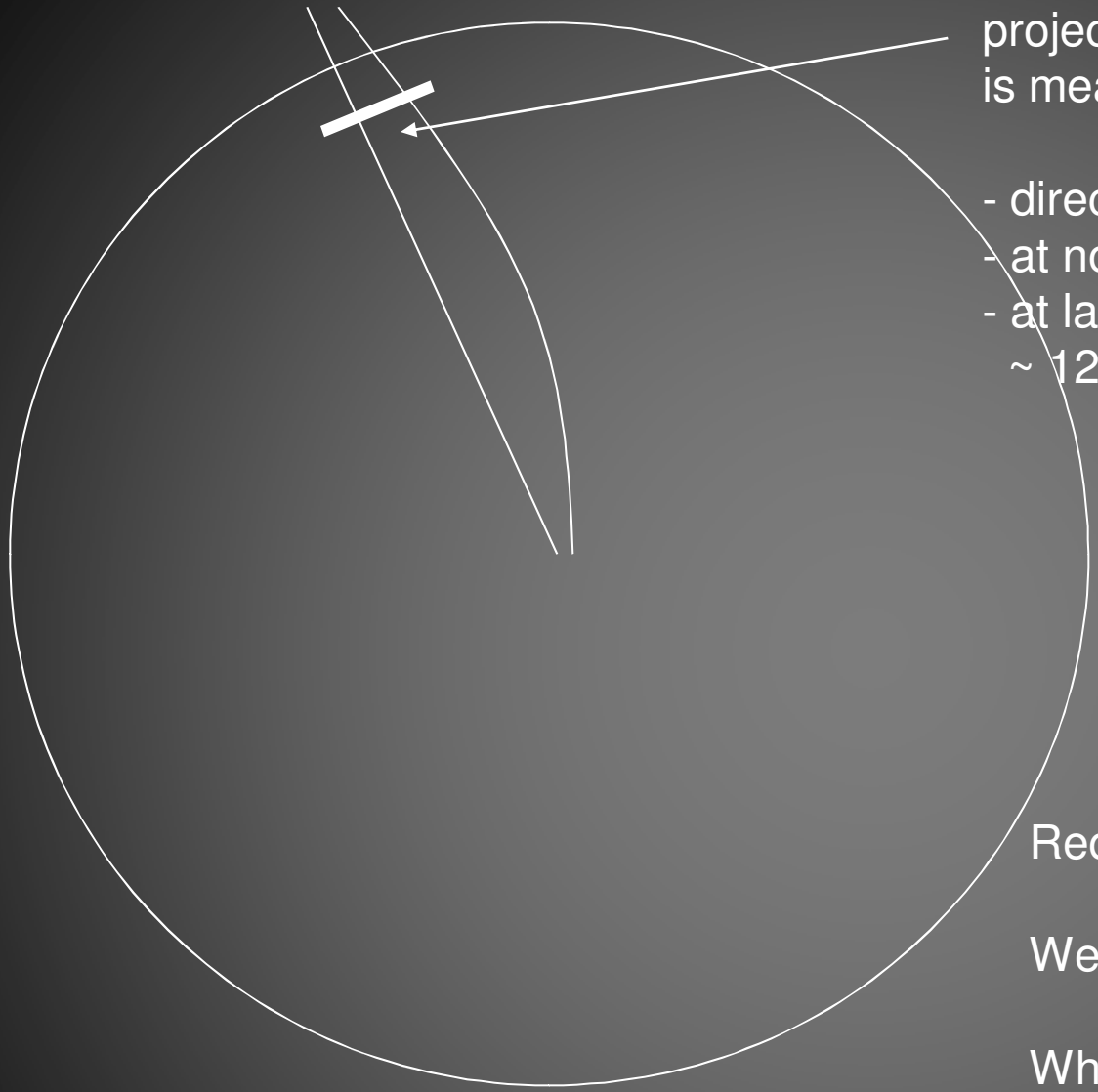
Double (Si) layers



Requires inter-pixel chip communication,
or data transport to common correlation processor



Gossip measures track segment vector in single layer



projected track length
is measure for momentum:

- directly available (LVL1)
- at no (extra) cost (mass, power)
- at larger R: gas drift gap ~20 mm
  ~ 12 BXs

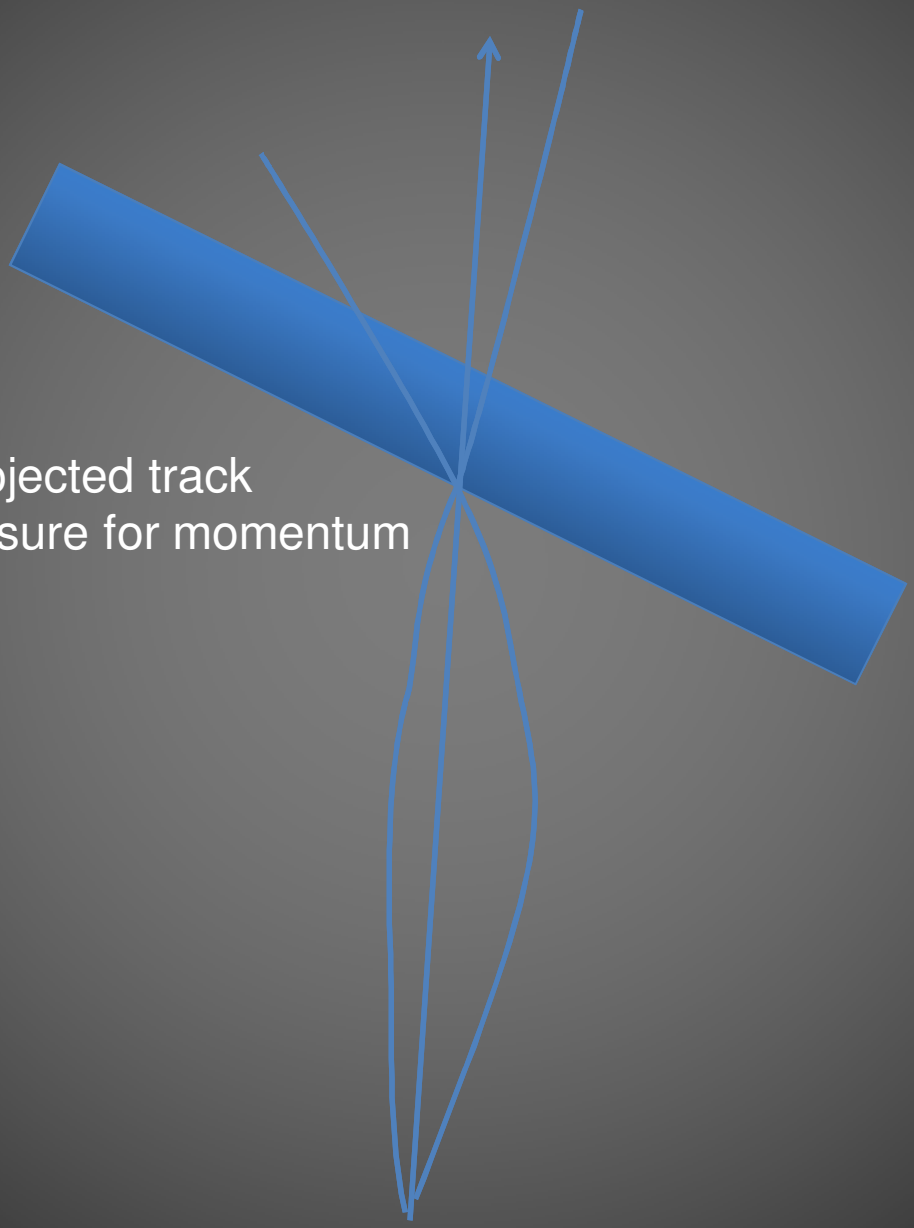
Requires fast on-pixel chip processing

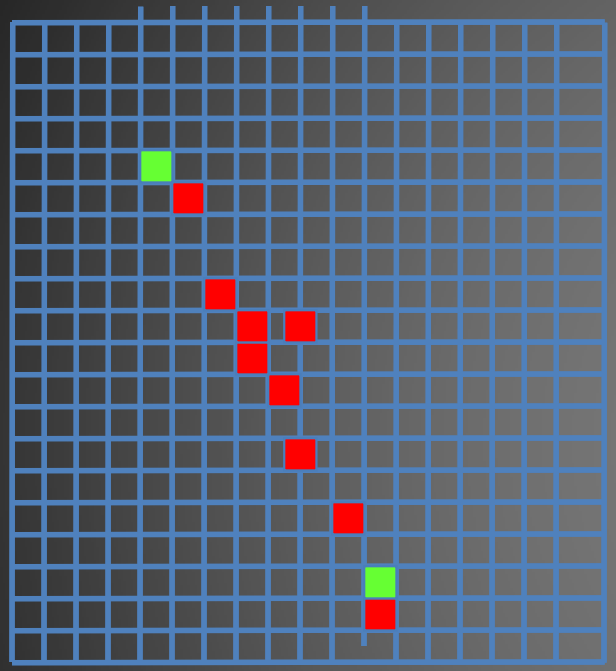
We are using 130 nm tech.

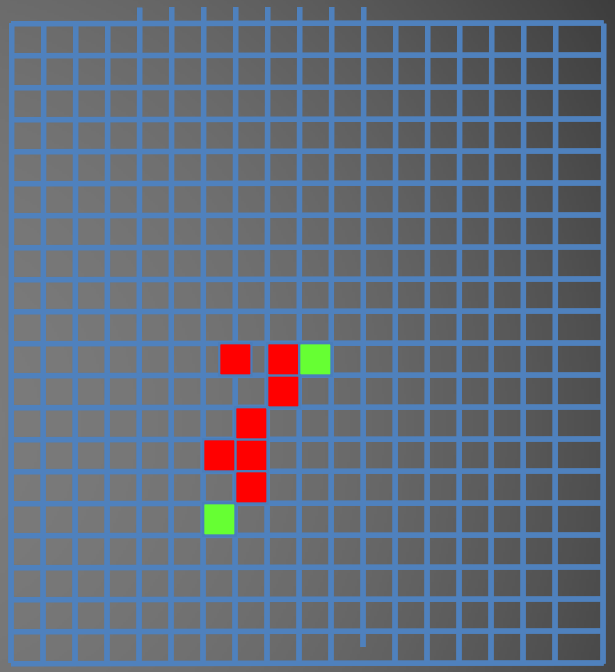
What about 45 nm tech?

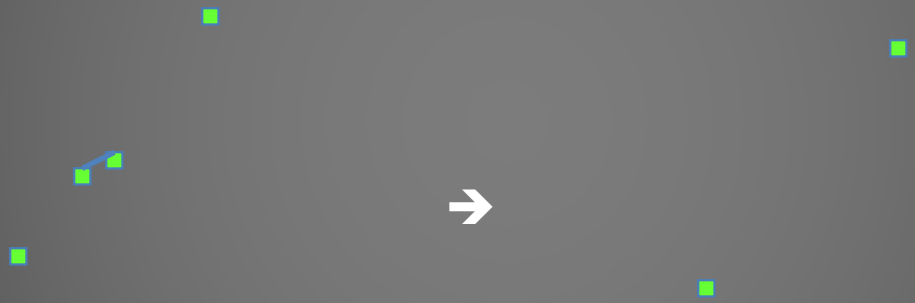
LVL1 trigger from inner tracker

Length of projected track
is direct measure for momentum

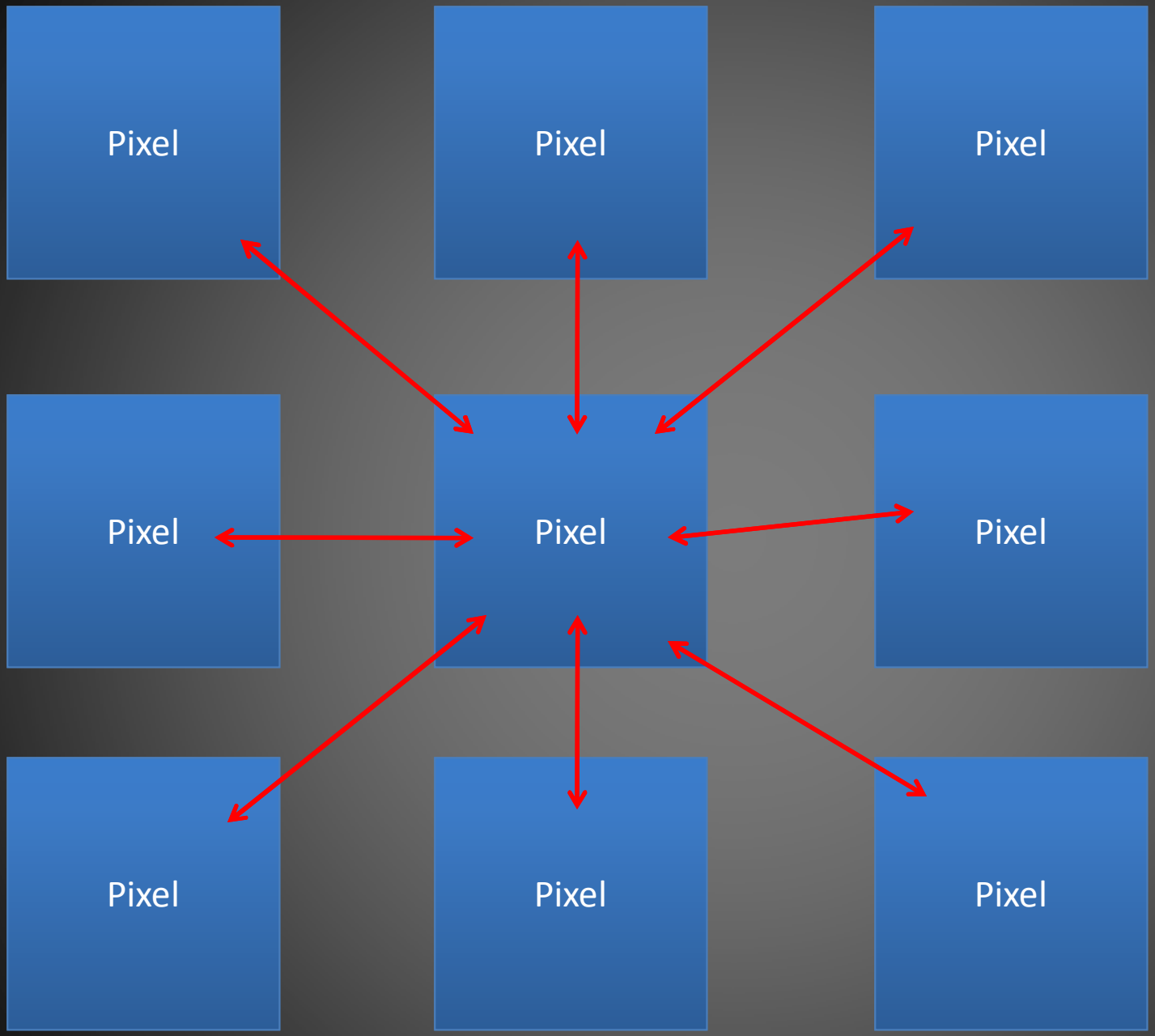


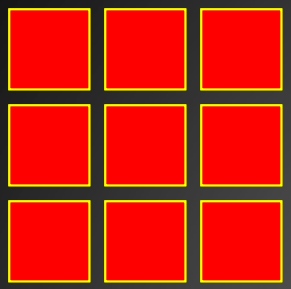






Endpoint Annihilation

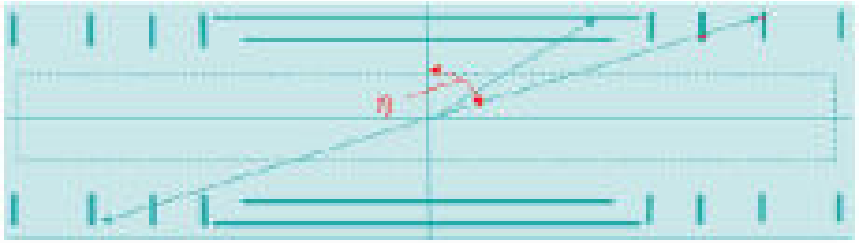

Pixel
Pixel
Pixel
Pixel
Pixel
Pixel
Pixel
Pixel
Pixel



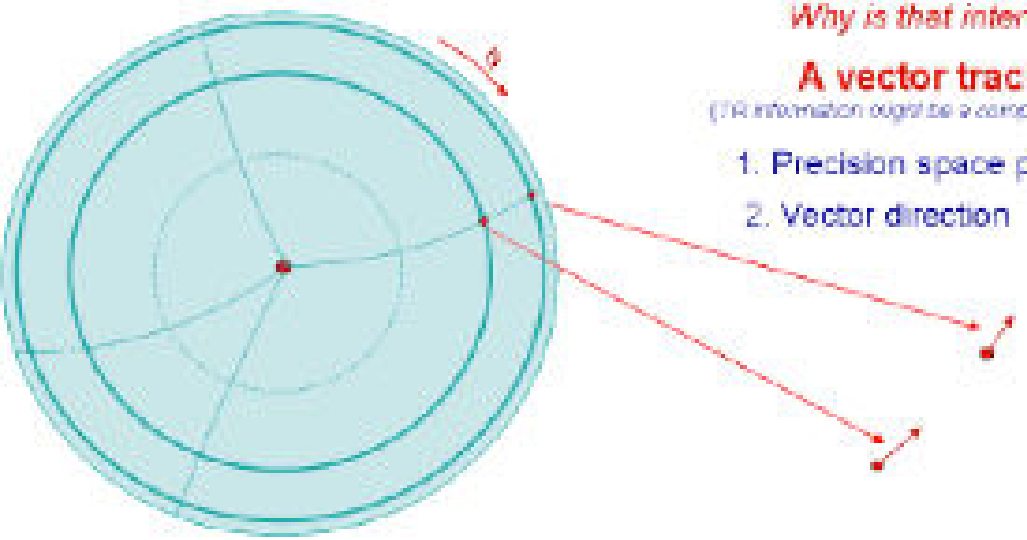
Goals of algoritm: find projected track length well within 1 μs, possible within ~ 10 ns.

- pixel: am I hit?
  -I may be part of a track
- is my neighbour hit?
- if two neighbours are hit I am probably not an endpoint
- if only one neighbourt is hit I may be an endpoint
- if there is another endpoint near me we should probably merge and annihilate
- Very unlikely to have two min. bias events on one chip

Large problem: projected tracks not contained in one chip
- at least two trigger LVL1 layers (maybe many more!)
- can be solved if ‘endpoint’ data can be processed externally



Possible layout:
Two layers interleaved with moderator or dense TR radiator.



Why is that interesting?

A vector tracking !

(TR information ought be a complementary feature)

1. Precision space points X,Y
2. Vector direction φ, η

Fig. 40. Possible layout of the GridPix tracker for the ATLAS Inner Detector upgrade for sLHC

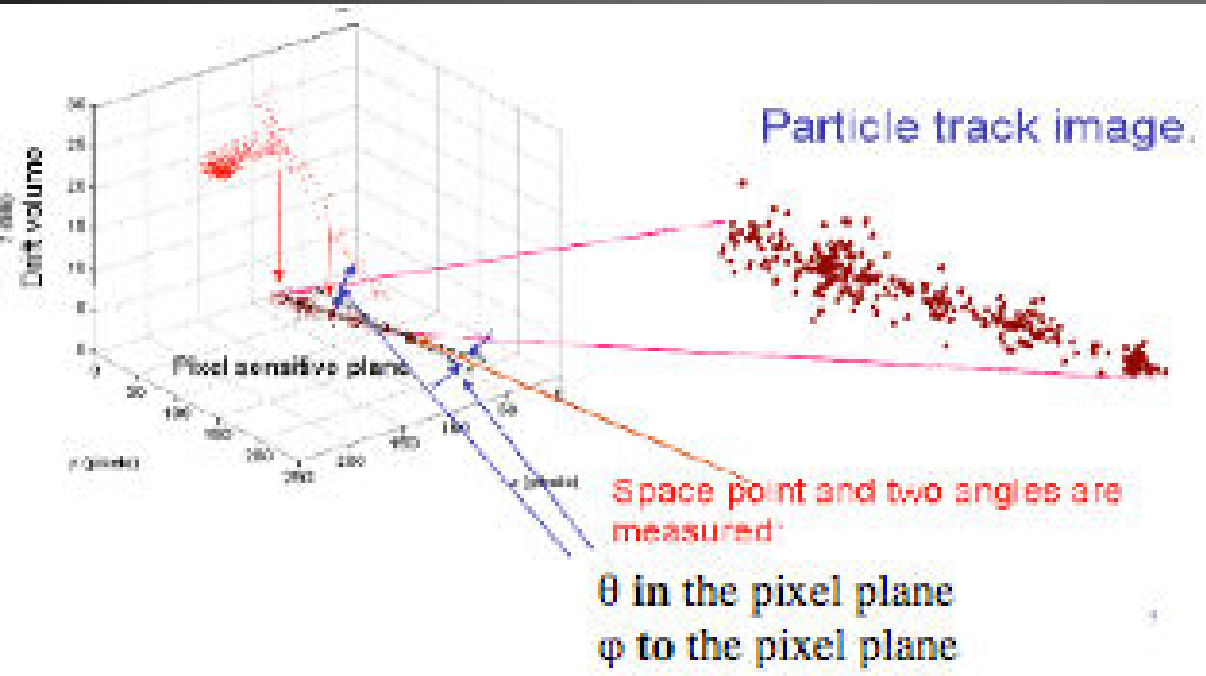


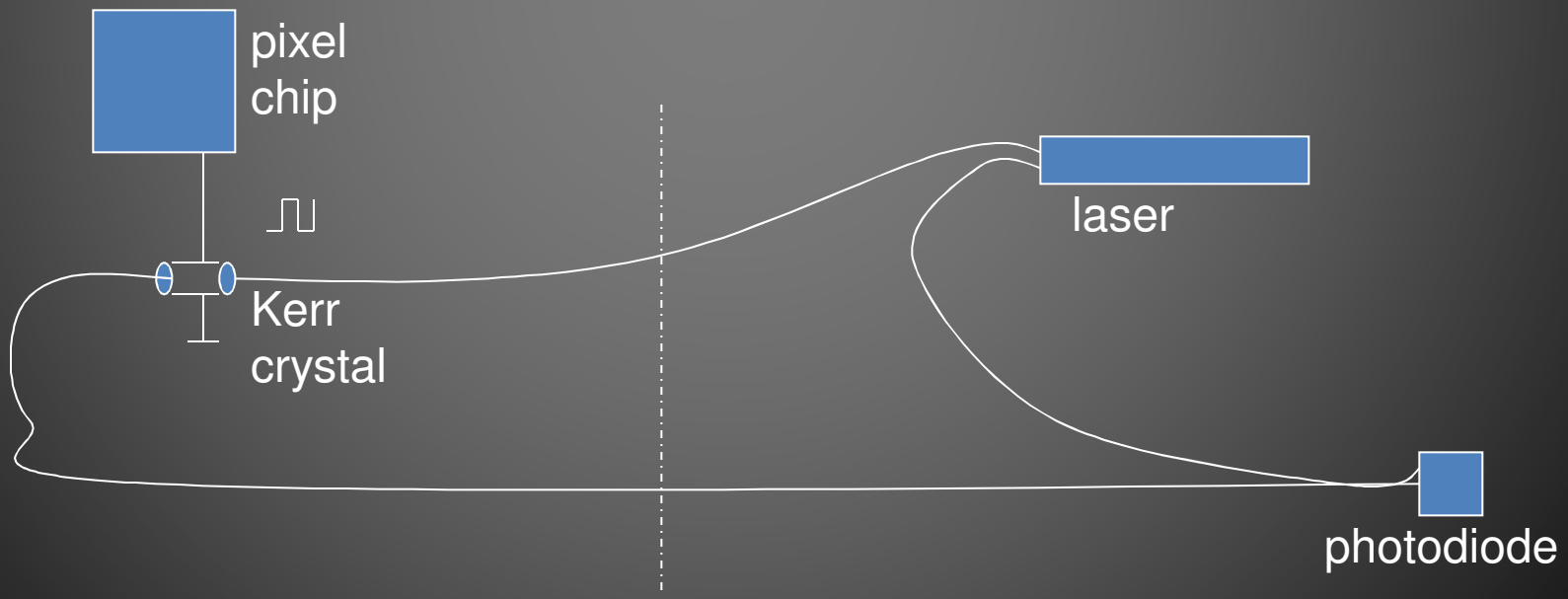
Fig. 41. Principle of the Grid-Pix tracker

First simulation results on momentum resolution
by Anatoli Romaniouk

Data Transport

- to outside world
- inter (pixel) chip communication
- Level 1 trigger

status: kapton/aluminium: dominant material for pixel detectors @ sLHC!
VCels + optical fiber: not rad hard, much material, much power required



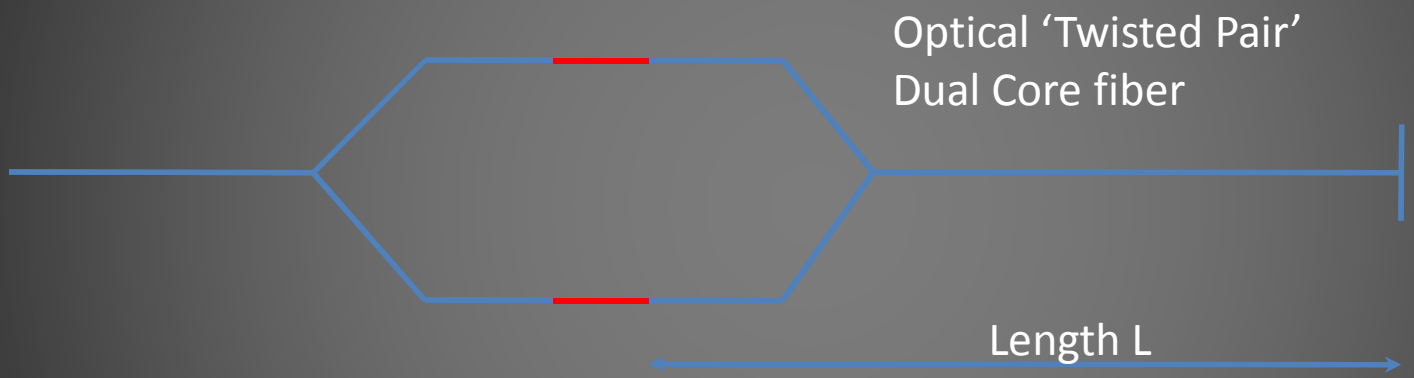
IfLink

A new optical fiber data connection based on interference

- one-way communication
- modulation directly on fiber with LVDS levels
- radiation hard
- low (essentially non) modulation power dissipation at sensor
- no modulator volume & mass

Essential: phase shift modulation in ‘thermally poled’ (quartz) fibers, or rad-hard LithiumNiobate Xtals (RD24 (1993)).

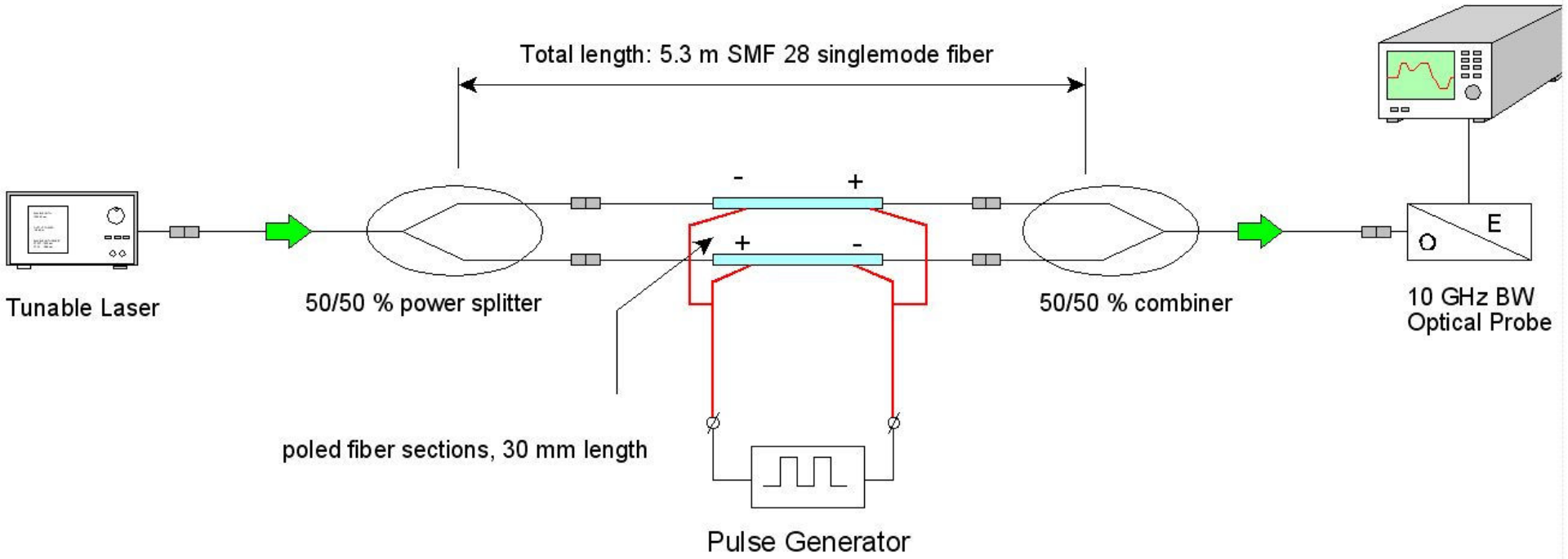
Final try: optical ‘twisted pairs



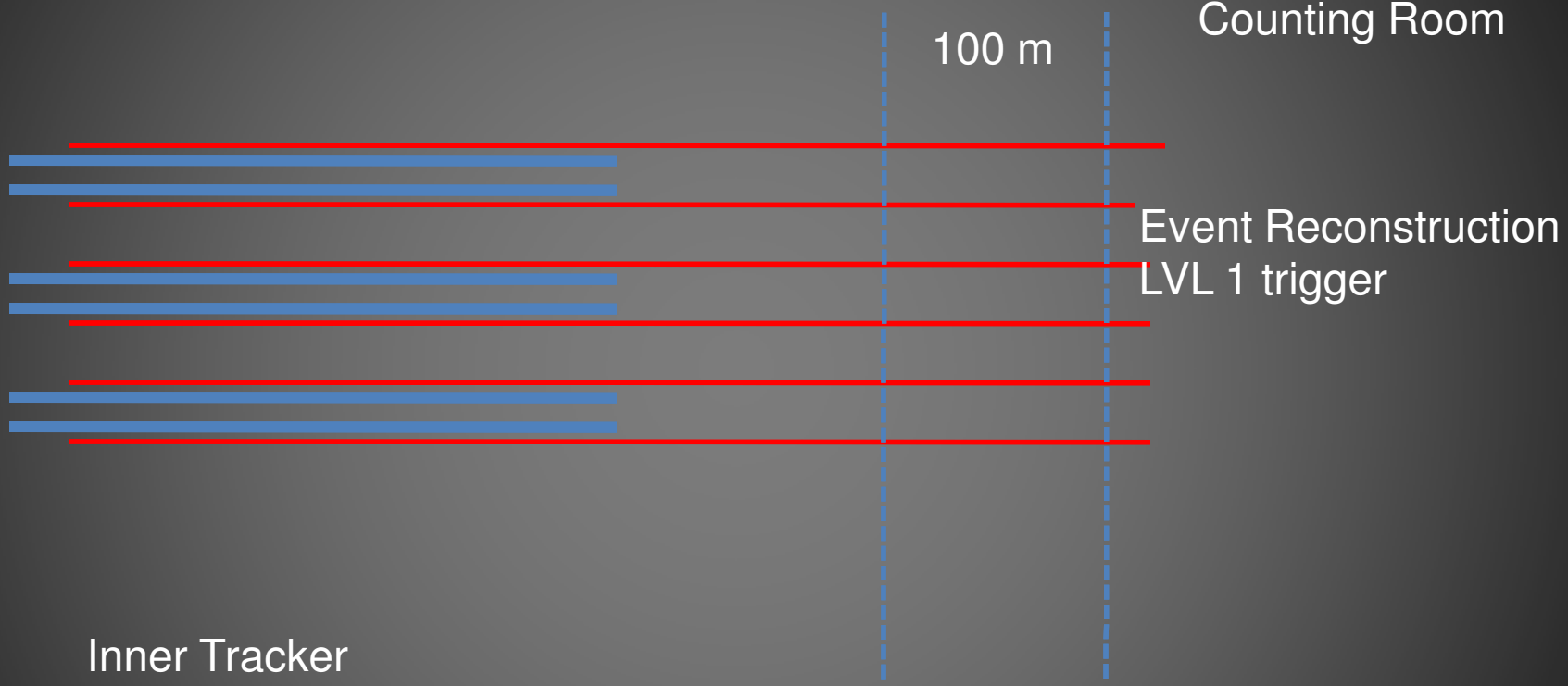
Set-Up moved to Delft Univ. of Technology
Results expected Oct 2009:
- Phase noise as a function of length L?

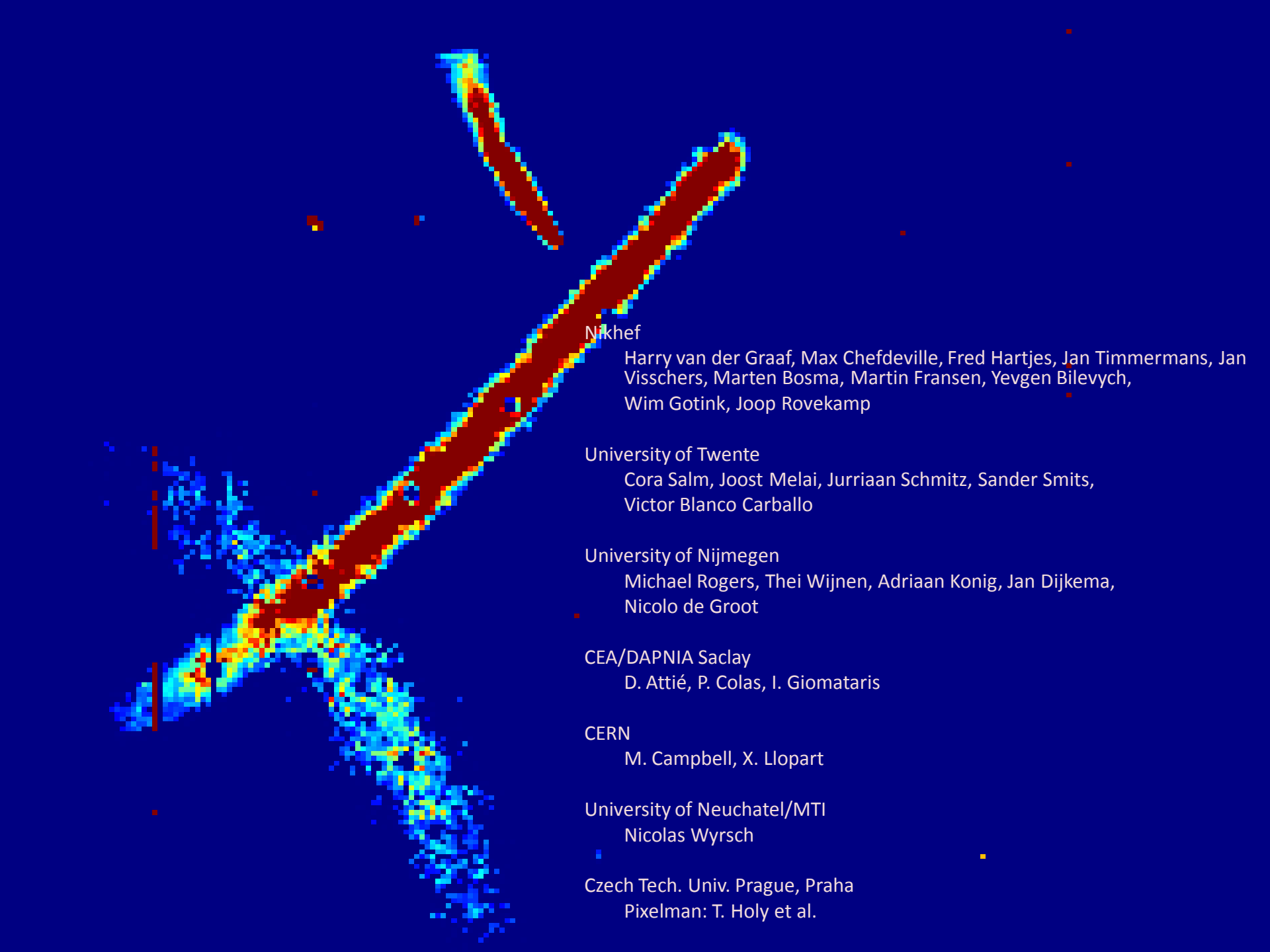
Interferometer with poled fibre sections in each branch

VANDERHOEKPHOTONICS



Path length tuning


100 m
Counting Room
Event Reconstruction
LVL 1 trigger
Inner Tracker
readout with fiber-per-(pixel) chip



Nikhef

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Pixelman: T. Holy et al.