Status of Medipix3 and possible input to Timepix2

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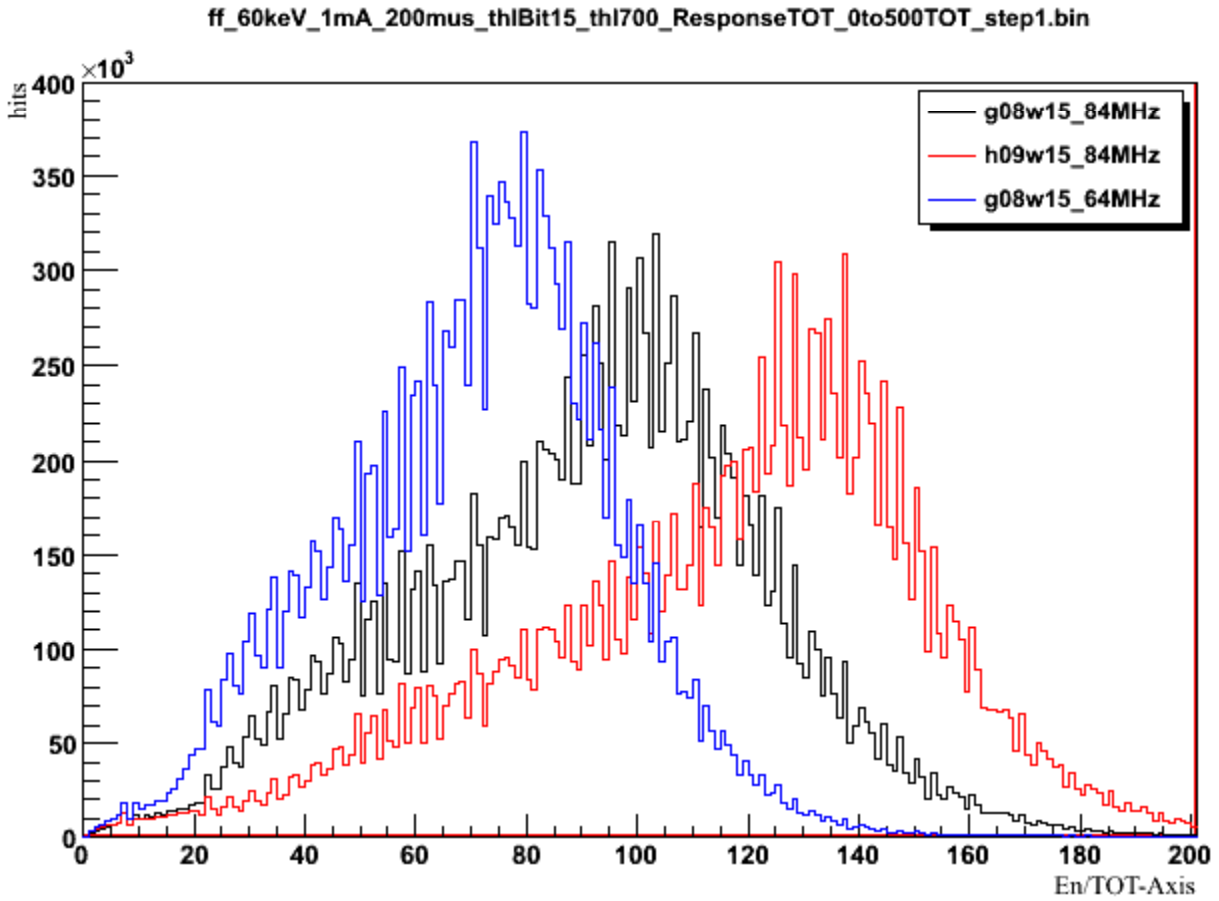
Outline

- Medipix3 - motivation for development
- Medipix3 prototype chip
  - Description of circuit
  - First results
- Status of full chip design
- Possible input to Timepix2
- Summary and conclusions

Introduction

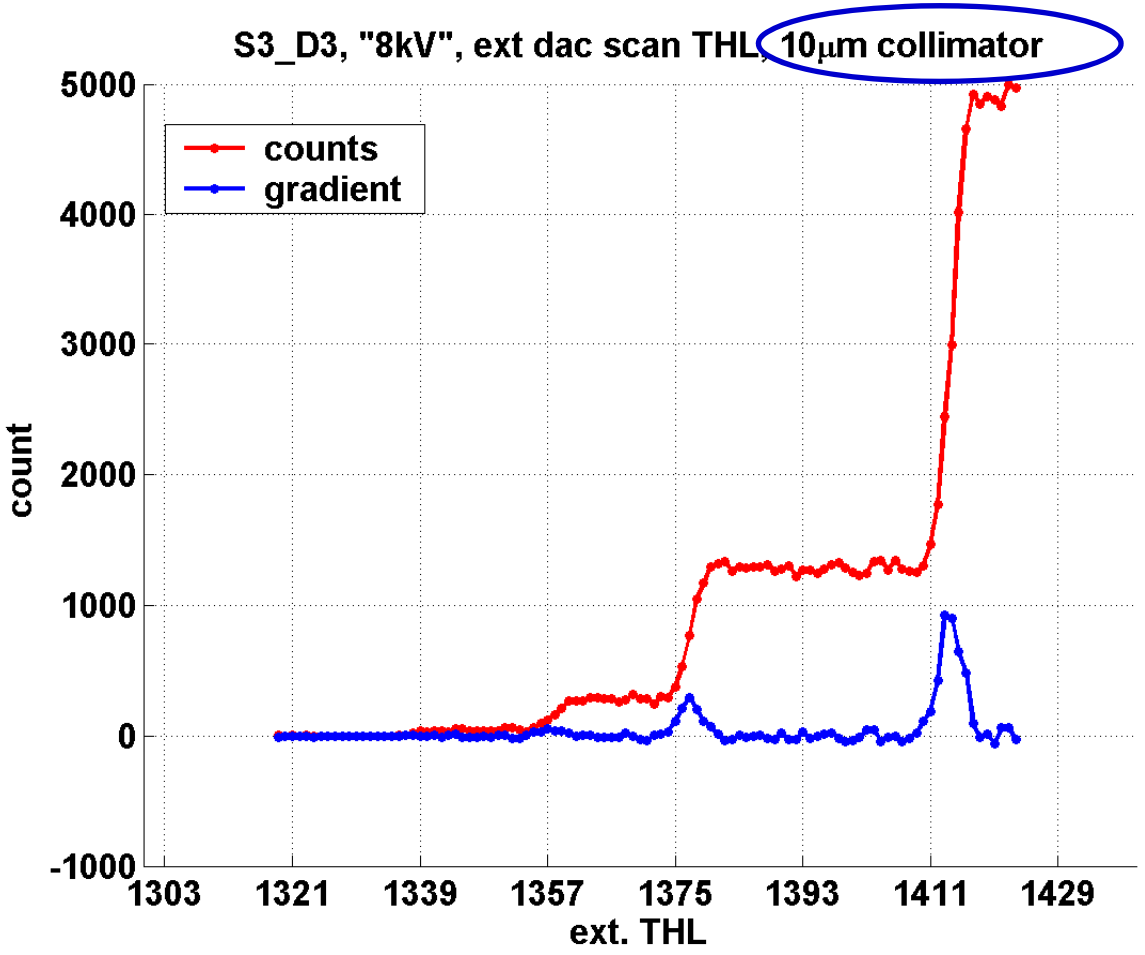
- Medipix2
  - 65k channel pixel readout chip
  - Window discriminator per pixel
  - Each pixel counts photons (particles) while shutter open
- Timepix
  - 65k channel pixel readout chip
  - Single discriminator per pixel
  - Each pixel measures either
    - Arrival time with respect to shutter
    - ToT while shutter open
    - Number of photons (particles) while shutter open

Recent (bad) news from Timepix



Recent tests using ToT mode in Erlangen show excessive fixed pattern of noise on spectroscopic data.
Effect only present at low thresholds (< ~2000 e^-)

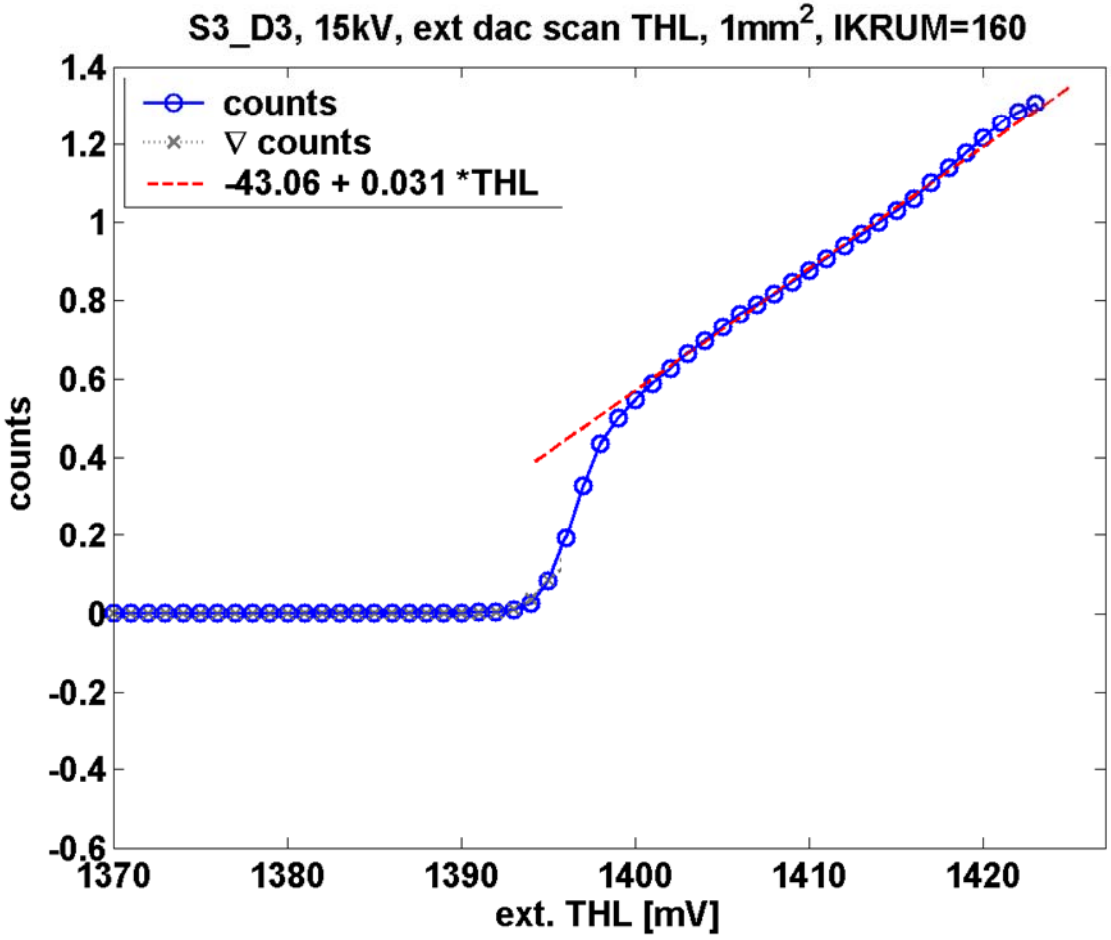
Motivation for Medipix3
synchrotron pencil beam at pixel centre



Increasing threshold

8kev plus harmonics….

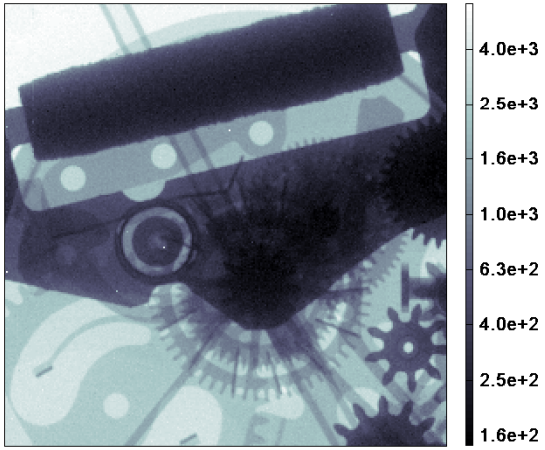
Motivation for Medipix3 – synchrotron 1mm^2 beam



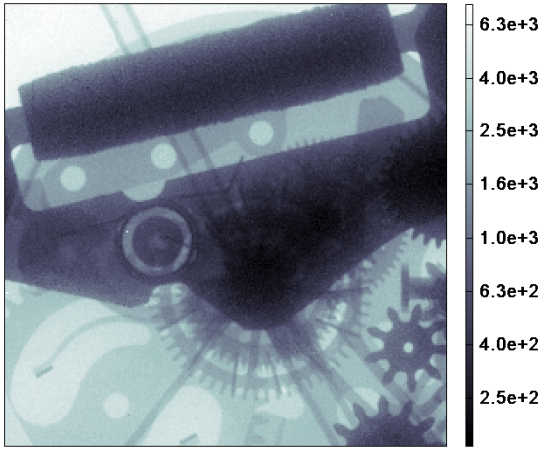
Increasing threshold

Energy Window (→ MPX3)

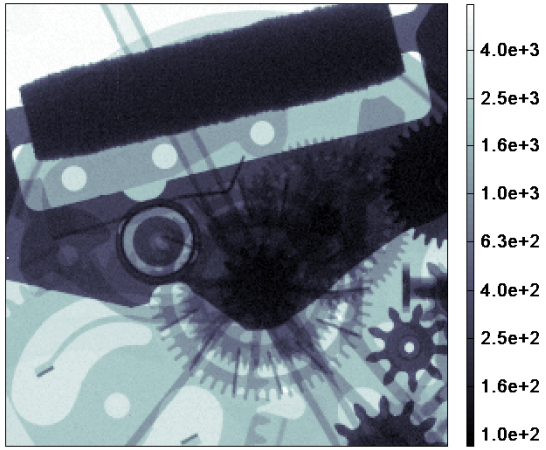
16.1-19.6 keV

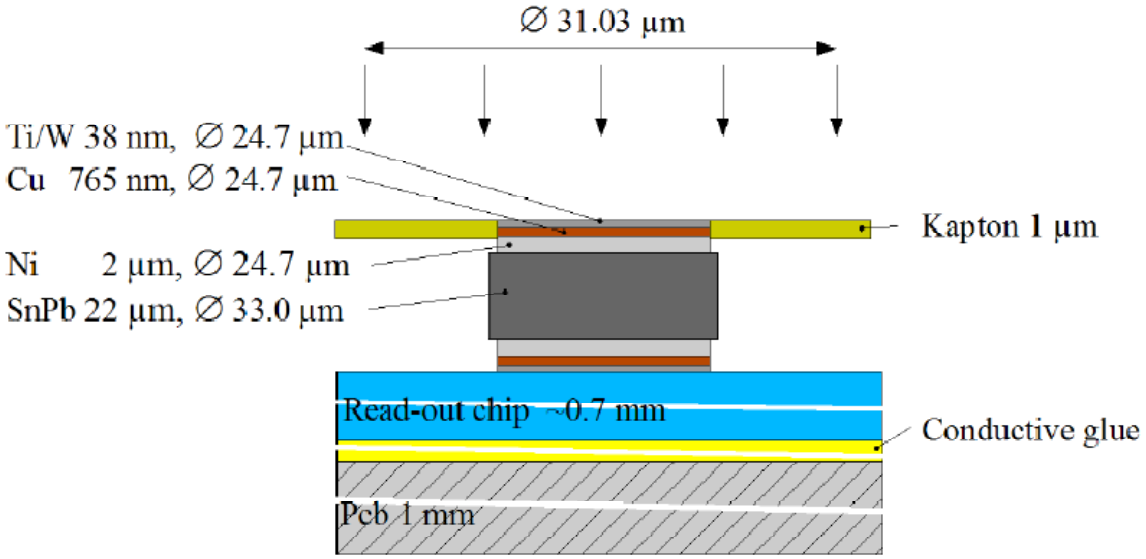


21.6-25.1 keV

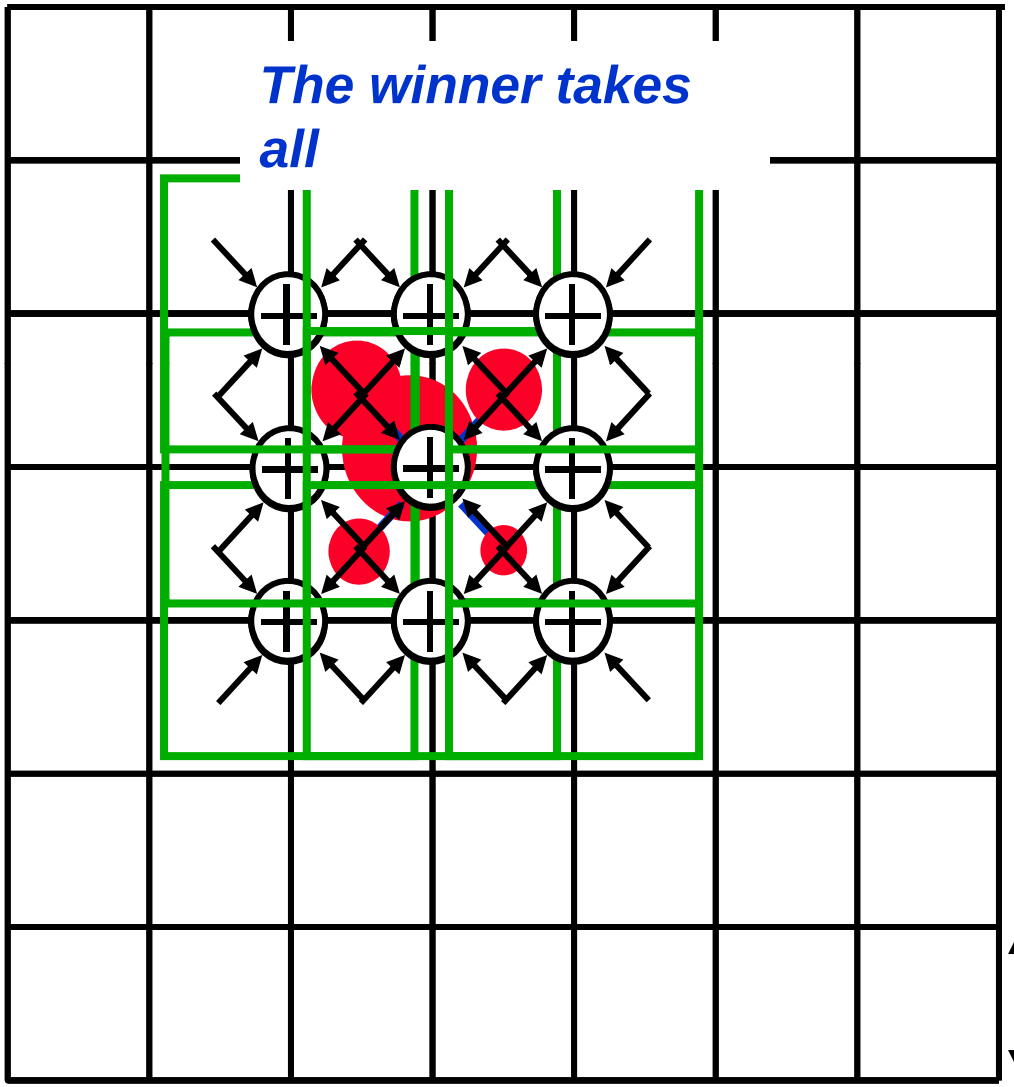


29-33.5 keV



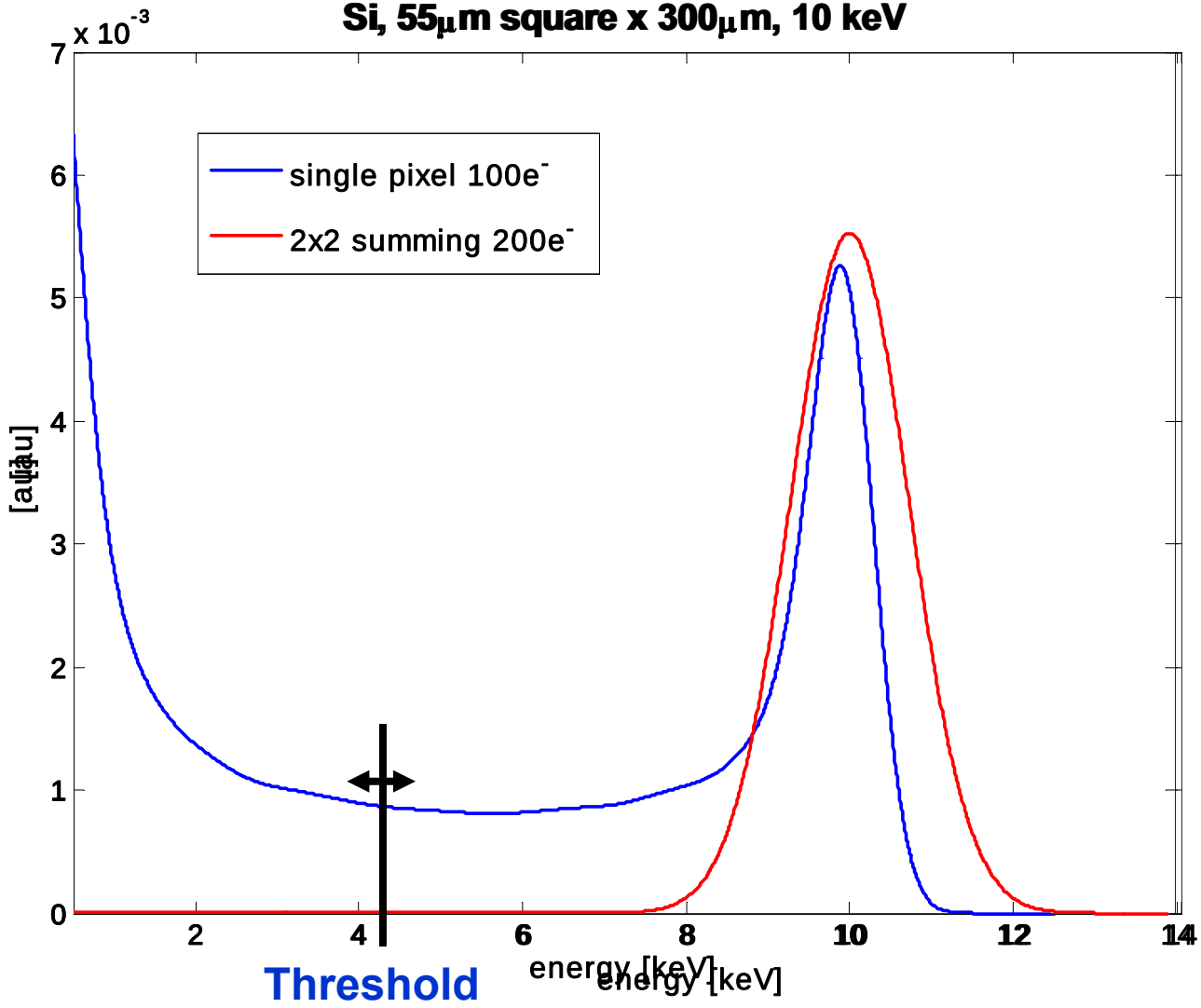


Medipix3 – charge summing concept



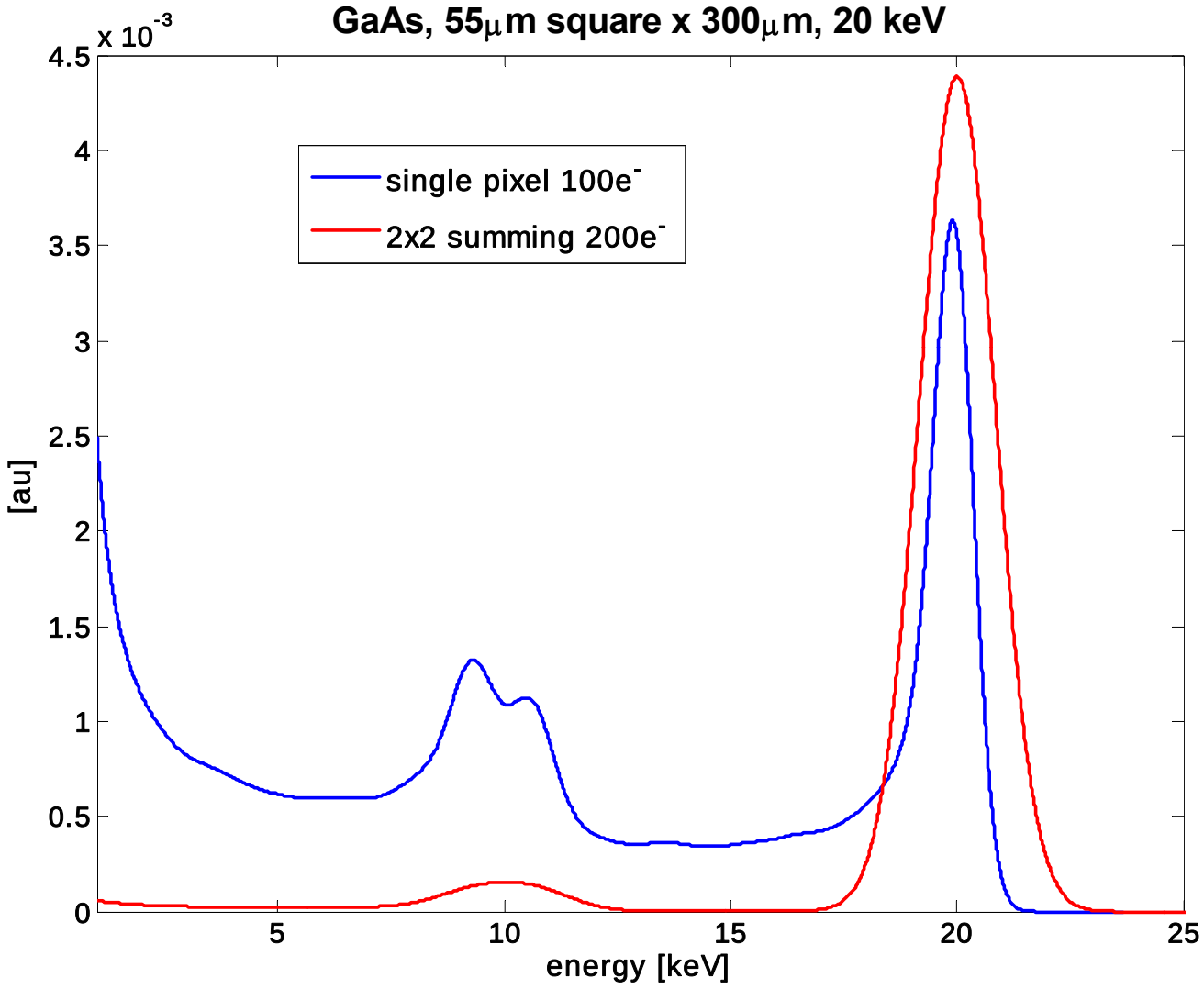
- *The charge processed is summed in every pixel cluster on an event-by-event basis*

Medipix 3 Simulation



- *Simulated Data*
- *Si 300μm, 55μm pixel*
- *10keV monochromatic photon beam*
- *Charge diffusion produces "charge sharing" tail*
- *Threshold variations produce fixed pattern*

Medipix 3 Simulation



- ***Simulated data***
- ***GaAs 300μm , 55μm pixel***
- ***20keV monochromatic beam***
- ***Fluorescence photons included in charge sum***

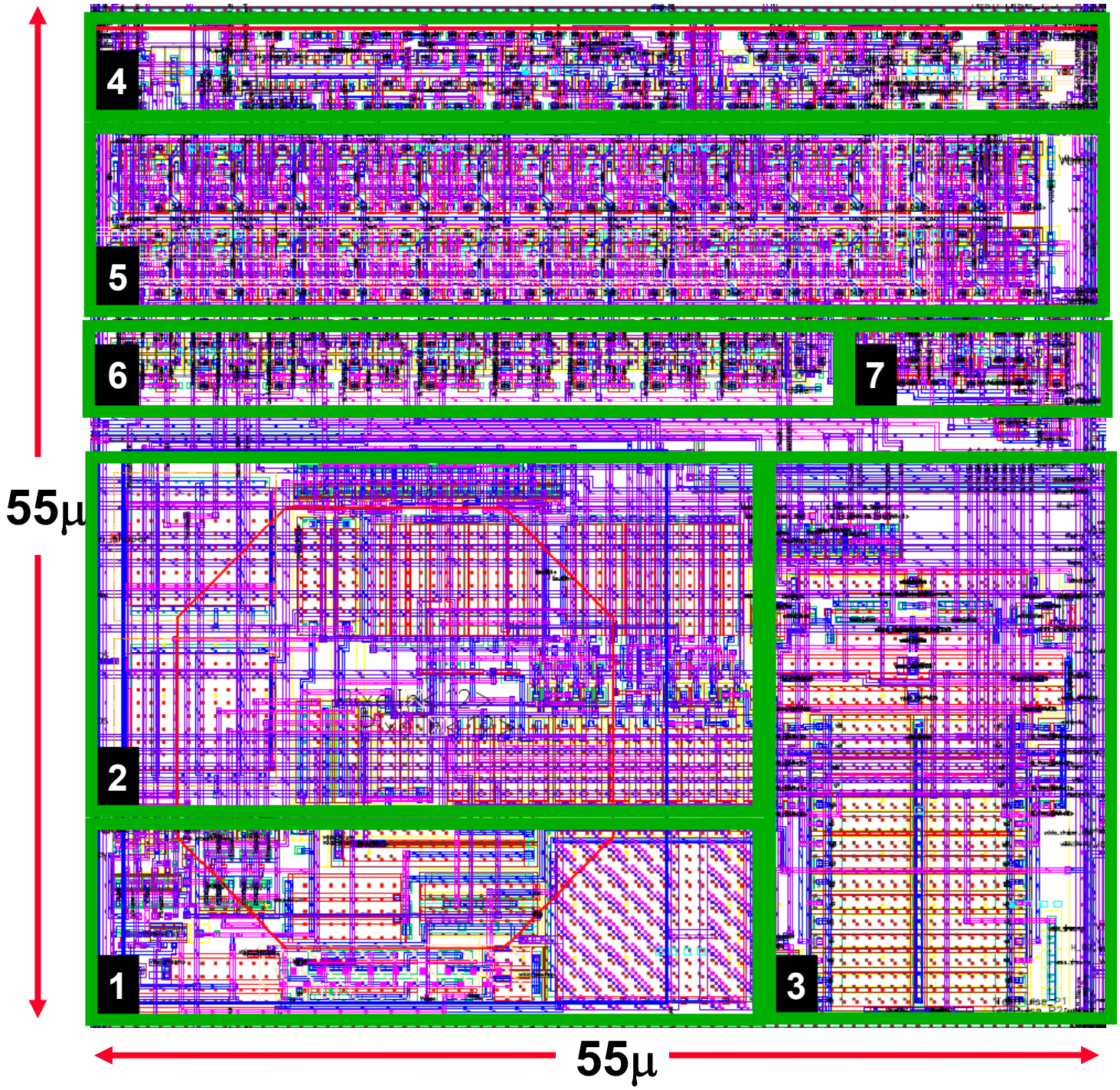
Medipix3 prototype – pixel block diagram

BLOCK DIAGRAM PIXEL E

Input Pad
C_f
g_m
C_{test}
TestBit
Test Input
V_{fbk}
+
g_m
−
PolarityBit
GainMode
ThAdjustBit
ChSummingMode
From adjacent pixels (F, H, I)
x3
x1
x3
To adjacent pixels (A, B, D)
TH1
TH2
Disc
Disc
B_TH<0:3>
B_TH<4>
From adjacent pixels (A, B, D)
x2
cluster common control logic + Arbitration circuitry
ModeContRW
DisablePixelCom
AdjustTHH
ModeCS_Cluster4
To adjacent pixels (F, H, I)
Previous Pixel SR1
MUX
15 bits Shift Register SR1
Next Pixel SR1
Previous Pixel SR2
MUX
15 bits Shift Register SR2
Next Pixel SR2

ANALOG

DIGITAL



DIGITAL CIRCUITRY

4. Control logic (124)
5. 2x15bit counters / shift registers (480)
6. Configuration latches (152)
7. Arbitration circuits (100)

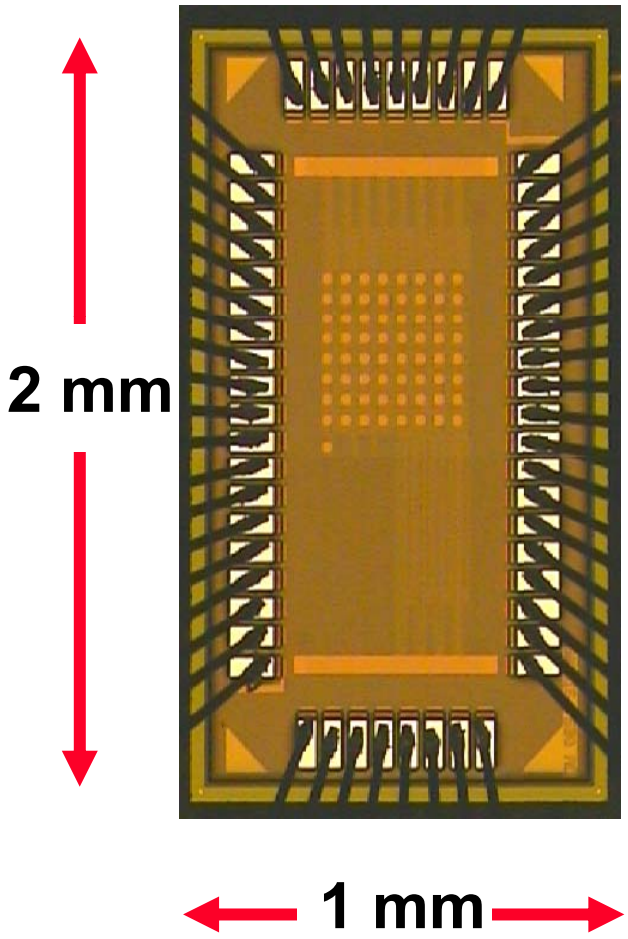
Total digital 856

ANALOG CIRCUITRY

1. Preamplifier (24)
2. Shaper (134)
3. Discriminators and Threshold Adjustment Circuits (72)

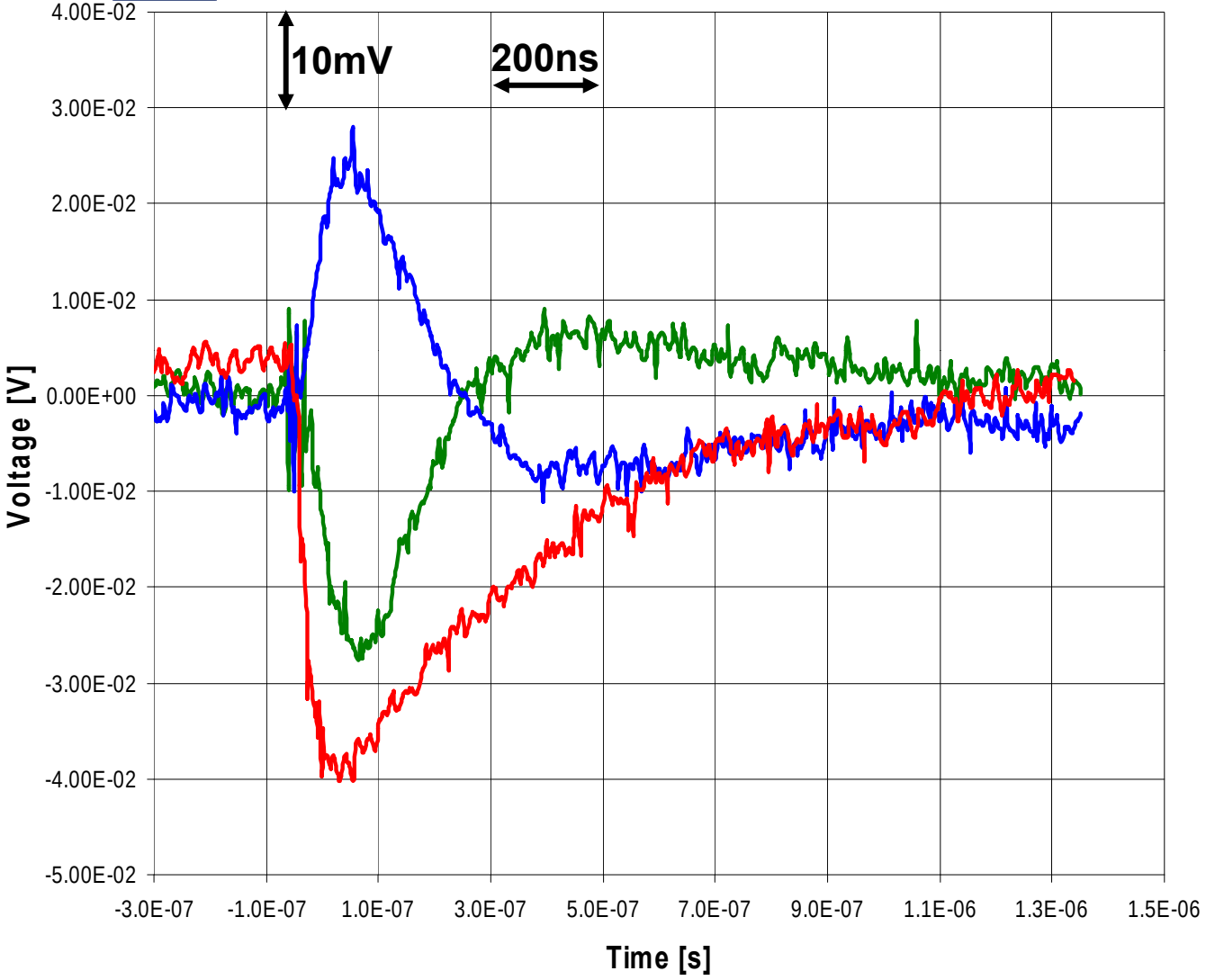
Total analog 230

The Medipix3 prototype chip



- 0.13μm technology
- 8 metal layers
- 8x8 pixel matrix

Pre-amp and shaper measurements



Response to a 3.71 Ke- input charge

Nominal Conditions

I_{CSA}=2μA

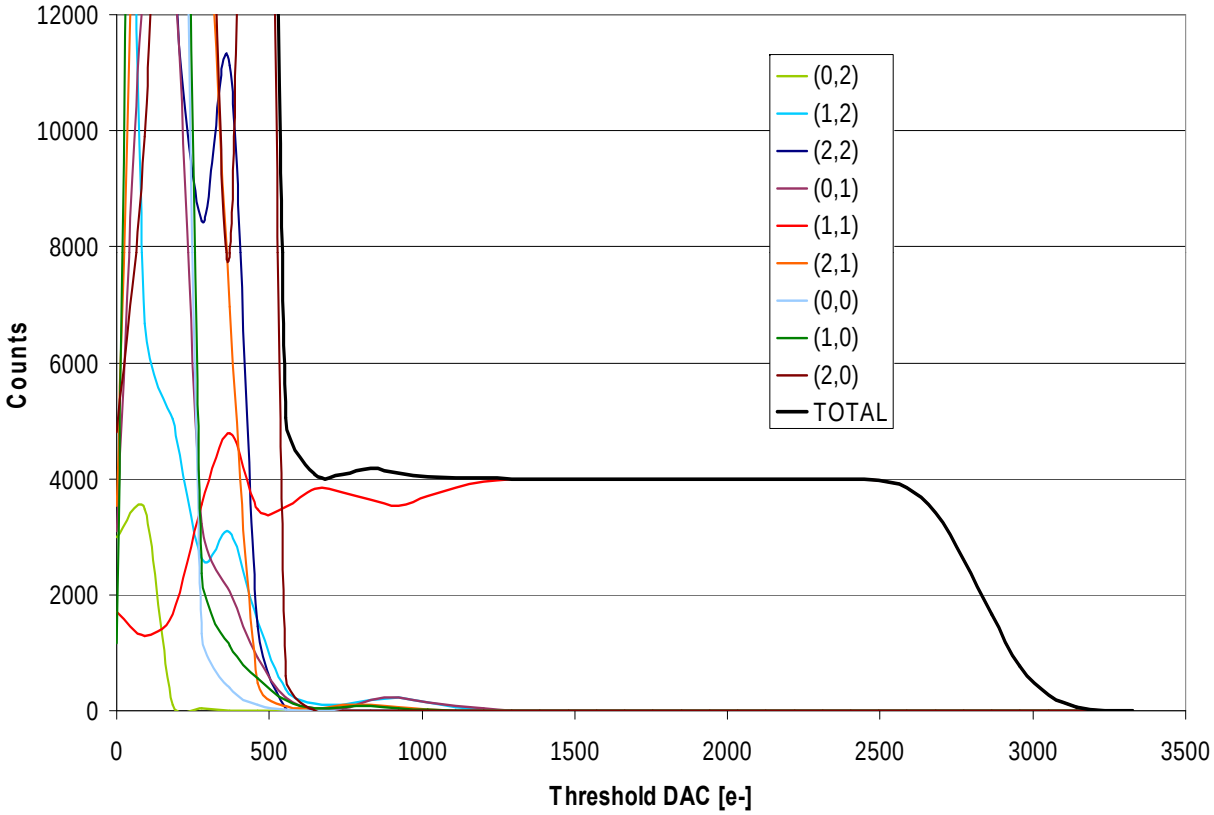
I_{RESET}=2.5nA

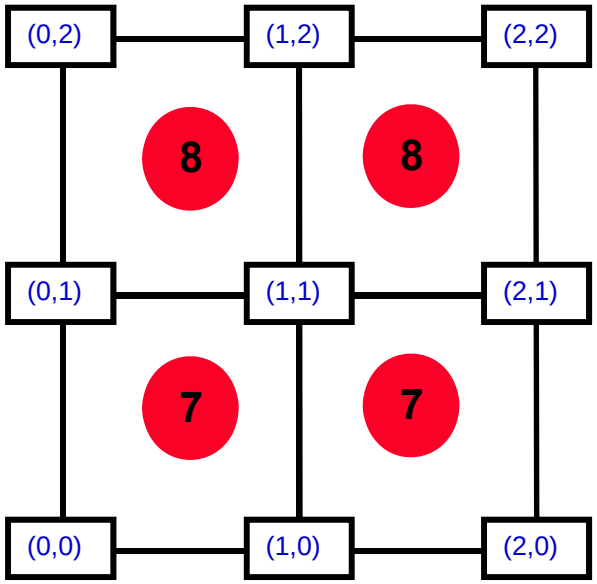
I_{SHAPER}=500nA

Medipix3 – charge summing measurements

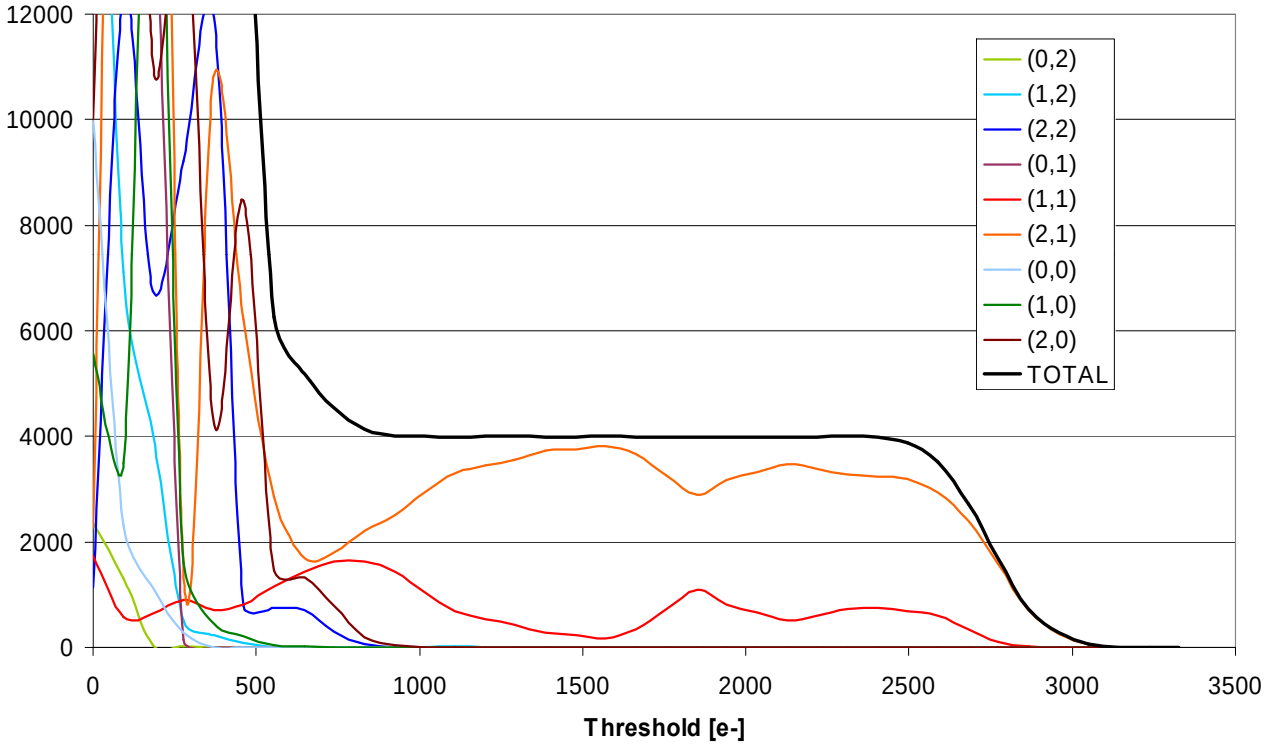
Input charge: 2.78Ke-
(30 DAC pulses)

4000 pulses





Medipix3 – charge summing measurements



Input charge: 2.78Ke-
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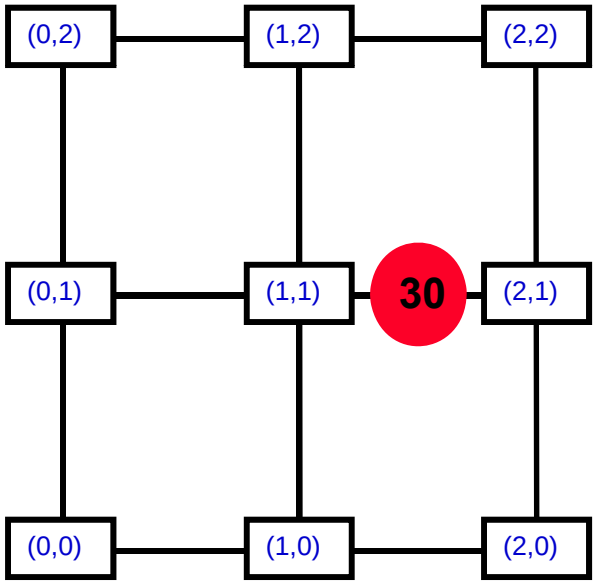
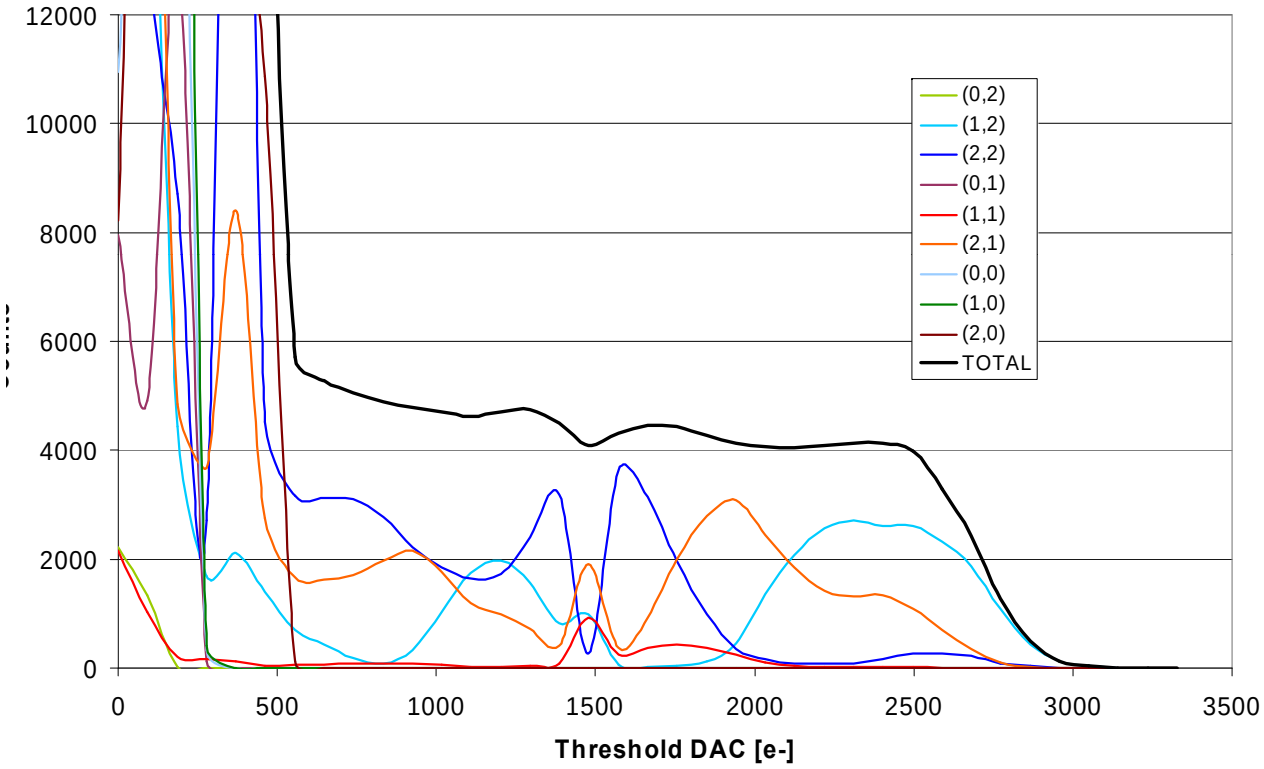
4000 pulses



Medipix3 – charge summing measurements



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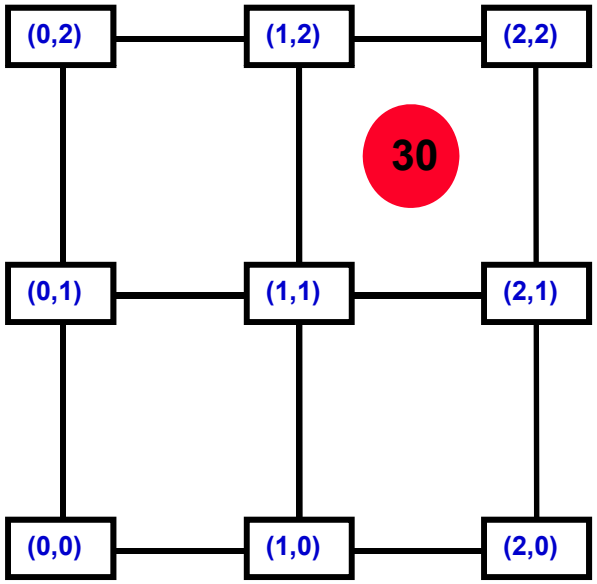


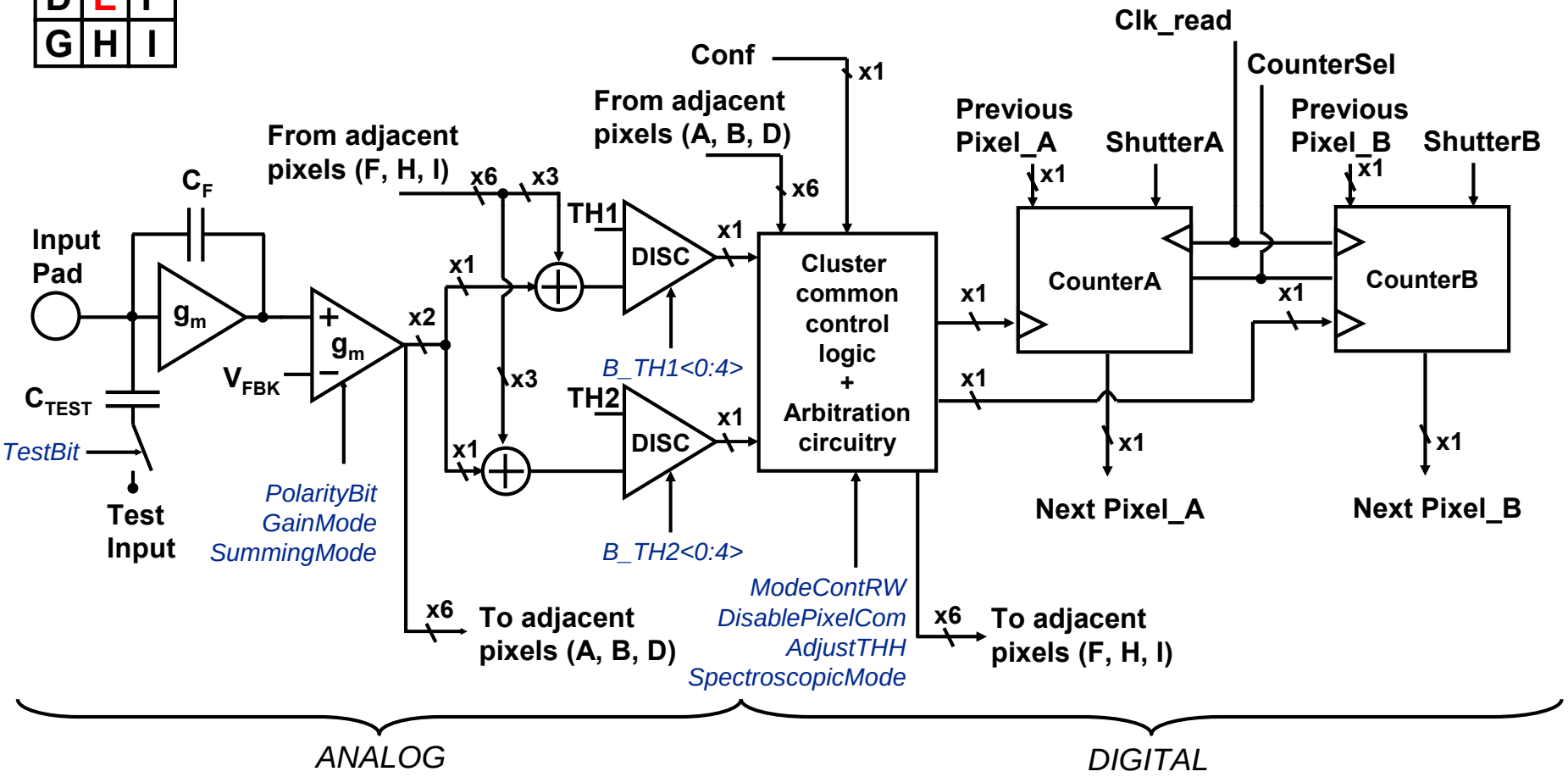
Medipix3 prototype – electrical measurements summary

Front End Operating Mode	Single Pixel Mode	Charge Summing Mode
CSA Gain (C_F)	11.4mV/Ke- (C_F=14fF)	
CSA-Shaper Gain	65nA/Ke- (High Gain Mode), 30nA/Ke- (Low Gain Mode)	
Non linearity	<5% 9Ke- (High Gain Mode) , <2% 22Ke- (Low Gain Mode)	
Peaking Time	~100ns	
Return to baseline	<1μs for 4Ke- (nominal conditions), <300ns (tuning R_F)	
Electronic noise	72e^- r.m.s.	144e^- r.m.s.
Analog power dissipation	16.2μW (nominal conditions)	

Medipix3 full chip – pixel block diagram

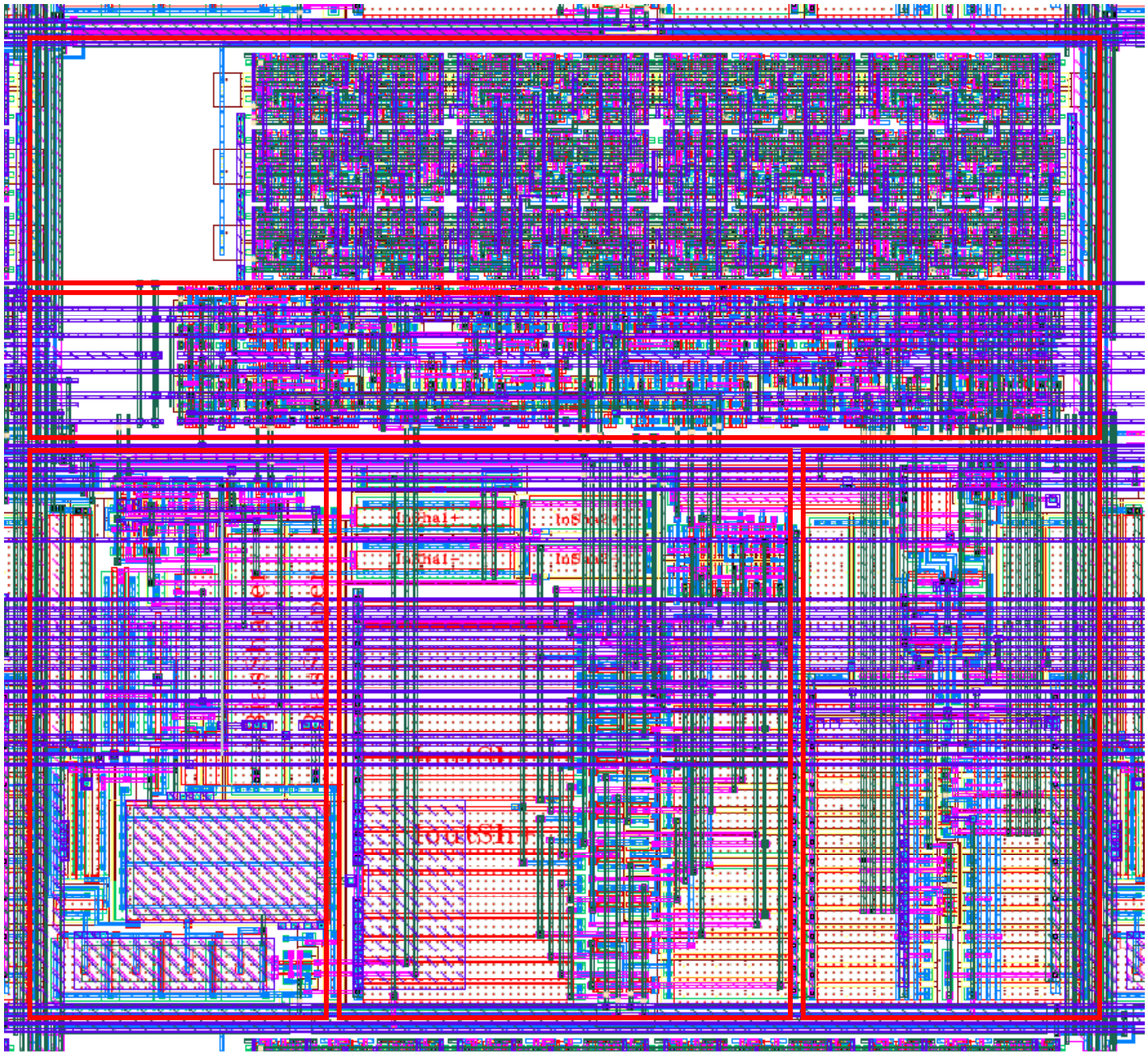
A	B	C
D	E	F
G	H	I

BLOCK DIAGRAM OF PIXEL E



Medipix3 full chip – pixel features

- Accepts positive or negative input polarity
- Preamp rise time 50ns
- Selectable gain shaper (shaping time ~ 120ns)
  - Linearity 1 - 10 ke^- @ ~70e^- rms noise
  - Linearity 5 - 25 ke^- @ ~90e^- rms noise
- Single pixel operation or charge summing
- Power consumption 9μW single 15μW charge summing
- Configurable counter
  - 2 x 1bit
  - 2 x 4 bit
  - 2 x 12 bit
  - 24 bit
- Continuous or sequential R/W
- Possibility to bump bond only 1 pixel in 4 to create super pixel with up to 8 counters/pixel.



Counter

Mode control logic

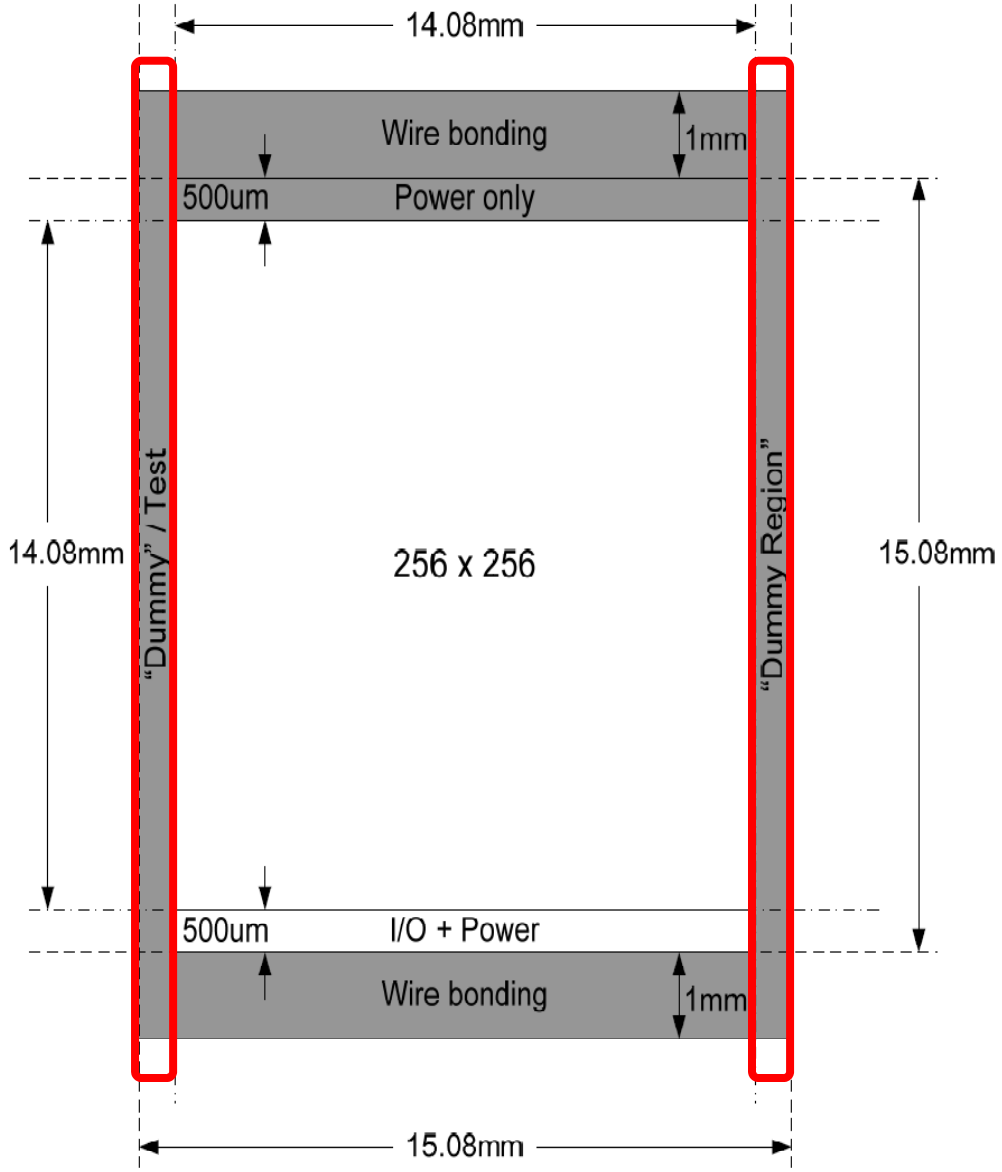
~ 2 000 transistors

Preamp

Shaper

Discrimination and arbitration

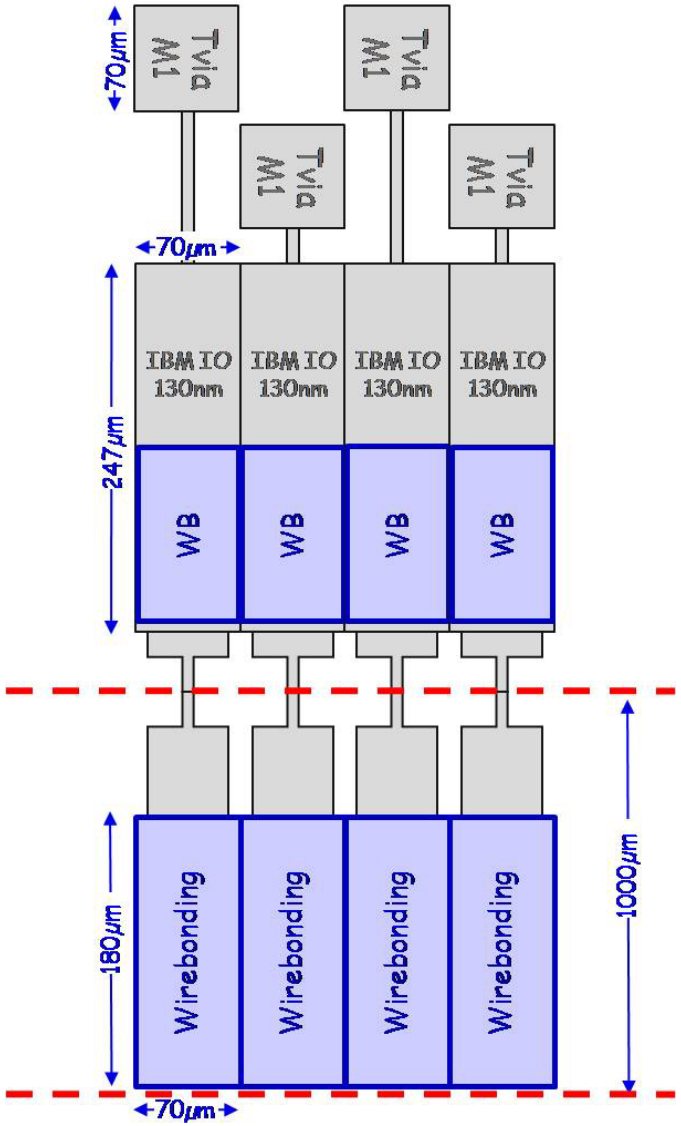
Medpix3 full chip - floorplan



Fully compatible with TSV technology e.g. RelaxD

IO proposed strategy

- The IO pads will be done using the GPIO MA CM0S8 Artisan library
- This library includes full ESD protection circuitry
- Double passivation opening in each pad for probe card testing and wire-bonding.
- If the chip is diced the chip guard-ring will be discontinued… unknown consequences
- This proposed scheme apply for top and bottom pads.
- We could fit up to ~200 IO pads of 70µm…



Summary of Medipix3 status

- First large photon counting pixel chip with colour imaging potential
- Submission foreseen May/June
- Around 10 man years of design effort (including prototype)
- Readout systems already under development
- Compatible with TSV technology permitting development of 4-side buttable tiles

Basic requirements for a general purpose gas and semiconductor readout chip (Timepix2)

- Clean hit information – good separation S/N
- Low and uniform threshold
- High spatial resolution
- Analog information – ToT?
- Precise time tagging (<= 25ns)

Timepix2 - Front end

- Single pixel operation only
  - Suitable for semiconductors and gas readout
  - Positive and negative inputs
  - Shaping time 25ns
  - Noise ~100 e^- rms
  - Minimum threshold ~750e^-?
  - Power <1W/cm^2
- Very precise timestamp (~2ns) needed for gas detector readout – depth of ionisation
  - Possibly use GOSSIPO solution (TDC per pixel)
- Use TOT for energy measurement and/or timewalk correction
  - 8-bit TOT precision

Timepix2 - Readout

- Fast OR output
  - Maybe fast multiplicity?
- Hit pixels store timestamp (cf Alice/LHCb pixels)
- All hit pixels read out
- On-chip zero suppression
- Fast serial bus
- 4 side buttable
- 0.13μm process – moderate radiation tolerance, no (few) special transistors shapes

Conclusions and remarks

- Medipix3 is in full development
- Will be first large pixel readout chip in 0.13mm CMOS
- Timepix2 type chip requested by:
  - Gas detector community
  - Medipix3 community (exotic semicondutors)
  - sLHC detector groups (thin and 3D Si sensors)
- Can a common set of specs be reached?
- Can enough effort be pooled to make 1 chip?