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TIPP 2011

SPACIROC: A Front-End ASIC for JEM-EUSO cosmic ray observatory

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Contents

- JEM – EUSO overview
- SPACIROC – Design & Architecture
- Latest characterisation results
- Conclusions

JEM–EUSO – Overview

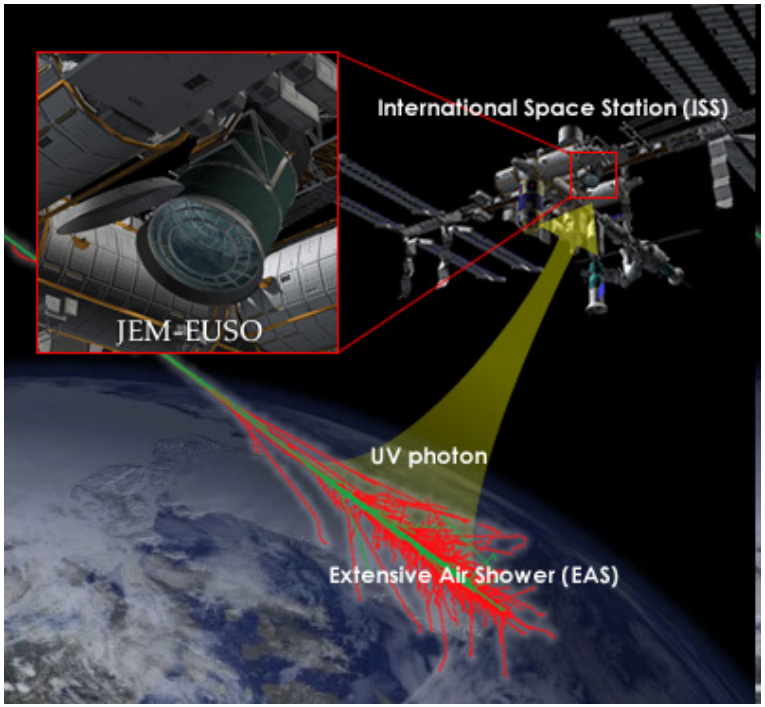
• A RIKEN-led project that will be installed on International Space Station (~ 2016).

•Installation on JAXA's "Kibo" External Exposure Module

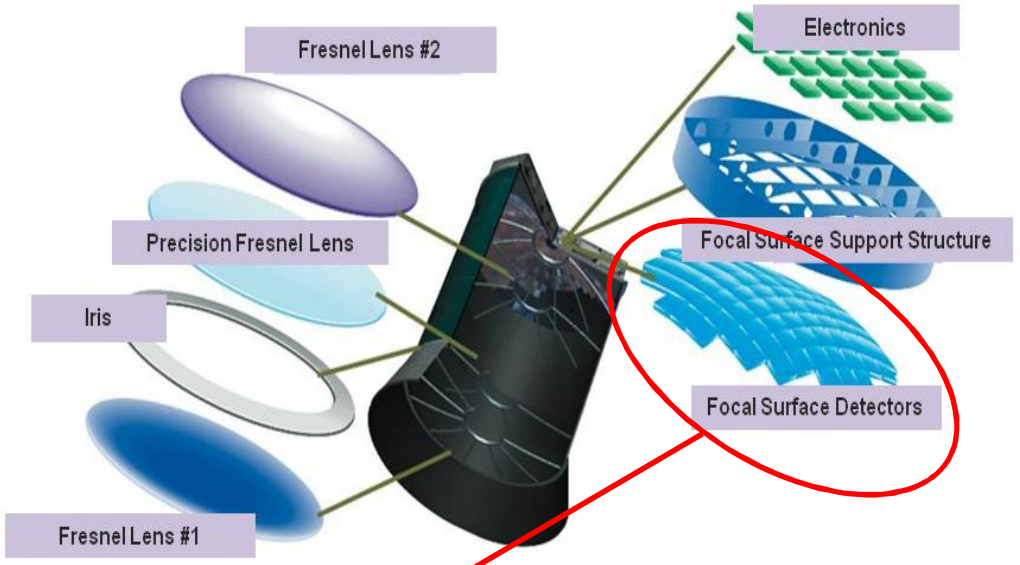
•International collaboration (Asia, EU, US) supported by 3 space agencies (JAXA, NASA, ESA).

Multi-purpose experiment:

- Study of cosmic rays and their sources
- Study of atmospheric physic
- Study of meteors
- Lightning study…



JEM–EUSO – Focal Surface Detector



*EC/FEE:

PDM Control Board:

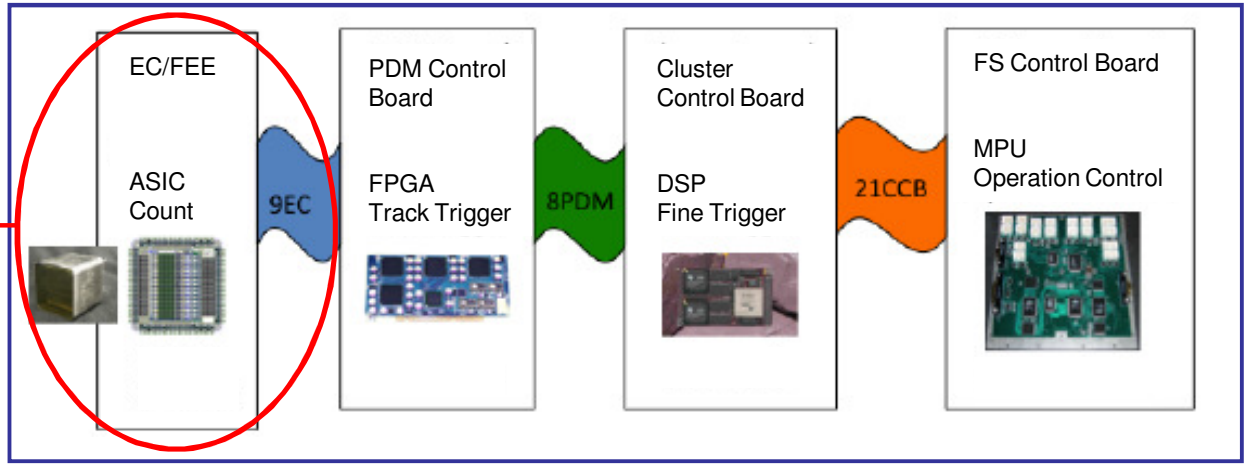
Cluster Control Board:

FS Control Board:

~5000 MAPMTs
~5000 ASICs
~300k pixels

SPACIROC ASIC

JEM-EUSO Data Acquisition Core Outline



JEM–EUSO – Front End ASIC

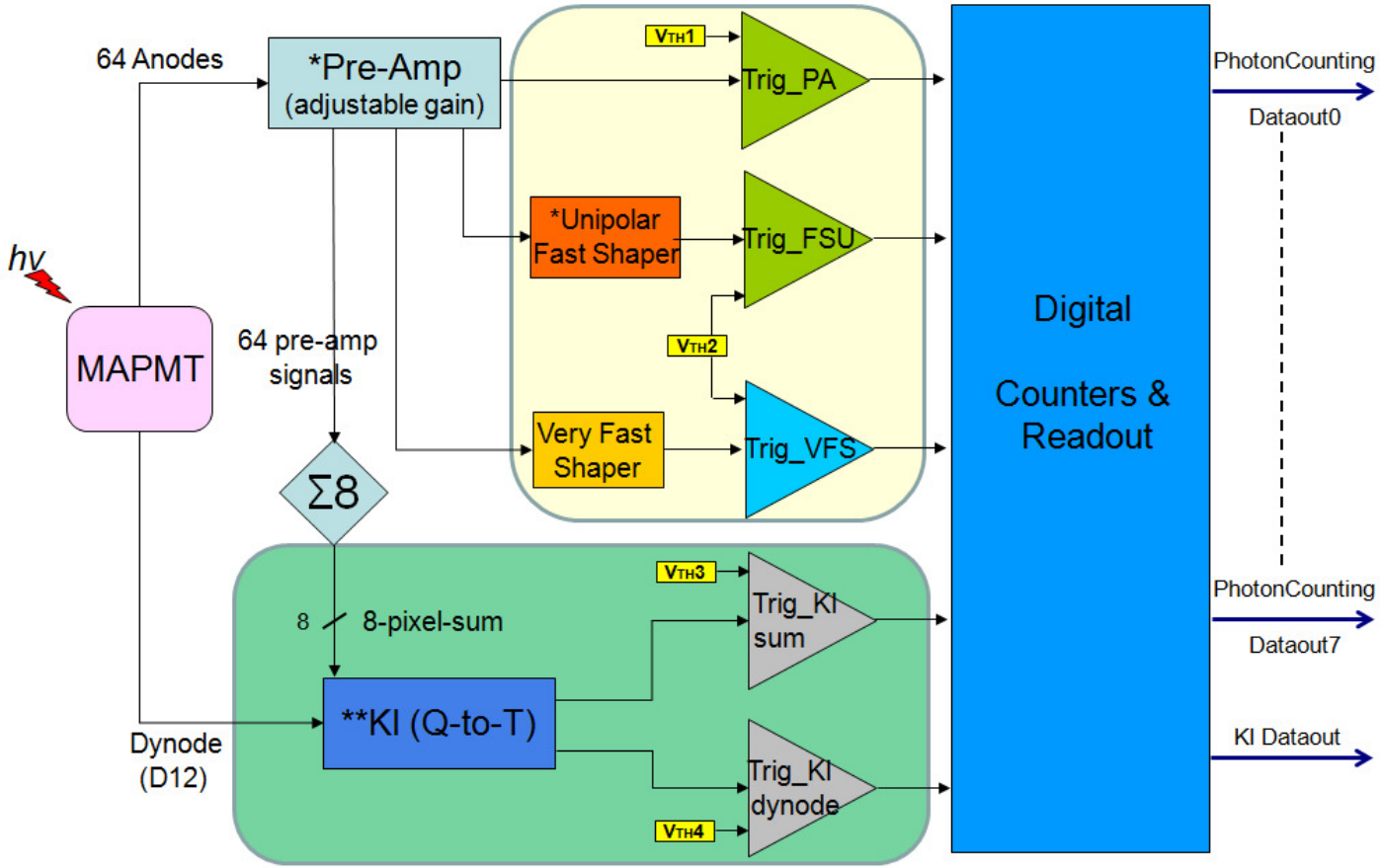
SPACIROC - Spatial Photomultiplier Array Counting and Integrating ReadOut Chip

- Readout chip for 64 channels MAPMT
- Low-power & radiation hardened
- Co-designed by LAL/ JAXA/ RIKEN

Features:

- 64 preamplifier with individual 8-bit gain adjustment
- 64 channels photon counting
  - 100% trigger efficiency: 50fC (1/3 pe @10^6 MAPMT gain)
  - Double pulse resolution : 30 ns
- Charges to Time (Q-to-T) converters
  - Pixels charge measurement:2.5pC – 250pC
  - MAPMT protection > 250pC
- Continuous Data acquisition & Readout every 2.5 μs (GTU)
- Radiation hardness
- Power budget : 1mW/channel

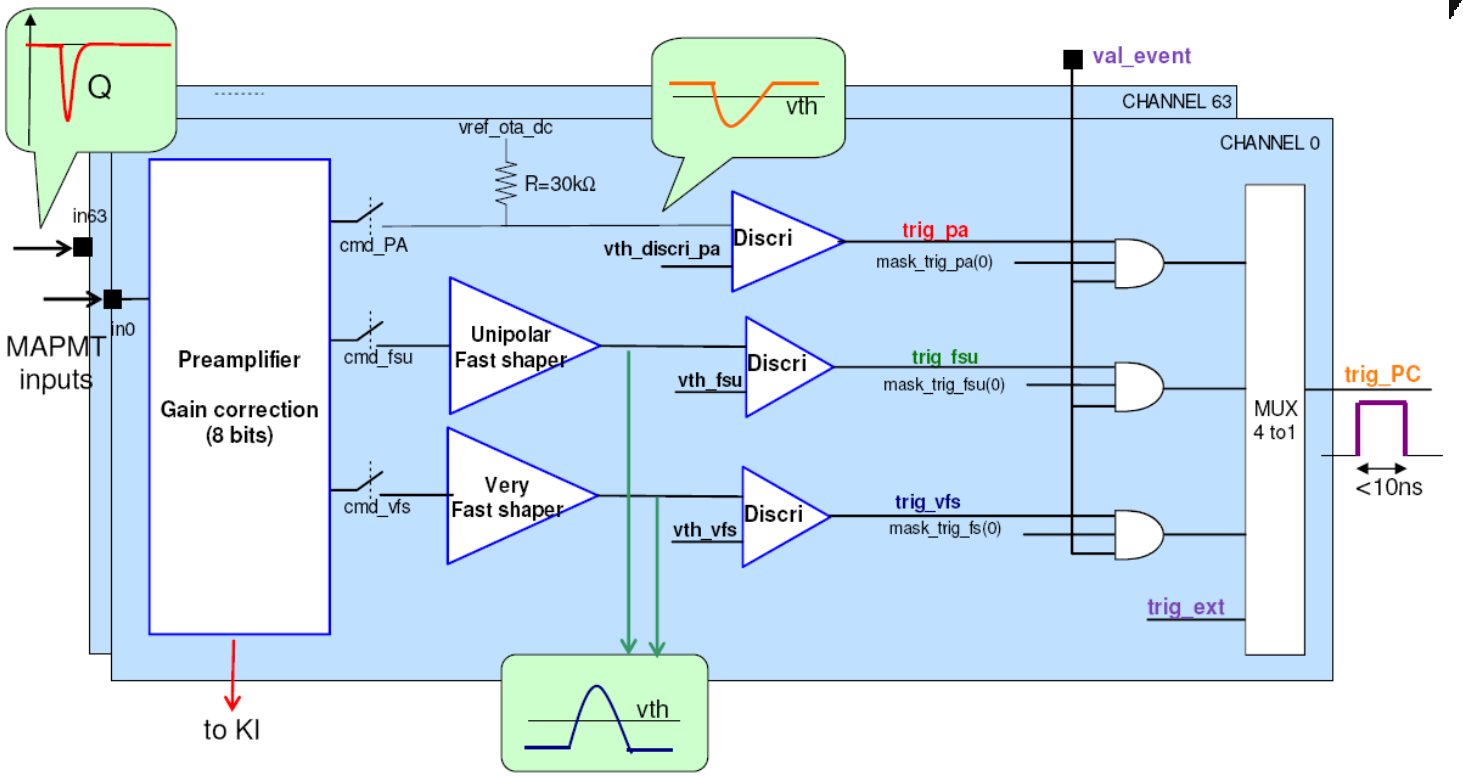
SPACIROC – Architecture



Specifications:

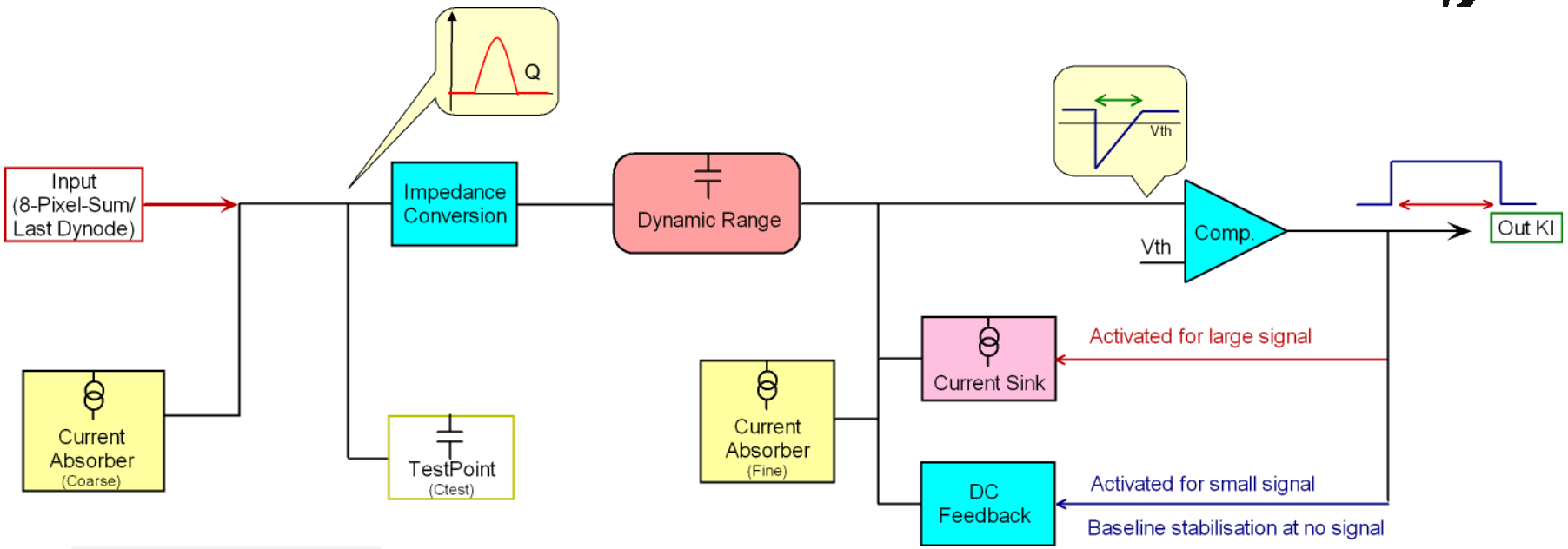
- Consumption: 1mW/channel
- Photon counting: 100% trigger efficiency@50fC (1/3pe, 10^6 Gain)
- KI input range : 2.5pc – 250pc (15.6pe - 1560pe)
- Radiation hardness
- Data out : Startbit + 64 bits + Parity

SPACIROC – Photon Counting



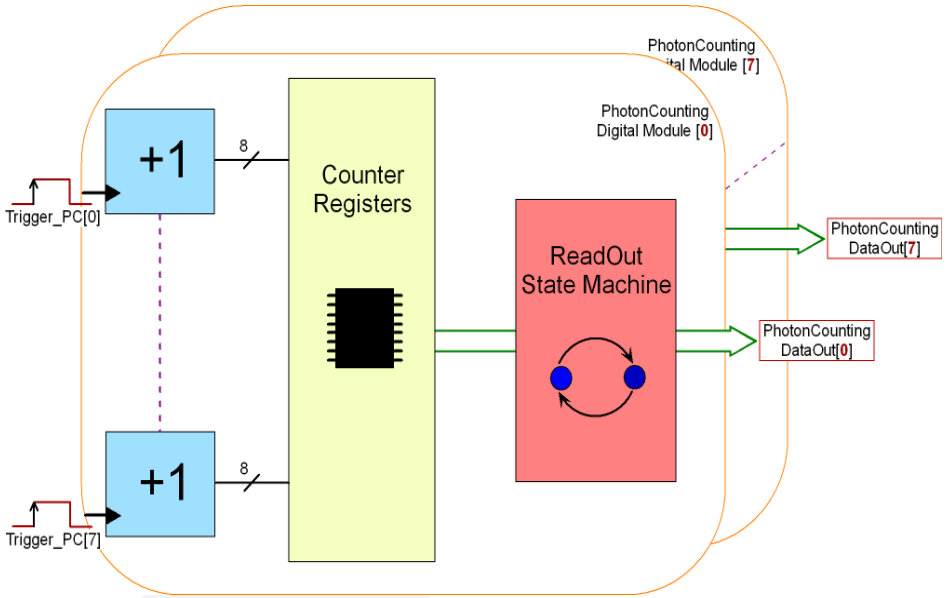
- 3 Discriminator outputs : Trig_PA, Trig_FSU, Trig_VFS
- Multiplexed Discriminator outputs to Digital part
- 2 x10-bit DAC for Discriminators threshold setting
- Available parameters: Preamp gain, Shaper & Discriminator Selection, Channel masking, FSU gain, KI summing,..

SPACIROC – KI

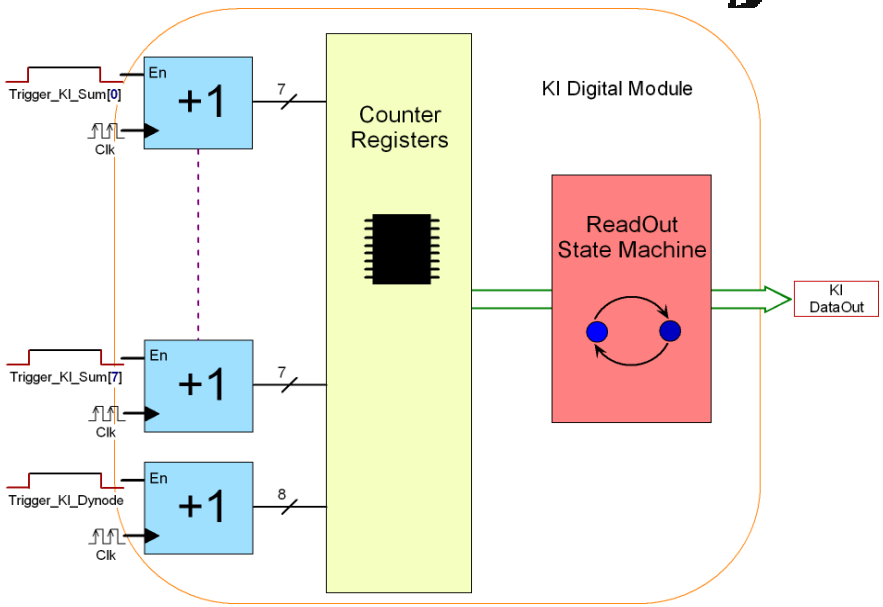


- Designed in collaboration with JAXA/RIKEN
- KI: 8 channels (8-Pixel-Sum) + 1 channel (Dynode)
- 2 x 10-bit DACs for setting the threshold
- Available parameters : Current absorber (Coarse/Fine), Integration Capacitors, Pulse Width Adjustement, Channel masking,…

SPACIROC – Digital Architecture



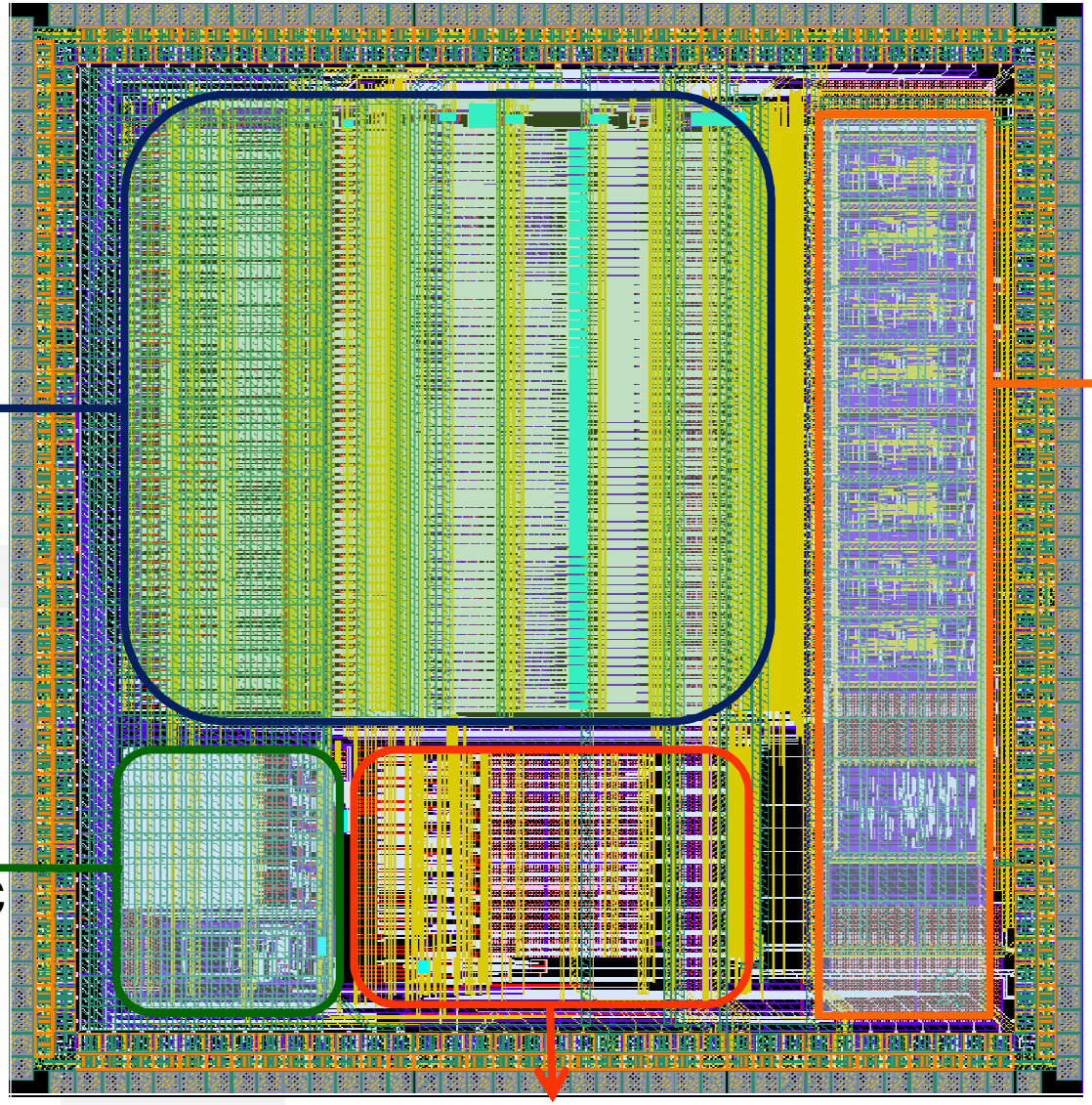
Photon Counting



KI

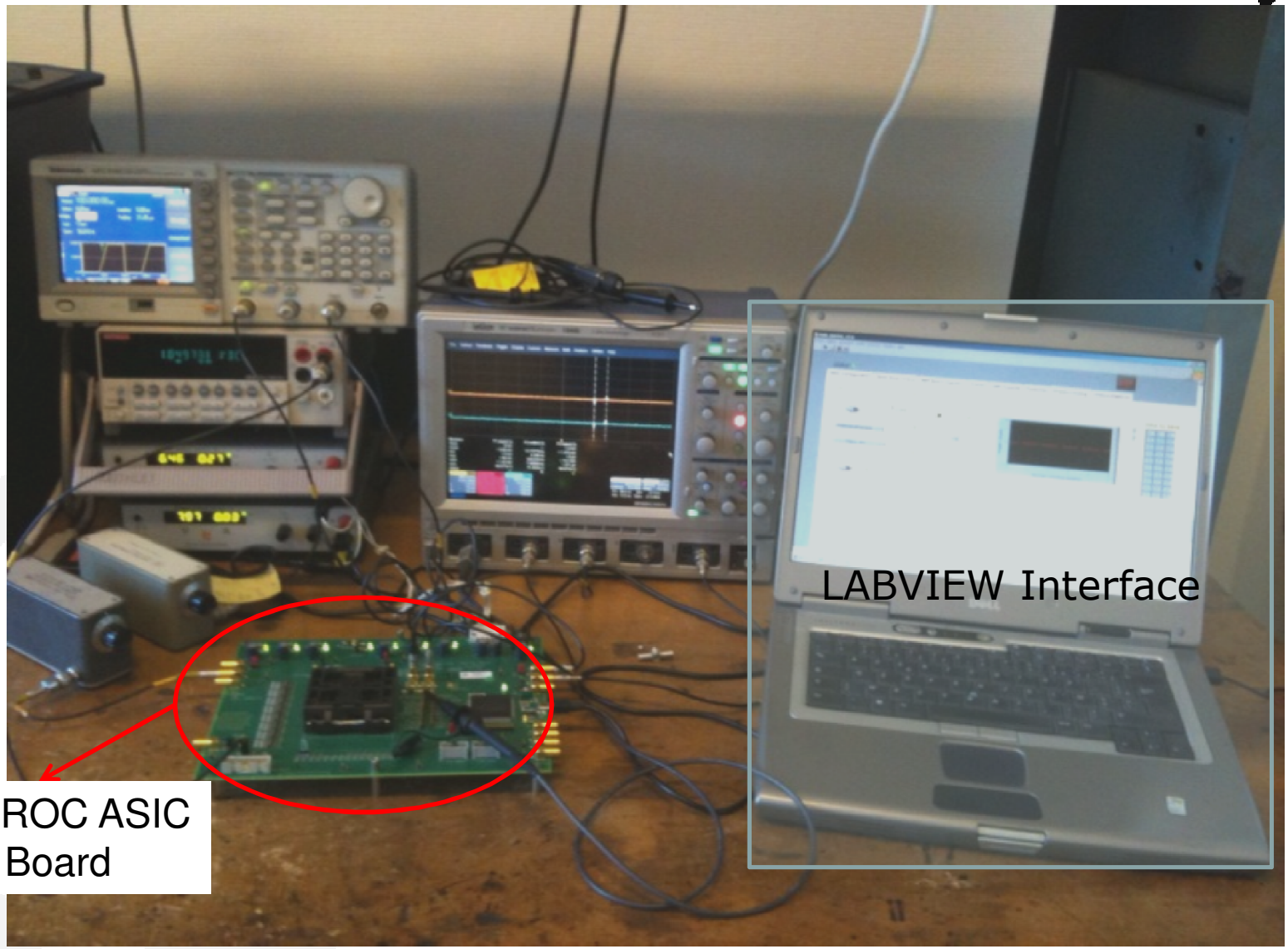
- 8 identical digital module for Photon Counting
- 1 digital module for KI
- Photon Counting Discriminators => clocking counters
- KI Discriminator => enable sampling
- 9 serial links for data readout + Transmit On signal
- Flip flops TMR in critical area

SPACIROC – Layout

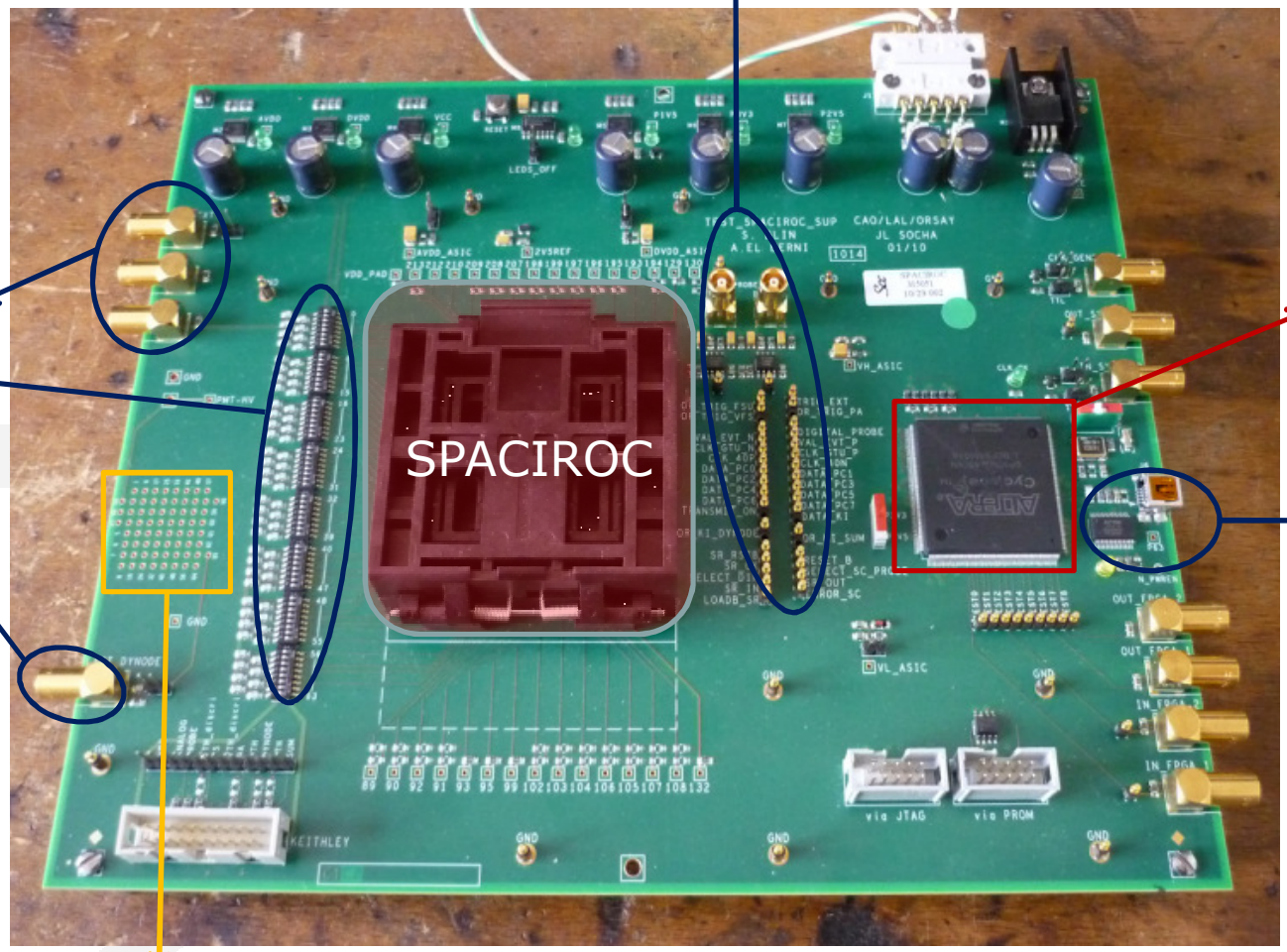


Submitted in March 2010
Technology:
AMS 0.35µm SiGe
Dimensions :
19 mm²
(4.6mm x 4.1mm)

SPACIROC – Test Setup

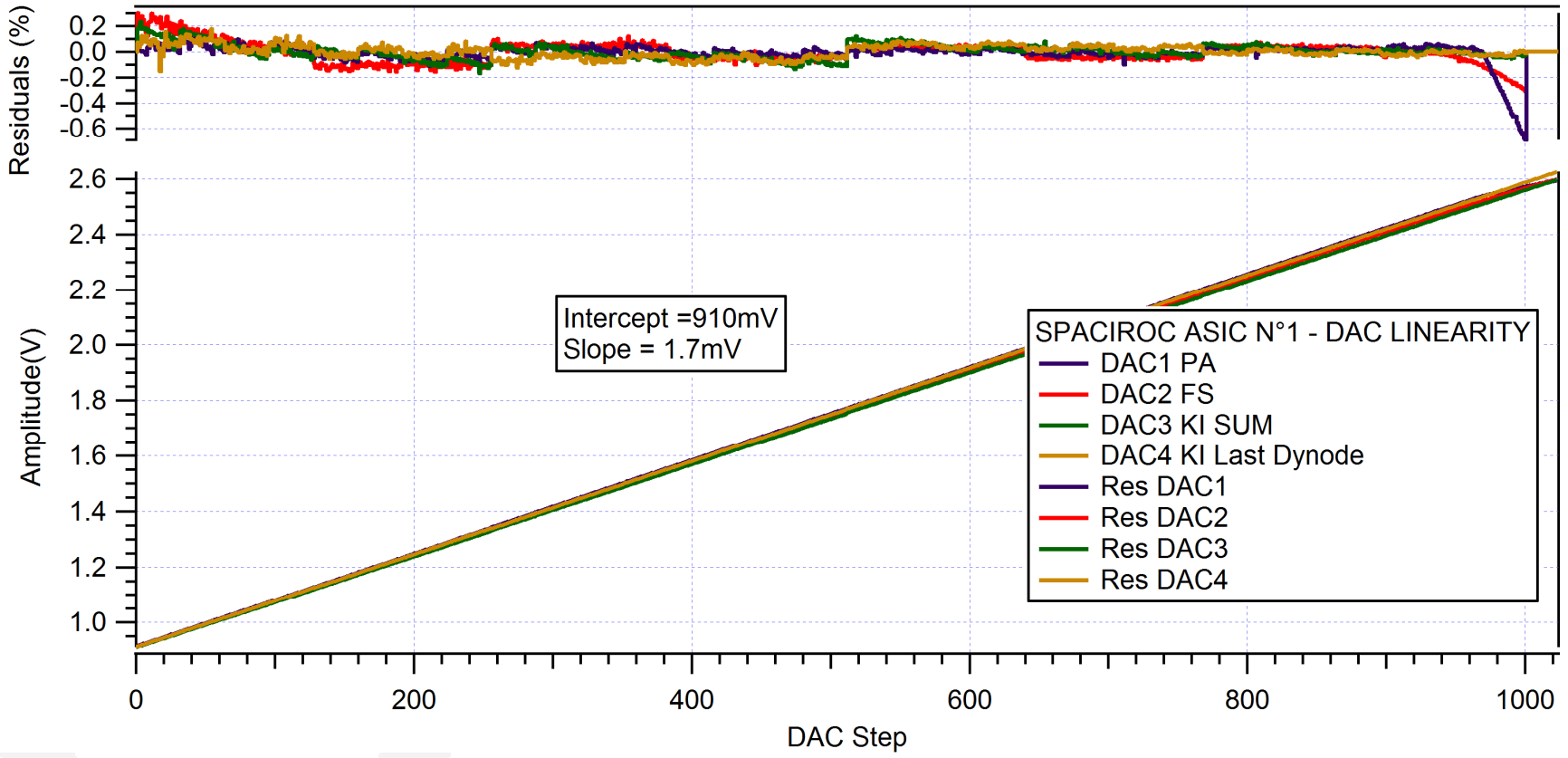


SPACIROC – Test Board



Latest Characterisation Results

- DACs Measurements



4x 10-bit DAC. Range : 0.9 – 2.6V. Linearity: ±0.2%. LSB:~2mV

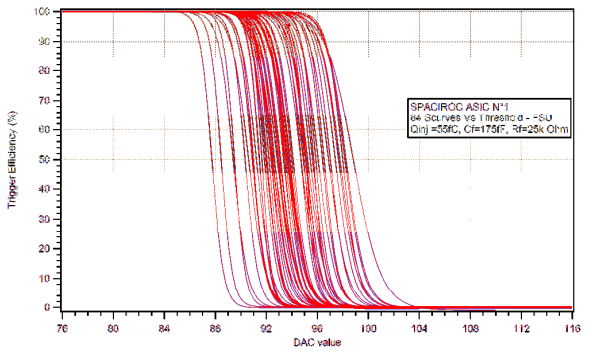
Latest Characterisation Results

Photon Counting:

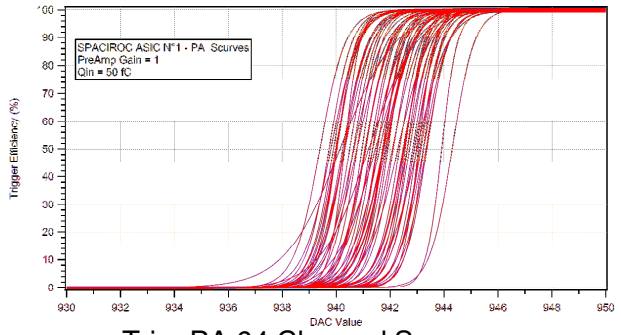
- Trig_FSU (Baseline):
  - Double pulse separation : 30 ns (low noise config)
  - Gain = 1mV/fC
  - Min input = 30 fC
  - Triggering Efficiency RMS = 2.5 DAC unit
  - Measured power consumption =0.4mW/ch

- Trig_PA:
  - Double pulse separation : 36 ns
  - Gain = 0.32mV/fC (PreAmp settings = 1)
  - Min input = 30 fC
  - Triggering Efficiency RMS = 1.8 DAC unit
  - Measured power consumption =0.1mW/ch

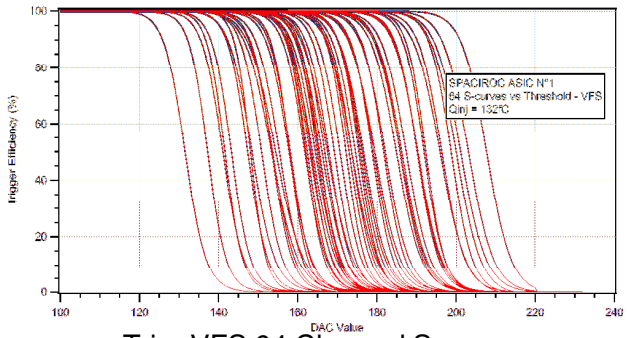
- Trig_VFS:
  - Double pulse separation : 15 ns
  - Gain = 1.3mV/fC
  - Min input = 60 fC
  - Triggering Efficiency RMS = 17 DAC unit
  - Measured power consumption =0.4mW/ch



Trig_FSU 64 Channel Scurves



Trig_PA 64 Channel Scurves

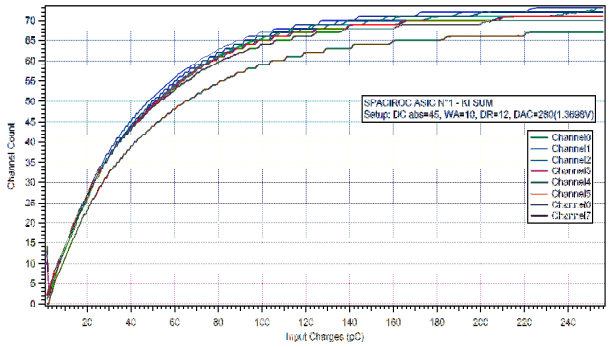


Trig_VFS 64 Channel Scurves

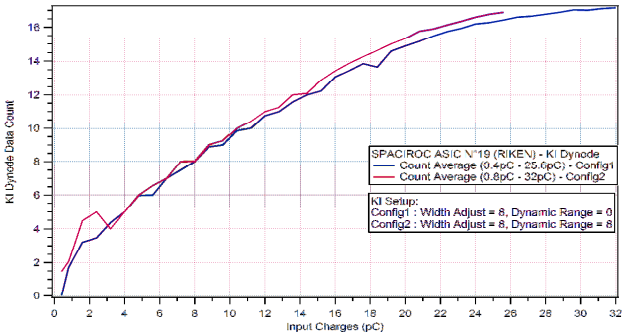
Latest Characterisation Results

KI:

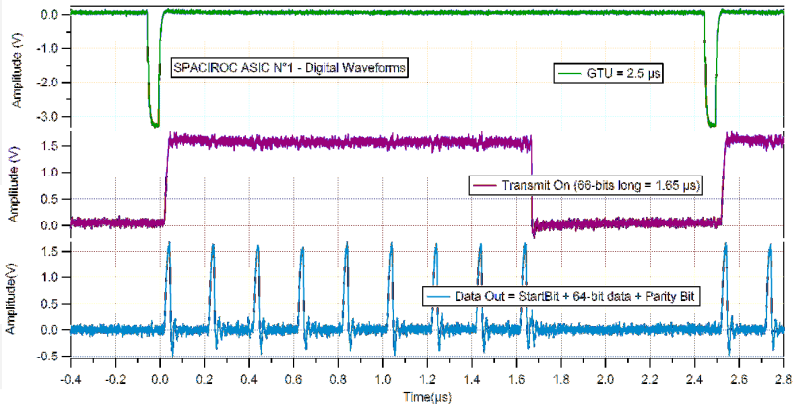
- 8-pixel-sum:
  - Input test: 1.6pC – 250 pC
- Dynode:
  - Input test: 0.8pC – 32 pC
- Fine tuning the settings (RIKEN)



KI 8-Pixel-Sum Measurements



KI Dynode Measurements



ASIC Digital System:

- Startbit, Data, TransmissionOn, Parity Bit
- Data output Vhi-Vlo: 1.5V - 0V

Conclusion

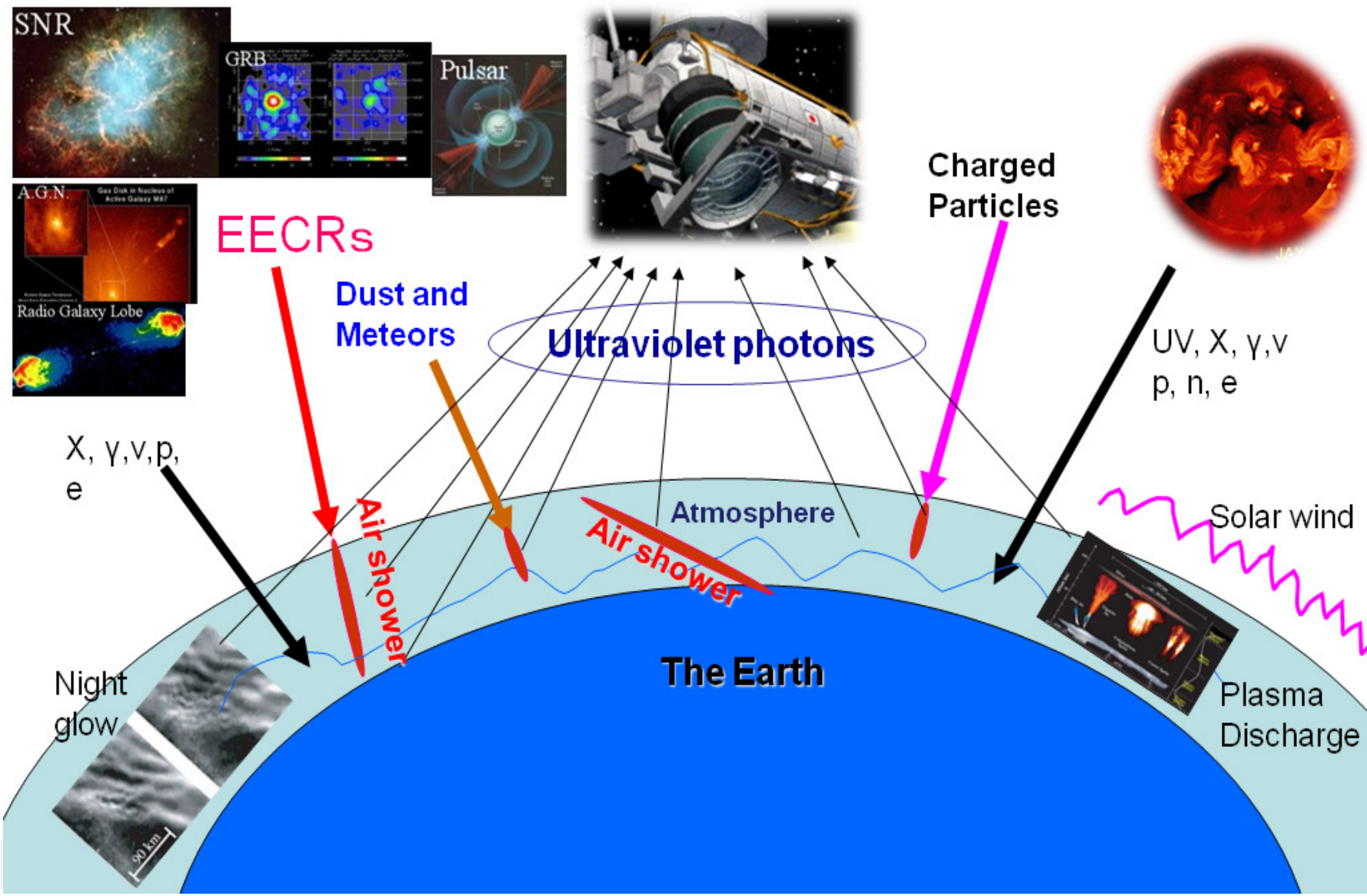
- SPACIROC exhibits good behavior for a first prototype
- Nearly all intended features & functionality are working
- Currently finalising characterisation of the ASIC
- The work for pre-production prototype is underway:
  - Final prototype before mass production
  - Target :
    - Improve power consumption
    - Better double pulse separation resolution
    - Improve KI performances

Summary of Current spec:

Item	Asic Spec
Power Consumption	1.1mW/ch
Photon Counting Minimum Input	30fC
Double pulse separation	30ns
KI 8-pixel-sum Dynamic Range	2pC – 200pC
KI Dynode Dynamic Range	0.8pC - 32pC
Digital module counting rate	50MHz

Thank you for listening !

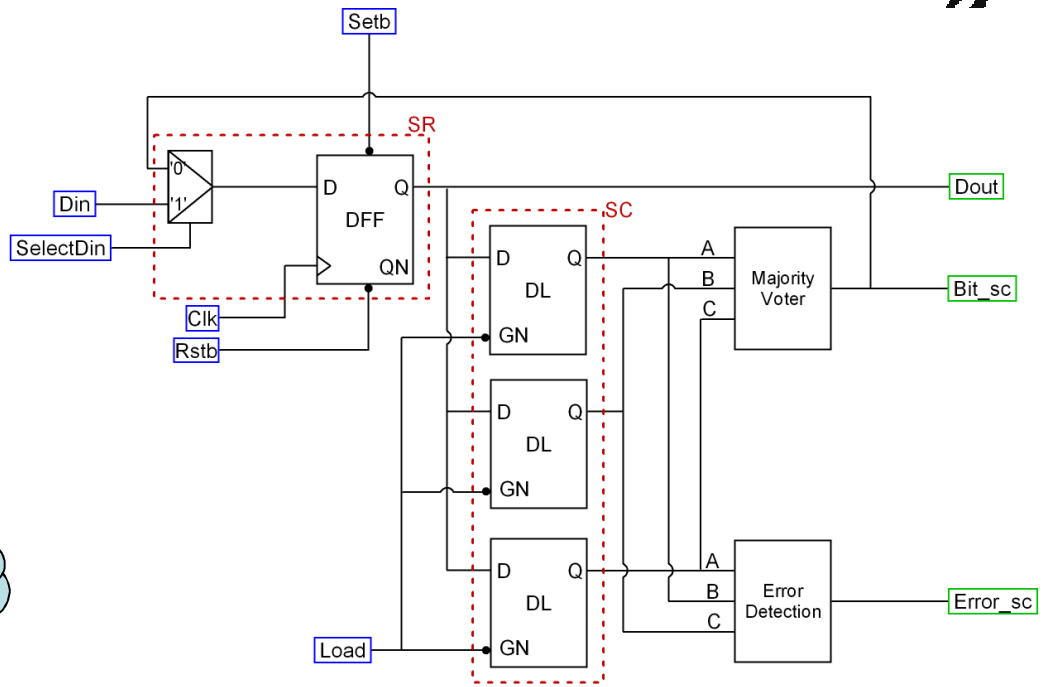
JEM–EUSO – Overview

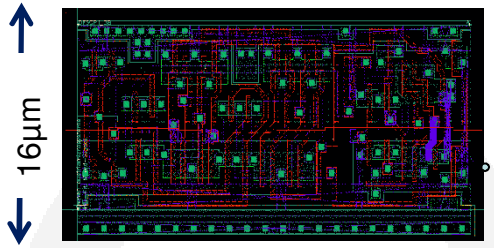


SPACIROC – Slow Control Cell

Slow control cell:

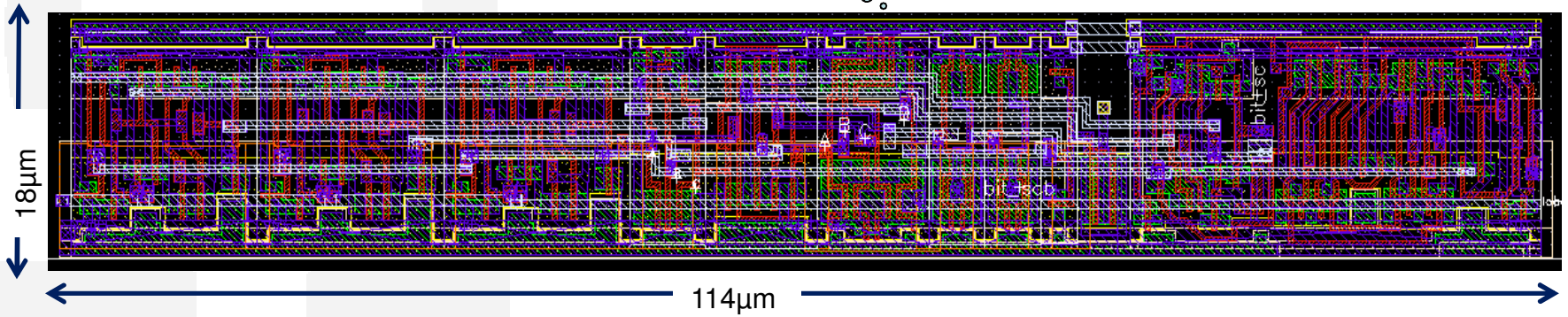
- 1 Scan DFF + triple Data latch
- Majority voter
- Bit error detection
- Non-destructive data readout
- Bigger layout : SEL protection,...





Layout DFF

Layout Slow Control Cell Spaciroc



Latest Characterisation Results

- SPACIROC General characteristics:
  - Typ power consumption : 1.1 mW/Ch (40 events/GTU/Ch)
  - TMR Slow Control Cells (898 bits) : Working, Non Destructif Readout
  - 4x 10-bit DACs: Good linearity (± 0.2% Residuals)
  - Bandgap Reference: 2.51V (Stable Room Temp)

- Photon Counting:
  - Trig_PA, Trig_FSU, & Trig_VFS : Working
  - Baseline :
    - Trig_FSU : Preamp + Shaper(FSU) + Discriminator + Digital
    - Best choice in term of design, robustnes & performances
- KI:
  - 8-Pixel-Sum : Working
  - Dynode: Working

- Digital : OK. No major issues.

Latest Characterisation Results

SPACIROC issues & bugs:

- Power consumption:
  - Due to design bugs, unused component can't be turned off.
    - In baseline mode(Trig_FSU), VFS shapers & Trig_PA discri are always ON! Non negligeable useless power dissipation.

- PC: Noise problem:
  - Digital noise polluting some inputs => uneven noise level for all channels
    - Noise level should be lower without ASIC socket (or COB)

- PC: Double pulse separation:
  - Off target for 10 ns. Probably unachievable.
    - Mixed-up between min discri pulse width & Double pulse separation

- PC : Trig_PA
  - Expected signal & gain too low compared to simulations
    - Very sensitive to layout parasitic capacitances

Latest Characterisation Results

SPACIROC issues & bugs:

- PC: Trig_VFS:
  - VFS has no power OFF switch!
  - Discri has very uneven behaviour due to process disparity
- KI: General:
  - Dynamic range & Pulse width parameters are shared between KI 8-Pixel-Sum & KI Dynode.
- KI : 8-Pixel-Sum
  - Linearity zone is 75% smaller than simulations
  - Integrated signal swing is 0.7V instead of 1.5V
    - Huge dynamic loss
- KI: Dynode
  - Difficulties to inject charges when synchronised to GTU=2.5µs
    - Input impedance too big? Input pad limiting signal?? Leakage current???
  - Nearly unresponsive to fast input signal (sub 10ns input pulse)