Focal Plane Instrumentation and Electronics for the SST

Overview

Richard White

SST Meeting, Liverpool, 7 - 8 Sep. 2010

Overview

Focal Plane Instrumentation & Electronics for the SST

- Overview
- Readout Electronics
- Photosensors
- SST - CAM

Overview

Focal Plane Instrumentation & Electronics for the SST

Overview

Readout Electronics

Photosensors

SST - CAM

- Introduce the FPI and ELEC work packages.
- Discuss the work to date.
- Requirements & relevance for the SST.
- What is and isn't being addressed by FPI and ELEC at the moment.

Overview

Focal Plane Instrumentation & Electronics for the SST

- Overview
- Readout Electronics
  - AGIS
  - NECTAR
  - DRAGON
  - FLASHCAM
- Photosensors
- SST - CAM

Overview

Focal Plane Instrumentation & Electronics for the SST

- Overview
- Readout Electronics
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- SST - CAM

- MAPMs
- GAPDs
- FACT (SiPMs)

Overview

Focal Plane Instrumentation & Electronics for the SST

Overview

Readout Electronics

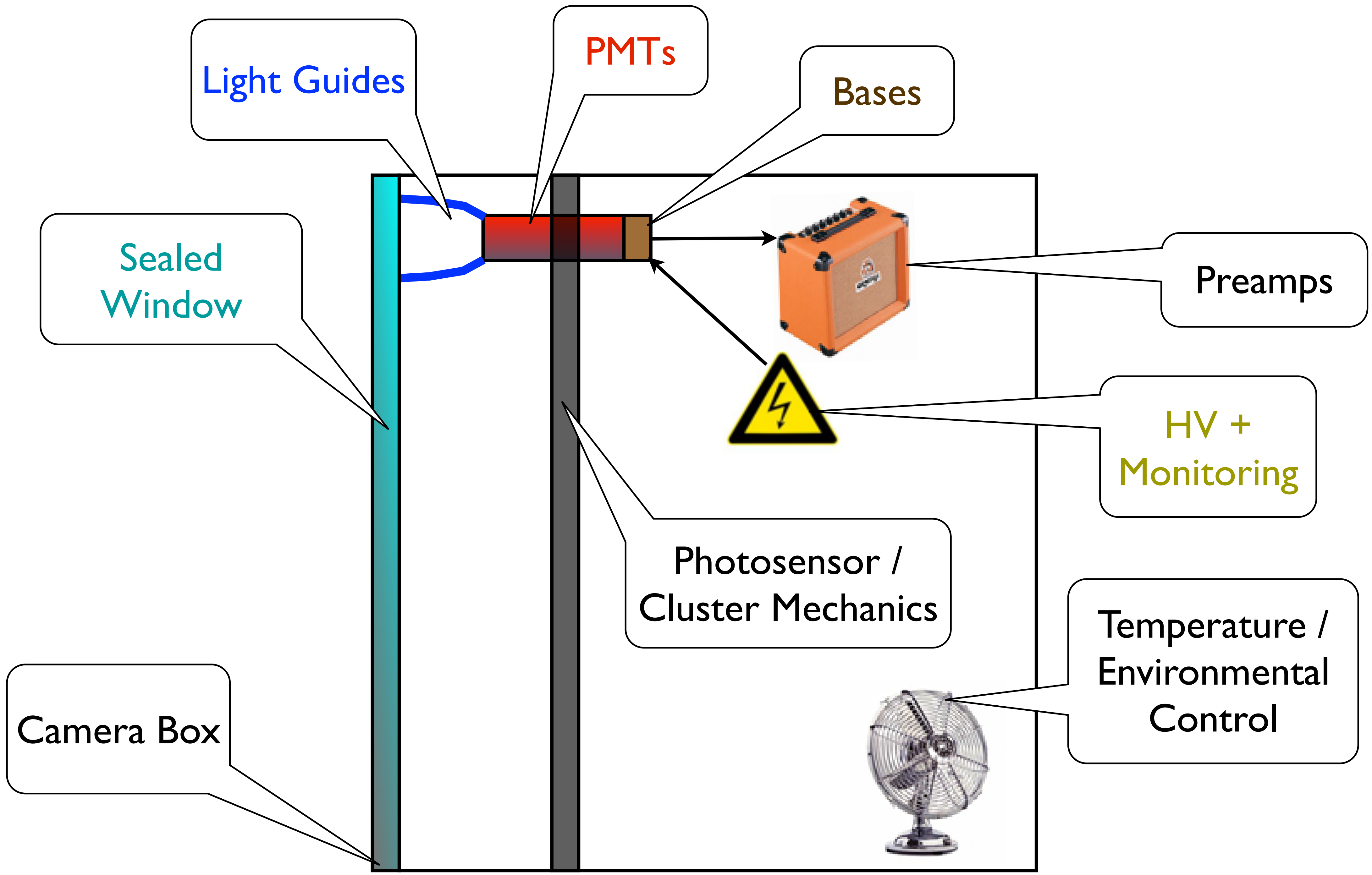
Photosensors

SST - CAM

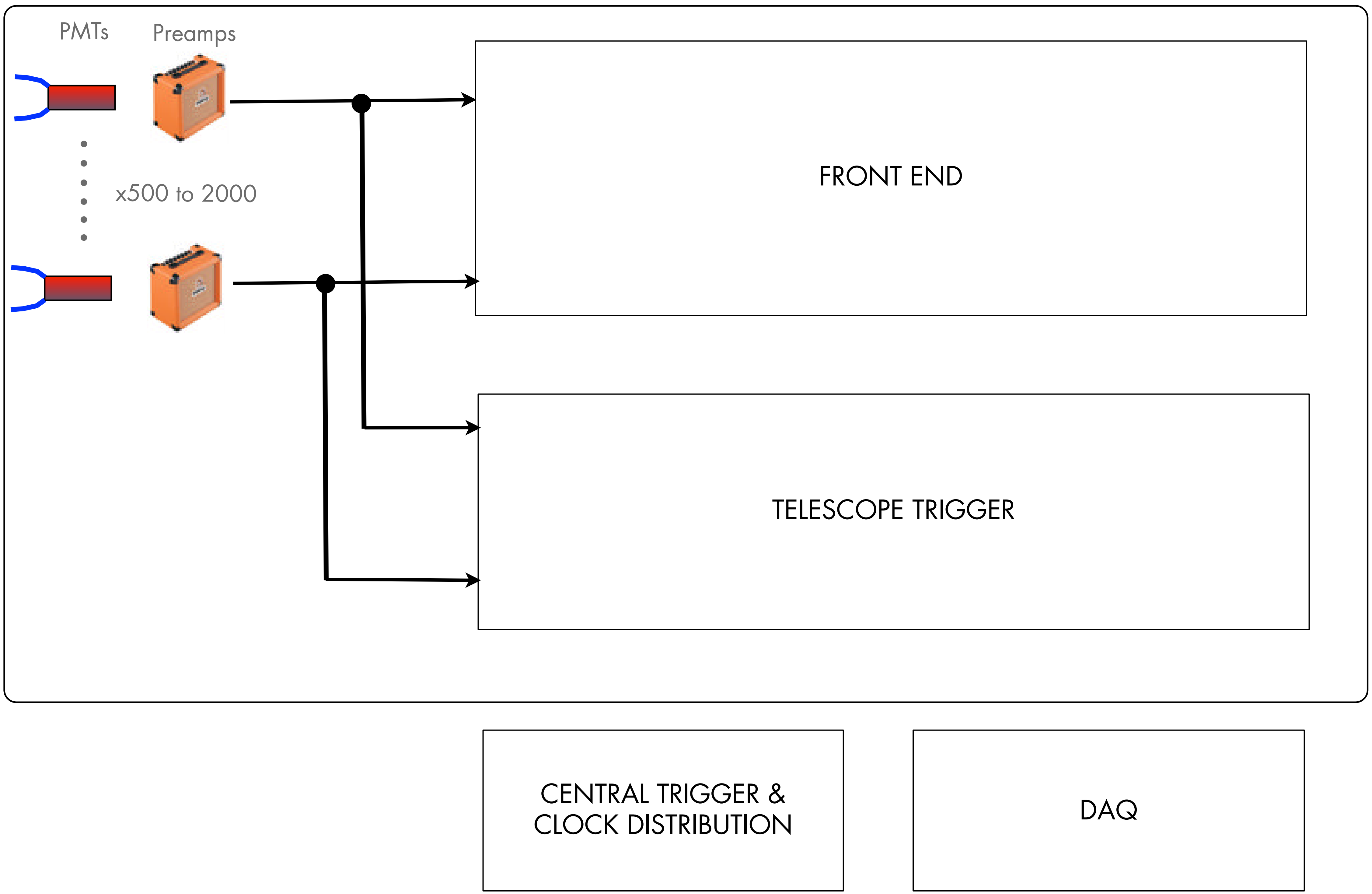
- What is SST-CAM
- Prep. Phase
- Timeline
- Work to be done.

Focal Plane Instrumentation

Overview

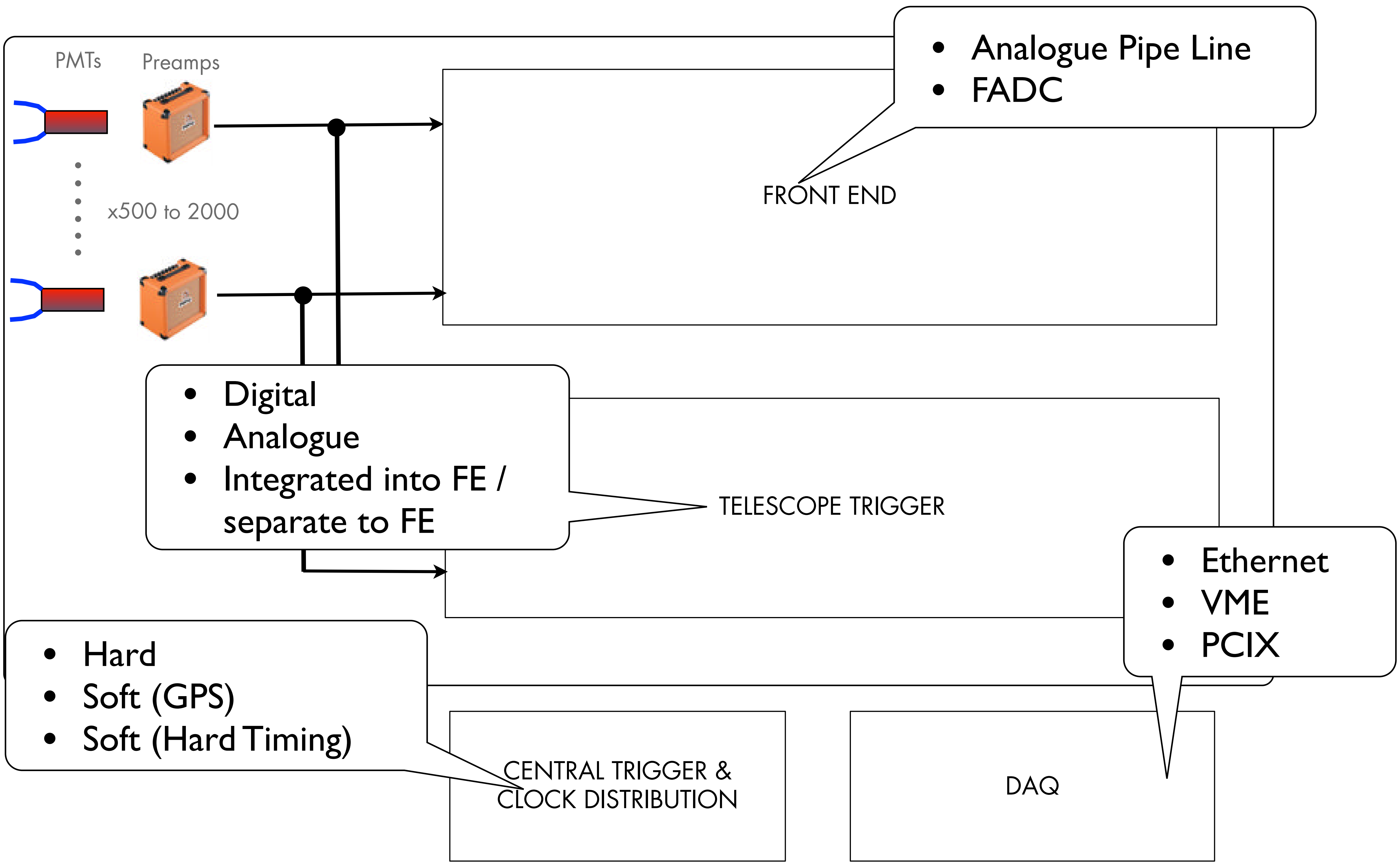


Electronics
Overview



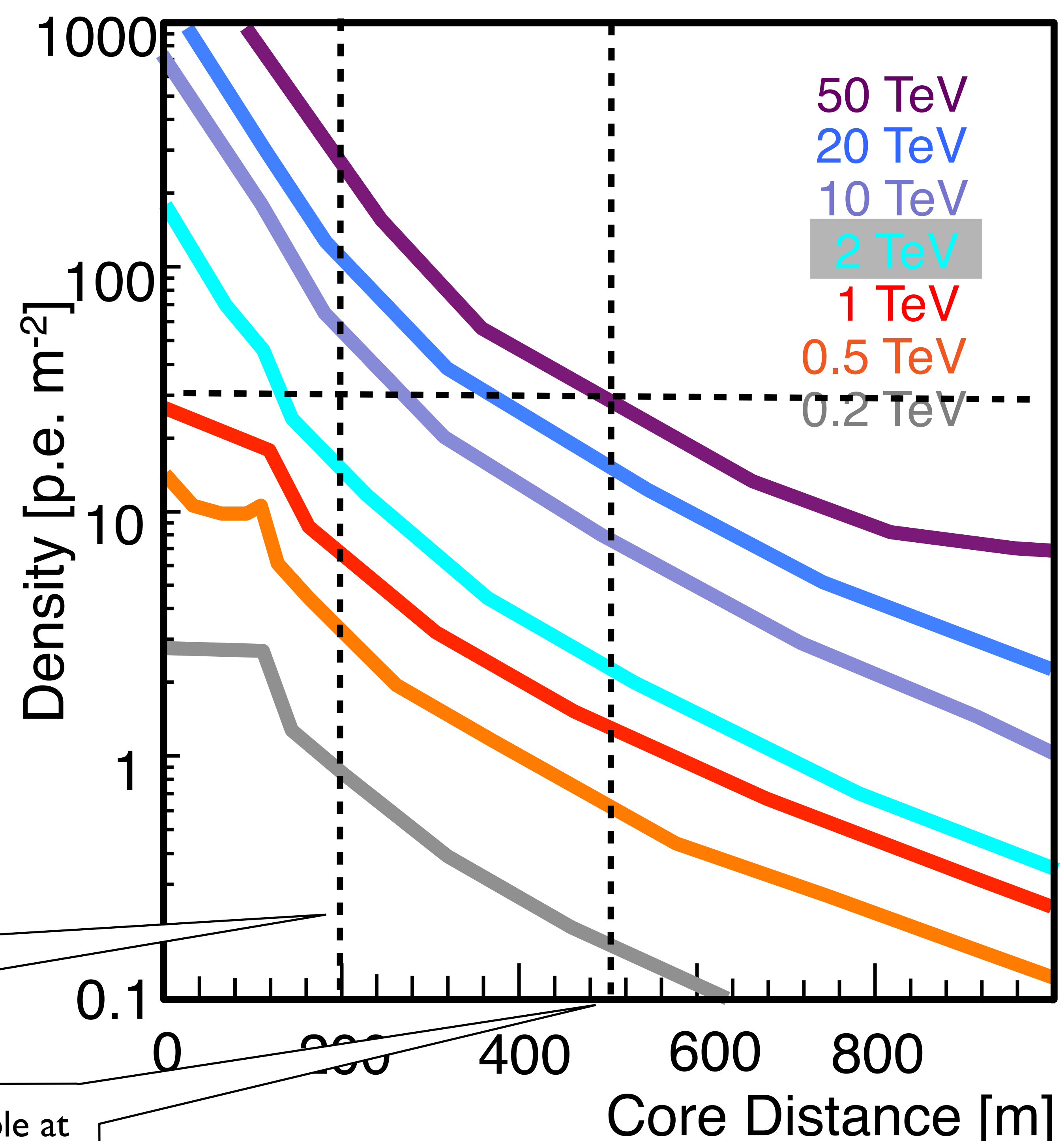
Electronics

Overview



SST Requirements
Image Spatial Properties

- Lateral Distribution:
  - 3 TeV ~100 pe @ 200 m for a 10m² mirror
  - No shoulder at high energy
- Image Size:
  - Length / Width increase as Log E
- Image Displacement:
  - 1° per 100 m (ish)
- Need 8-10° camera



200 m is a good spacing for angular resolution and provides enough light with 10 m²

At the highest energies, images will be visible at large distances

...adapted from S. Biller

SST Requirements

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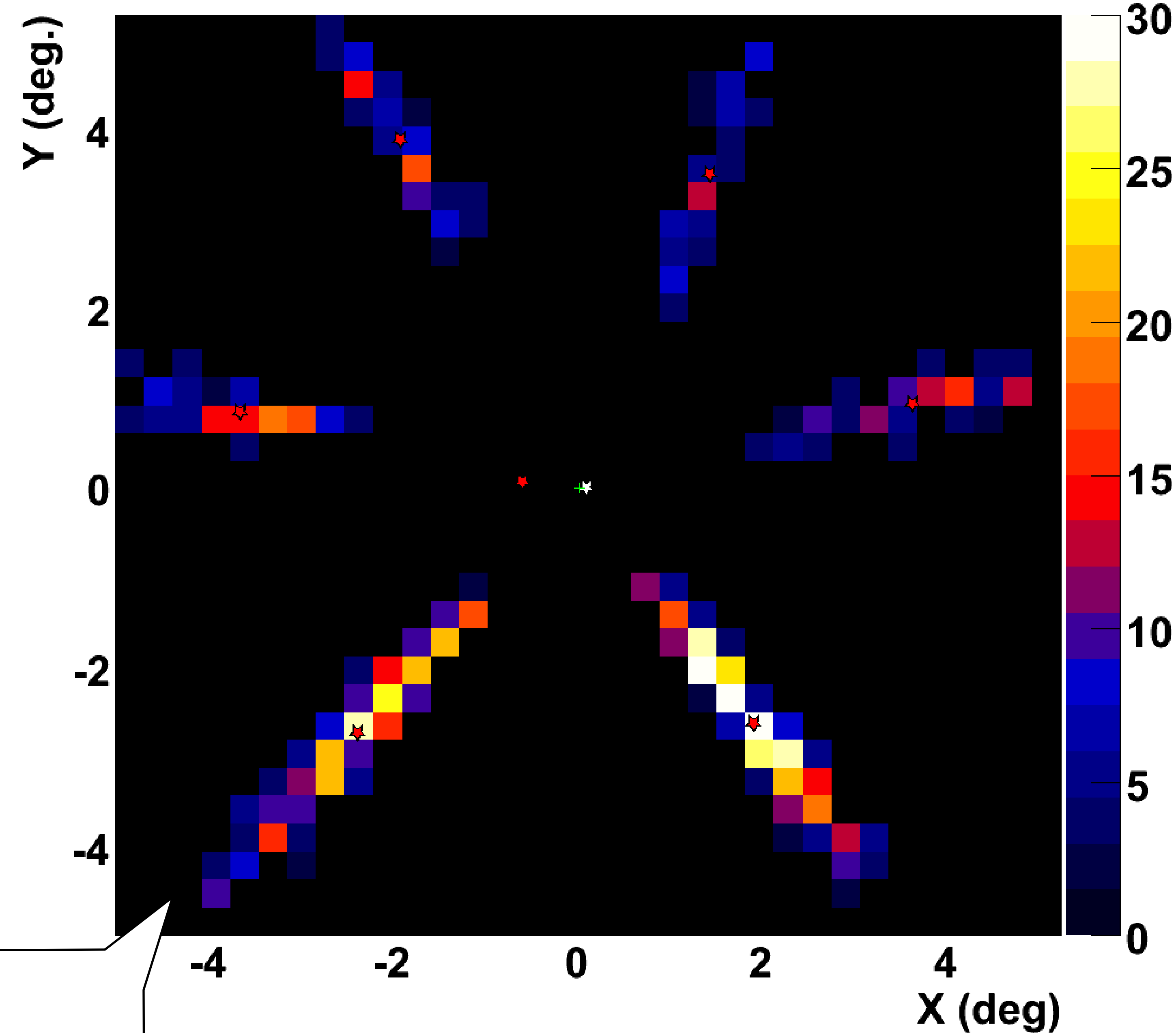


J. Hinton

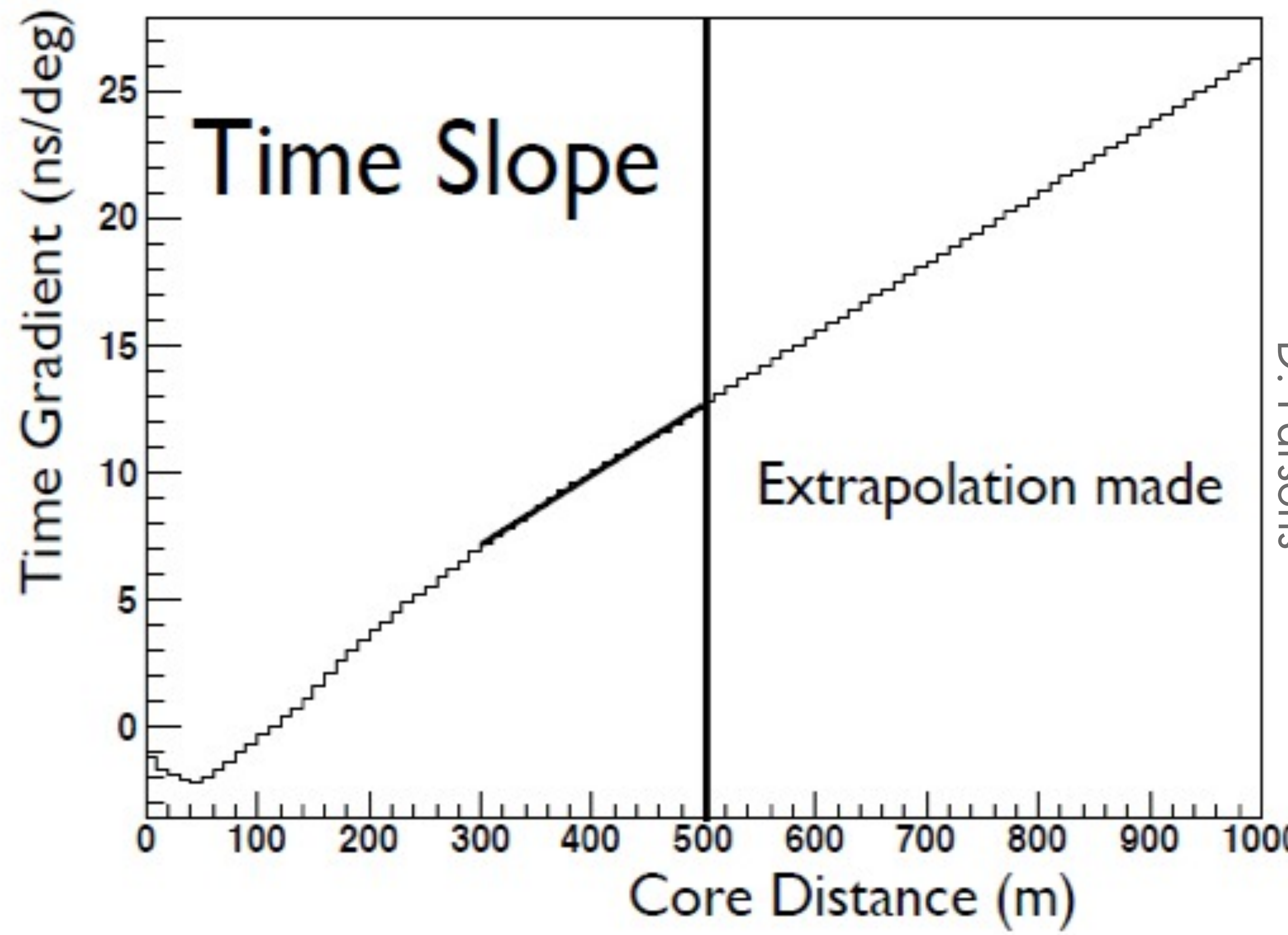
Example:

- Six 10° FoV (0.25° pixel) cameras (30 m^2 telescopes)
- ~500 m from the core
- 14 TeV shower

SST Requirements

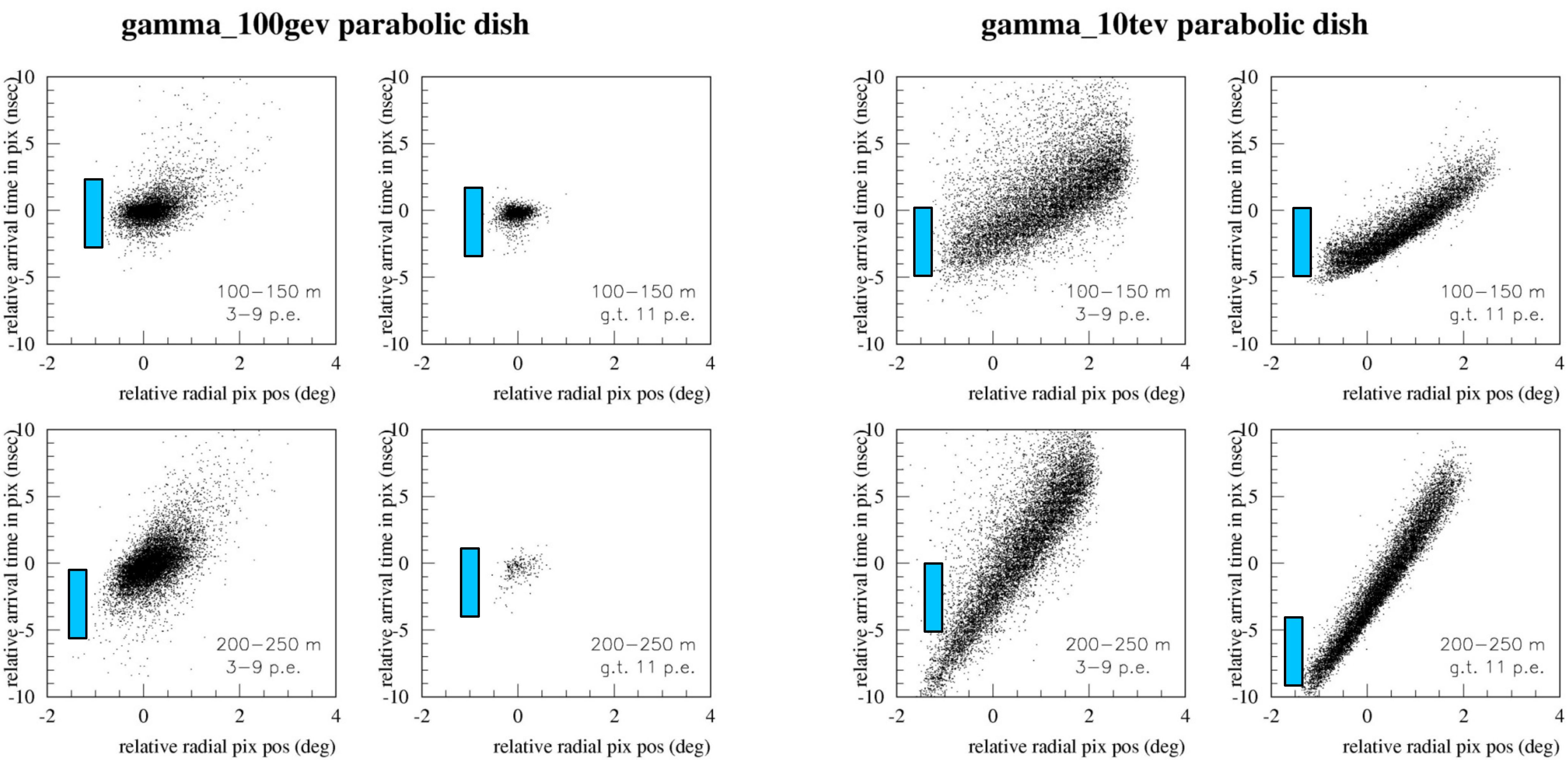
Image Timing Properties

- Time gradient along shower increases with impact distance.
- As the length of the image is also increasing, the total image duration grows quickly far from the core.



D. Parsons

SST Requirements
Image Timing Properties



German and Konrad

- At 1km from the core, images last hundreds of ns.

SST Designs
Camera Overview

3 - 7 m Telescopes

8 - 10° FoV

0.2 - 0.3° Pixels

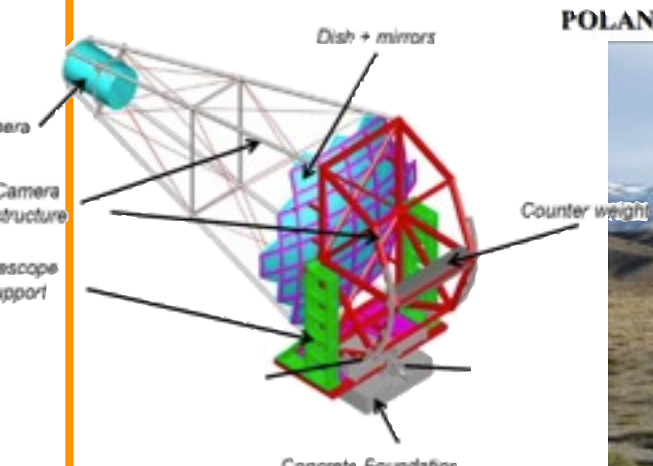
DC/SO f/D 0.5 - 1.7

Conventional DC:
- 7 m (12 m)
- 0.25°, 50 mm () pixels
- 1.5 m (3 m) camera
- 8° (10°) FoV
- Cam. Challenges:
  - Cost

DC + SiPM:
- 3.5 m
- 0.16°, 3 mm + solid cone
- Cam. Challenges:
  - Cost
  - SiPM availability

SO:
- 3.5 m
- 0.2°, 6 mm pixels
- 40 cm, camera
- 8° FoV
- Cam. Challenges:
  - Curved focal plane
  - Large angles
  - Cost

INAF



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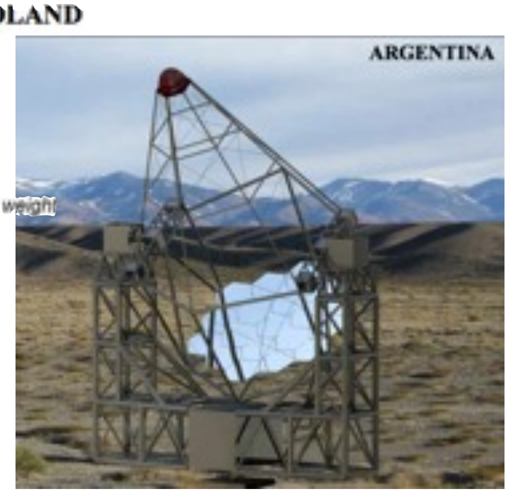
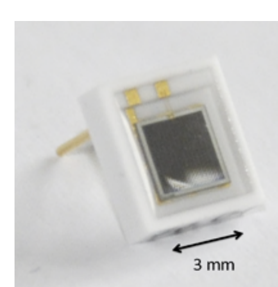
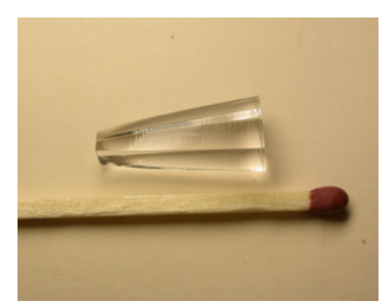






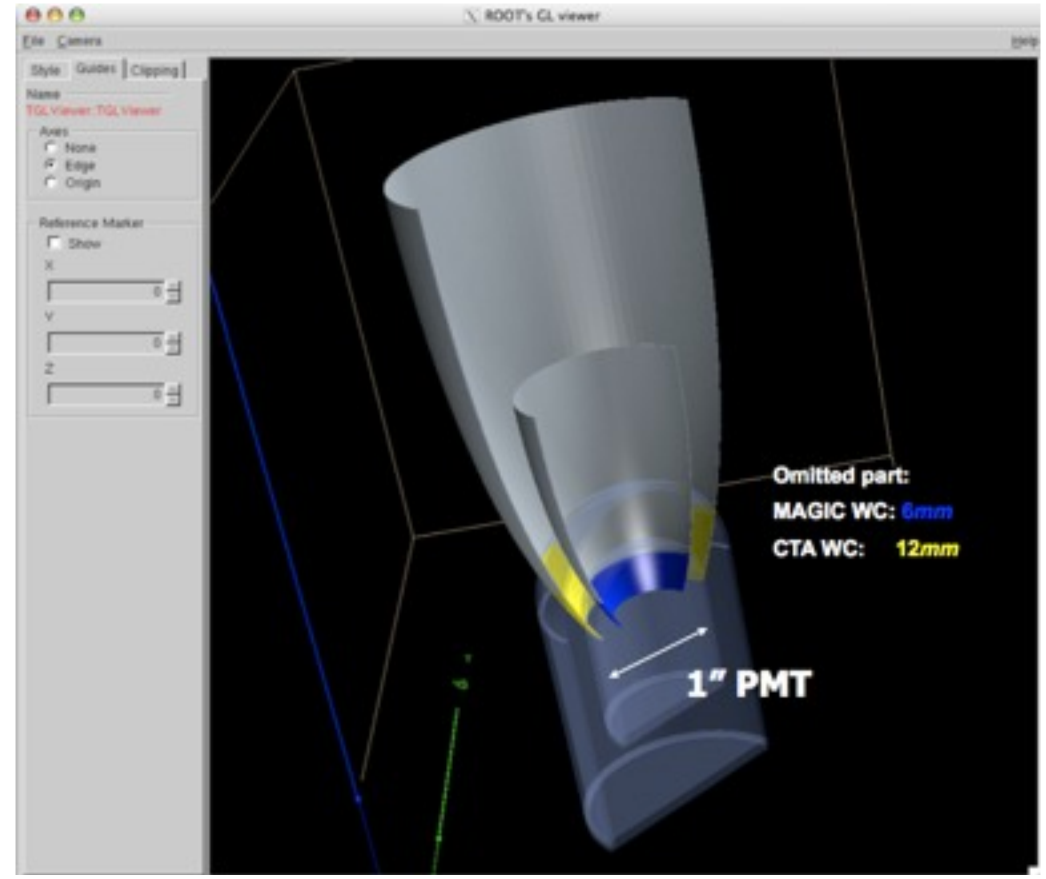
INAF

UK

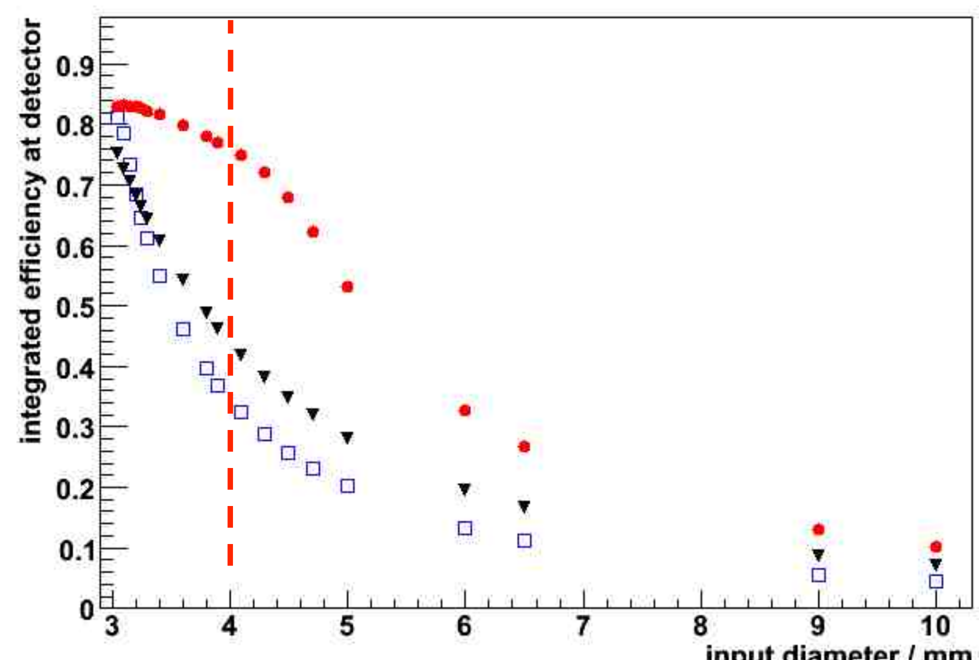
Focal Plane Instrumentation

Light Guides

- Zurich, MPI Munich, Marseille
- EG: Munich:
  - D_{in} = 54 mm
  - θ_{acc} = 25°
  - D_{out} = 23 mm
  - L = 82 mm (ideal) , 70 (reduced)
  - Concentration Factor: 5.6 (ideal), 2.5 (reduced)
- For the SST:
  - Could be as for MST and LST in the conventional solution.
  - For SO or DC+SiPM the angles are large, but Zurich are investigating solid cones for SiPMs at large acceptance angles (75°)



M. Shayduk, et al

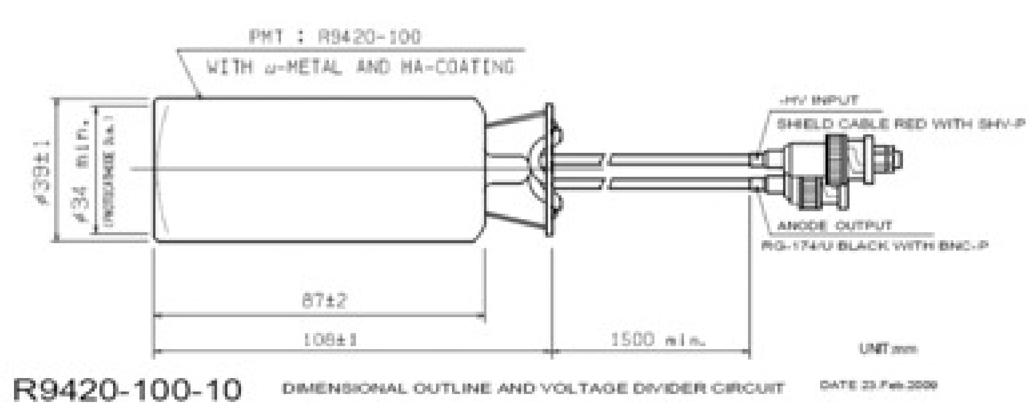


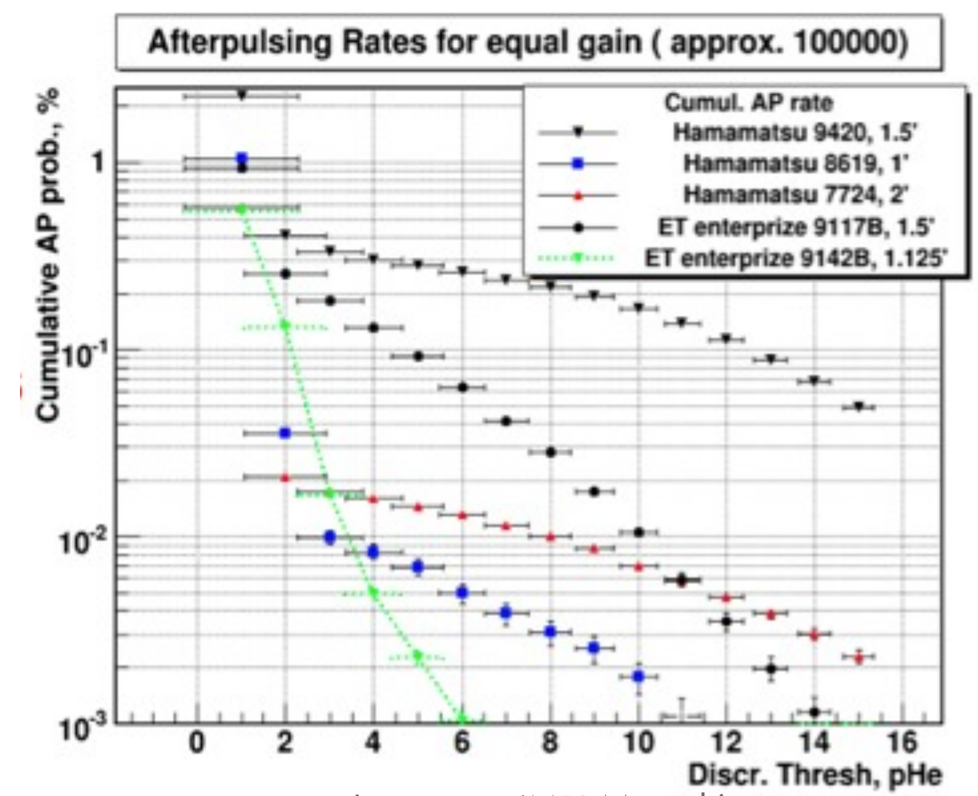
Isabel Braun

Focal Plane Instrumentation
Photosensors

- Focus so far on conventional PMTs:
  - Low afterpulsing (10^{-4} above 4 pe)
  - High PDE
  - Hamamatsu
  - ELT
- Recent work at MPI Munich:
  - QE measurements
  - Afterpulse rate of R9420 reduced by x5-6... still 2-2.5 x too high.
  - Time Response

Company	Type	QEpeak(λ)	$\langle QE \rangle_{Cher}$
Hamamatsu	8619	28,7 ± 2,2 (390 nm)	19,4 ± 0,3
Hamamatsu	9420	34,6 ± 3,1 (370 nm)	22,9 ± 0,4
Hamamatsu	7724	38,9 ± 3,3 (370 nm)	25,7 ± 0,4
Electron Tubes	9117B	34,0 ± 3,2 (360 nm)	19,9 ± 0,3
Electron Tubes	9142B	30,2 ± 2,7 (370 nm)	16,5 ± 0,3



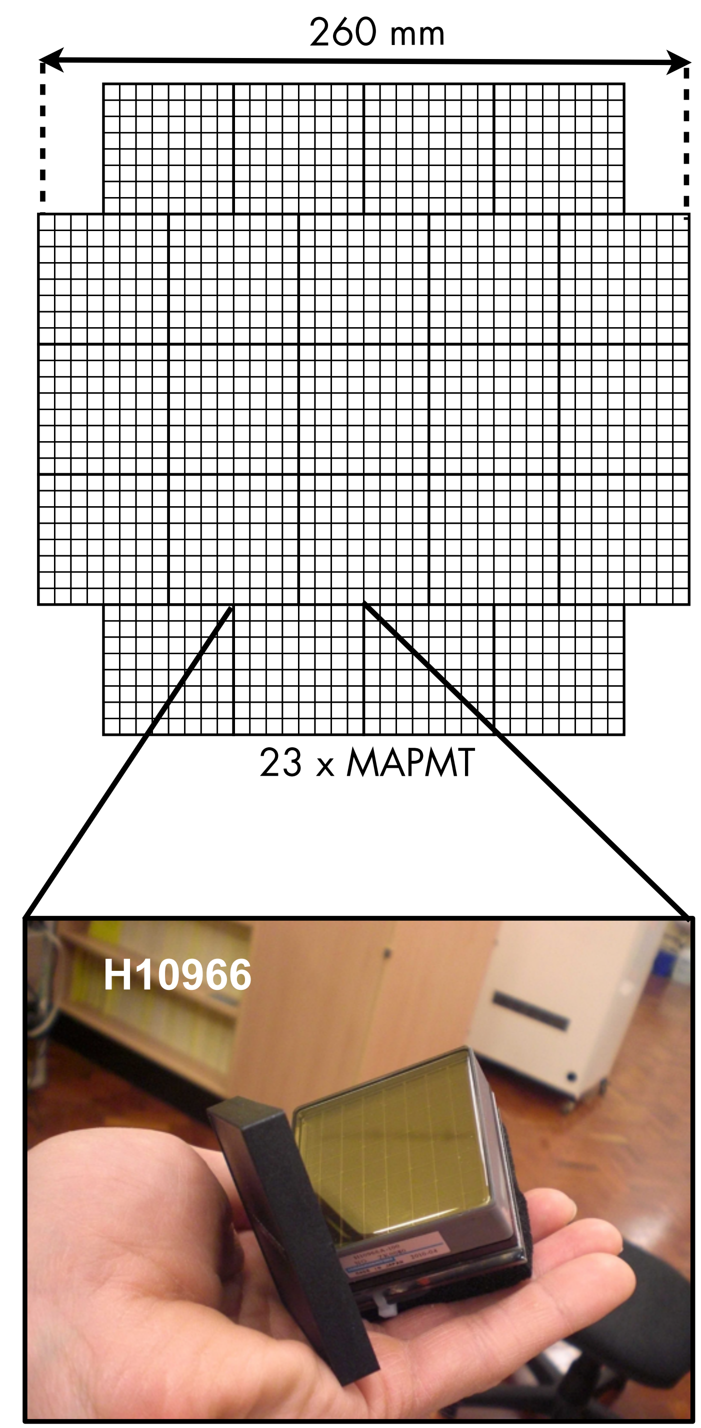


Matthias Kurz (MPI Munich)

Focal Plane Instrumentation

Photosensors

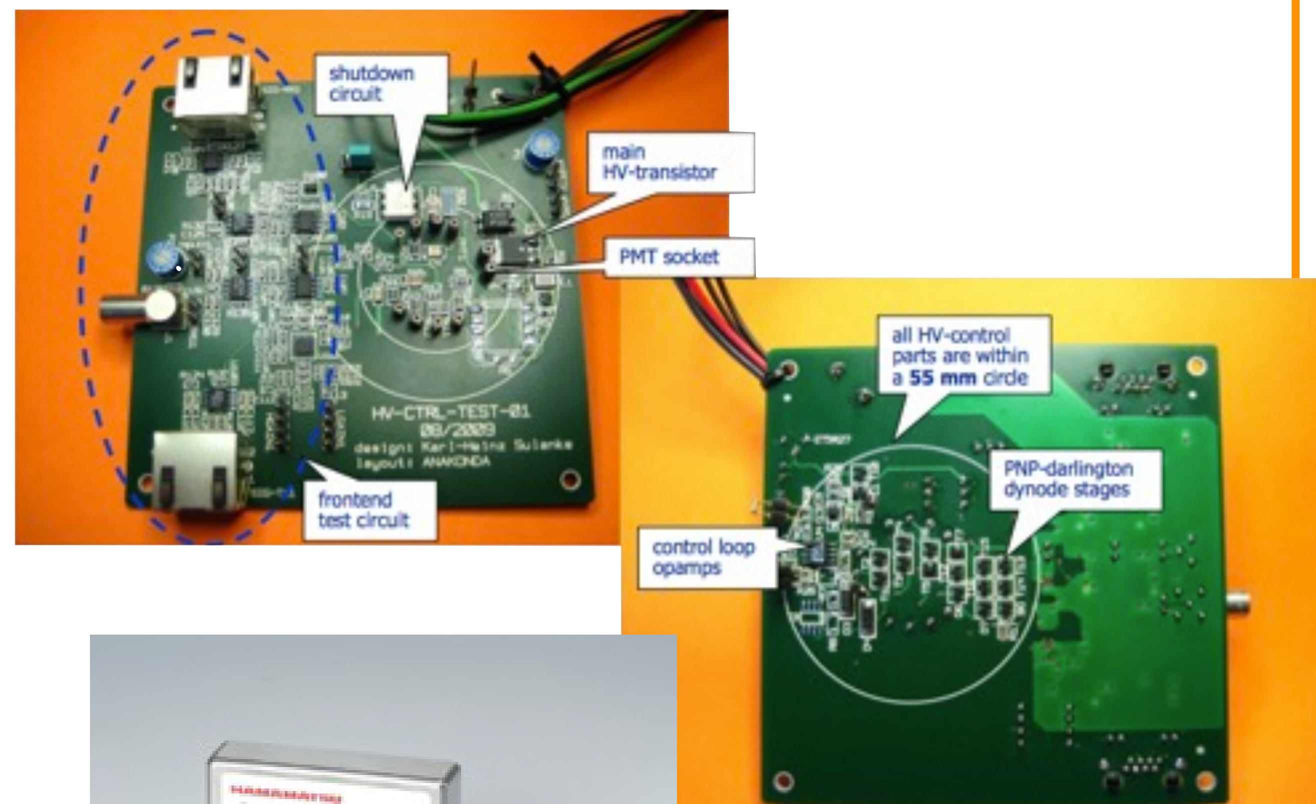
- SST - DC
  - R9420-100, 1.5" + LG => 54 mm == 0.29°
  - 150k per camera
- SST - SO
  - MAPMT
    - H8500, 64 ch, 52 mm, 6x6mm pixels, G=0.5-1.5x10^6
    - H10966, G=1-3.3x10^5 (sBa Photocathode available)
    - 23 E/ch (Ba), 27 E/ch (sBa) (Large Quantities)
    - 0.64 E/mm^2 and 0.75 E/mm^2 (34k, 40k per camera).
    - Performance checks: SPE, after pulsing, uniformity, dynamic range.
    - But how to turn off pixels with stars in them!
  - SiPM (alias G-APD, MPPC, SPM)
    - Scale is small...3 - 5 mm.
    - Development is strong
    - Cost may not be there yet: >5 E/mm^2 (300 k/camera)
    - Can be used in DC + LG option as well as SO



Focal Plane Instrumentation
HV

- Two methods:
  - Central HV, distributed to clusters then controlled to individual pixels.
  - Cockcroft-Walton, local, HV for a cluster.

- Solutions under development:
  - DESY (distributed) (30E/ch)
  - NECTAr + ISEG (Cockroft-Walton, based on HESS) (32E/ch)
  - Hamamatsu (Cockroft-Walton, based on MAGIC)
  - AGIS (Hamamatsu) 100E/ch (64 pixels per ch => 1.6 E/ch)

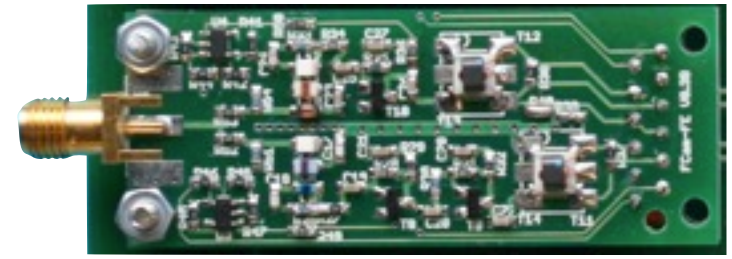


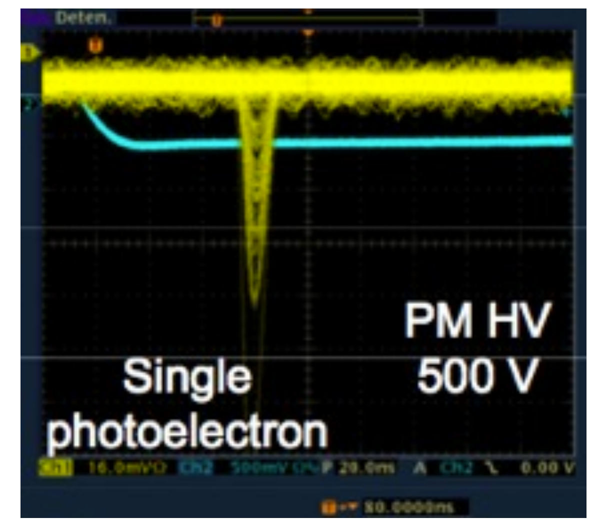
- SST:
  - Had a target of 20E/ch in the conventional design.
  - SO, assuming 64 ch MAPMTs cost is ok.

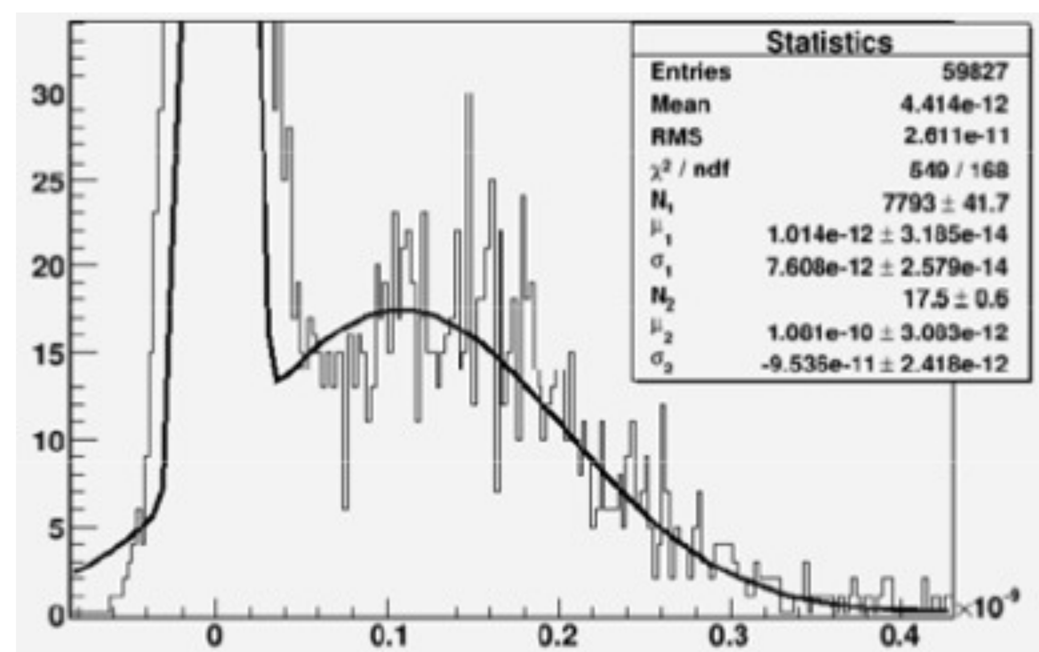
Focal Plane Instrumentation

Preamps

- Dynamic range1 pe - 6000 pe hard to obtain at digitisation stage (FE Elec), so pre-amp:
  - Hi Gain, Lo Gain
  - Non-linear
- Can have preamp at PMT with full dynamic range + FE preamp with shaping and Hi/Lo/non-linear gain or just the FE preamp.
- FlashCam Preamp 125 MHz (U. Zurich)
  - One stage, covers range with 2 amps, 1st - lo gain 1st+2st - hi gain.
  - Prototype with Hi, Lo Gain
  - Cost <10 E/ch
- NECTAr Preamp Scheme 400 MHz (Barcelona)
  - Two stages - one behind PMT (if PMT gain 4e4), one at FE
  - PMT preamp:
    - Atlas LAr preamplifier
      - SPE resolvable
      - But input saturates at 5 mA (1500 pe)
    - ASIC based
      - under investigation.
      - Noise level is easier to achieve on an ASIC (interesting for SiPMs)
  - FE preamp:
    - Commercial.... speed may not be achievable.
    - ASIC based... just include in the NECTAr chip.
- Dragon Preamp:
  - Lo x 1 and Hi x 10 Gain
  - 2.3 GHz Op Amp







Focal Plane Instrumentation

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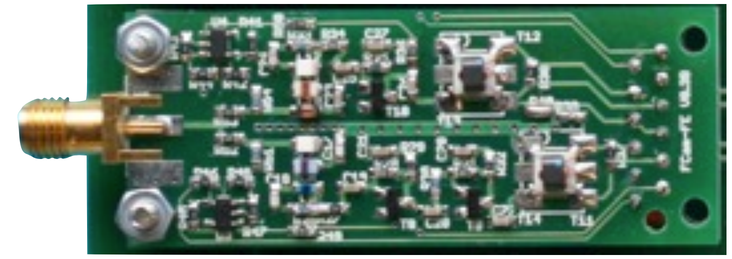

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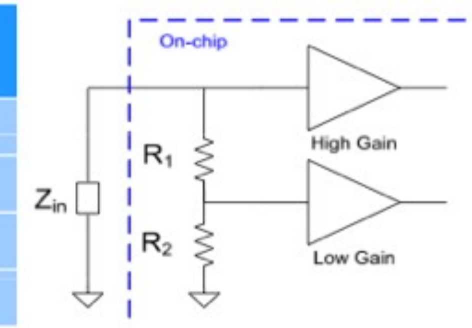
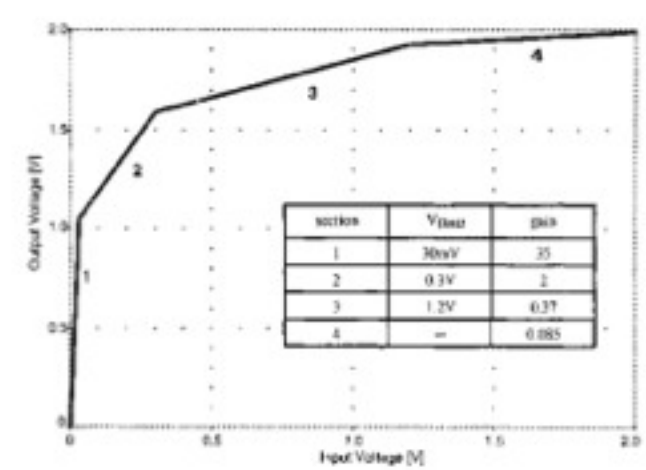
Range	High Gain	Low Gain
Phe	200	6K
In [mA]	2	~50
In [V]	0.1	~ 2.5
Out [V]	~ 2	~ 2

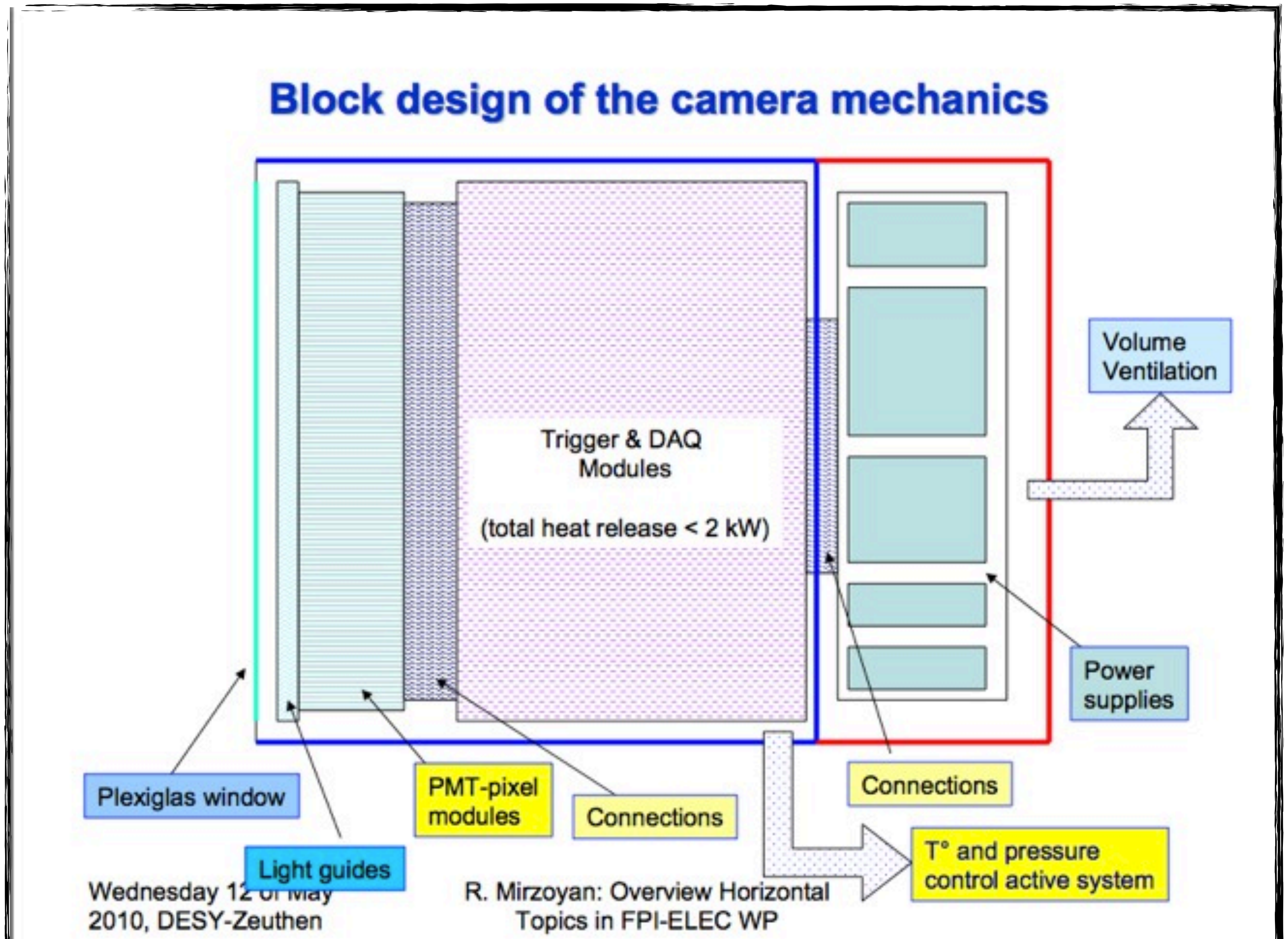




Focal Plane Instrumentation

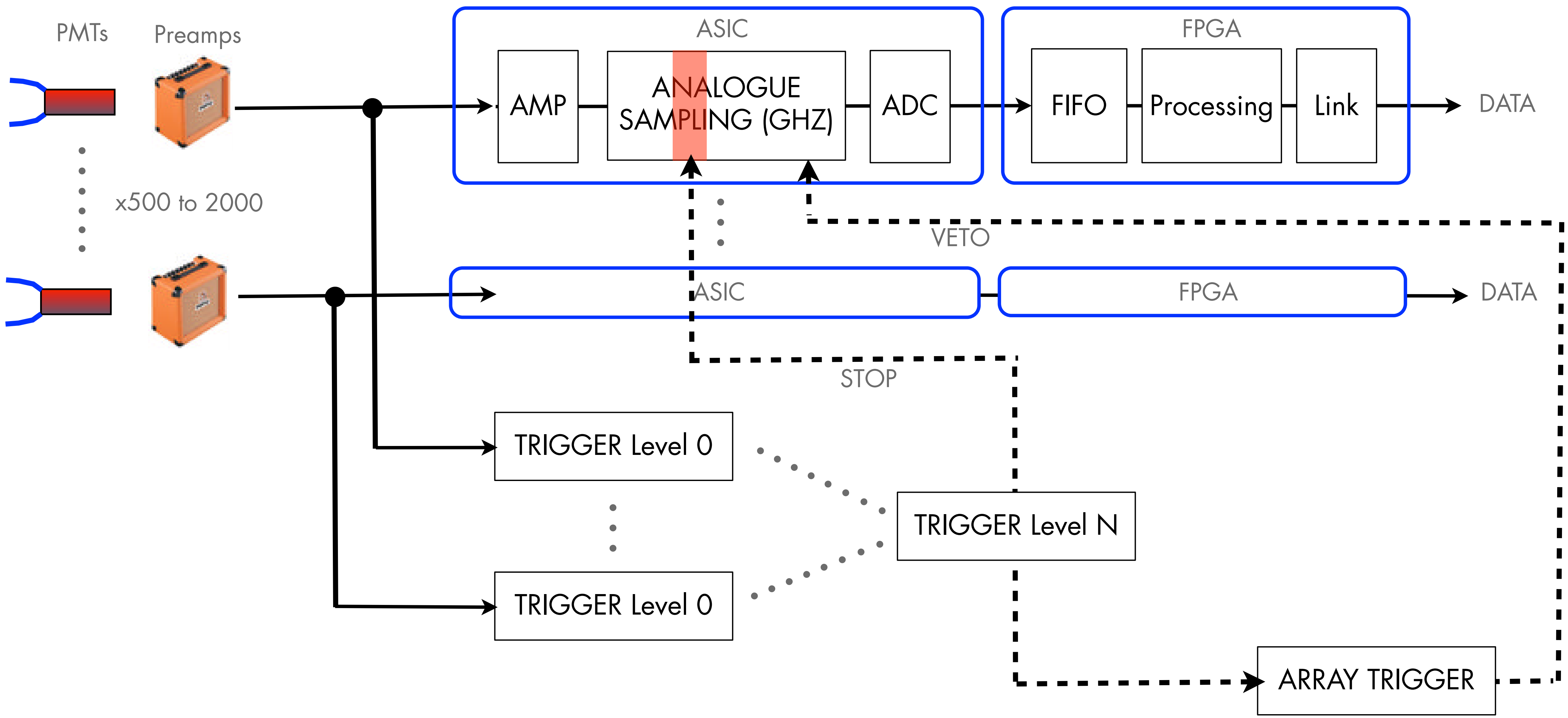
Camera Integration

- No thoughts yet for the SST?



Front-End Electronics

Analogue Pipeline



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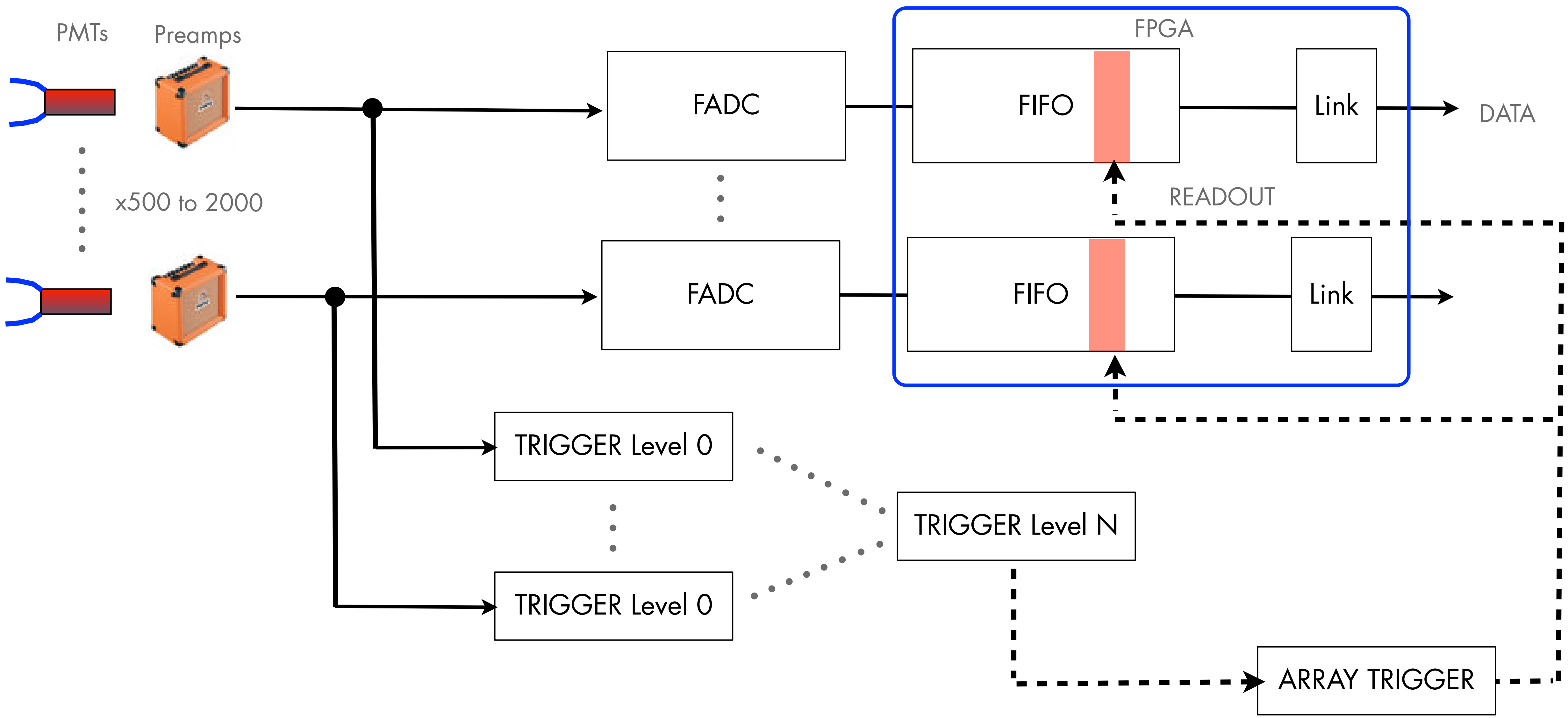
NECTAr

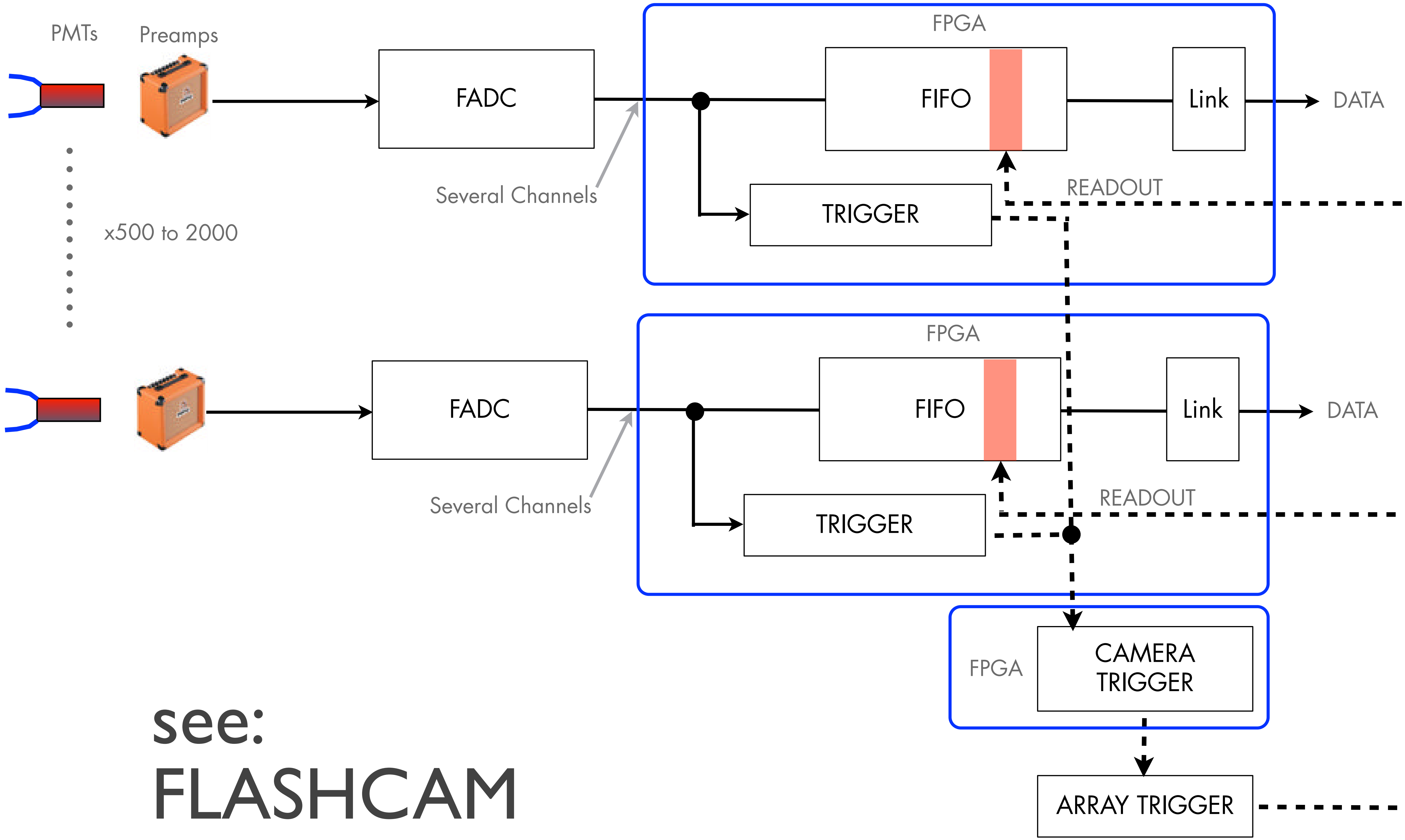
DRAGON (DRS4)

AGIS (TARGET)

Front-End Electronics
FADC



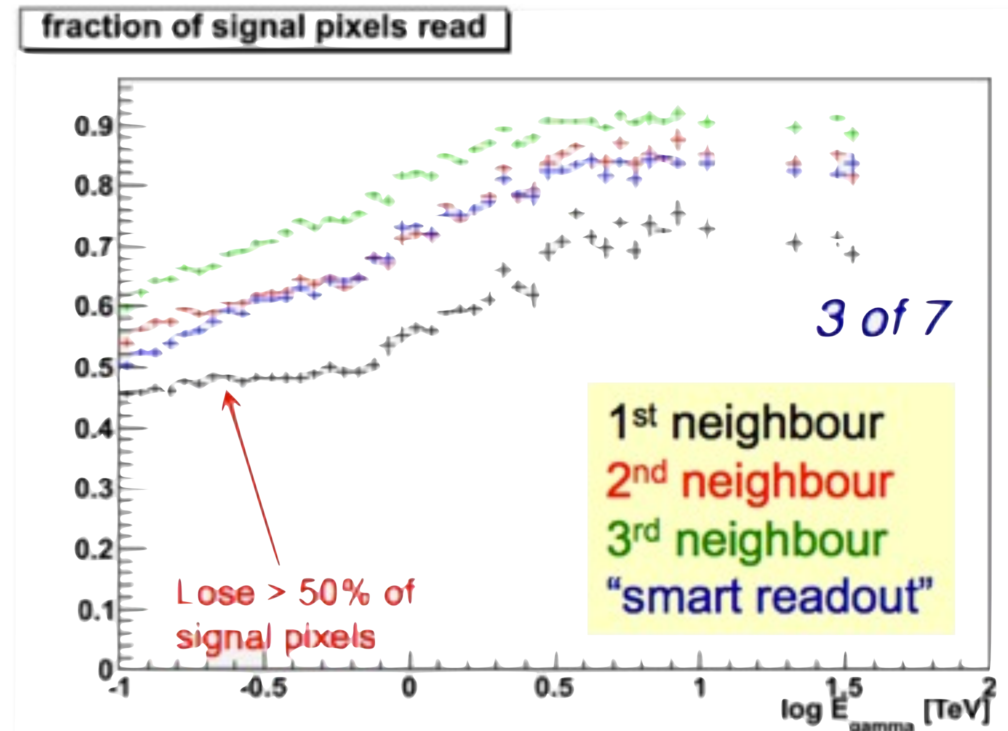
Front-End Electronics
FADC



see:
FLASHCAM

Electronics
Telescope Trigger

- Schemes:
  - Majority of neighbours above threshold
  - Clipped Sum
  - Many more.
- Implementation:
  - Analogue
    - Sum signals from pixels
  - Digital
    - Threshold then digital lookup in FPGA (13 E/ch)
    - Use FADC samples and sum - pure digital (free)



Christopher Lindsay Naumann

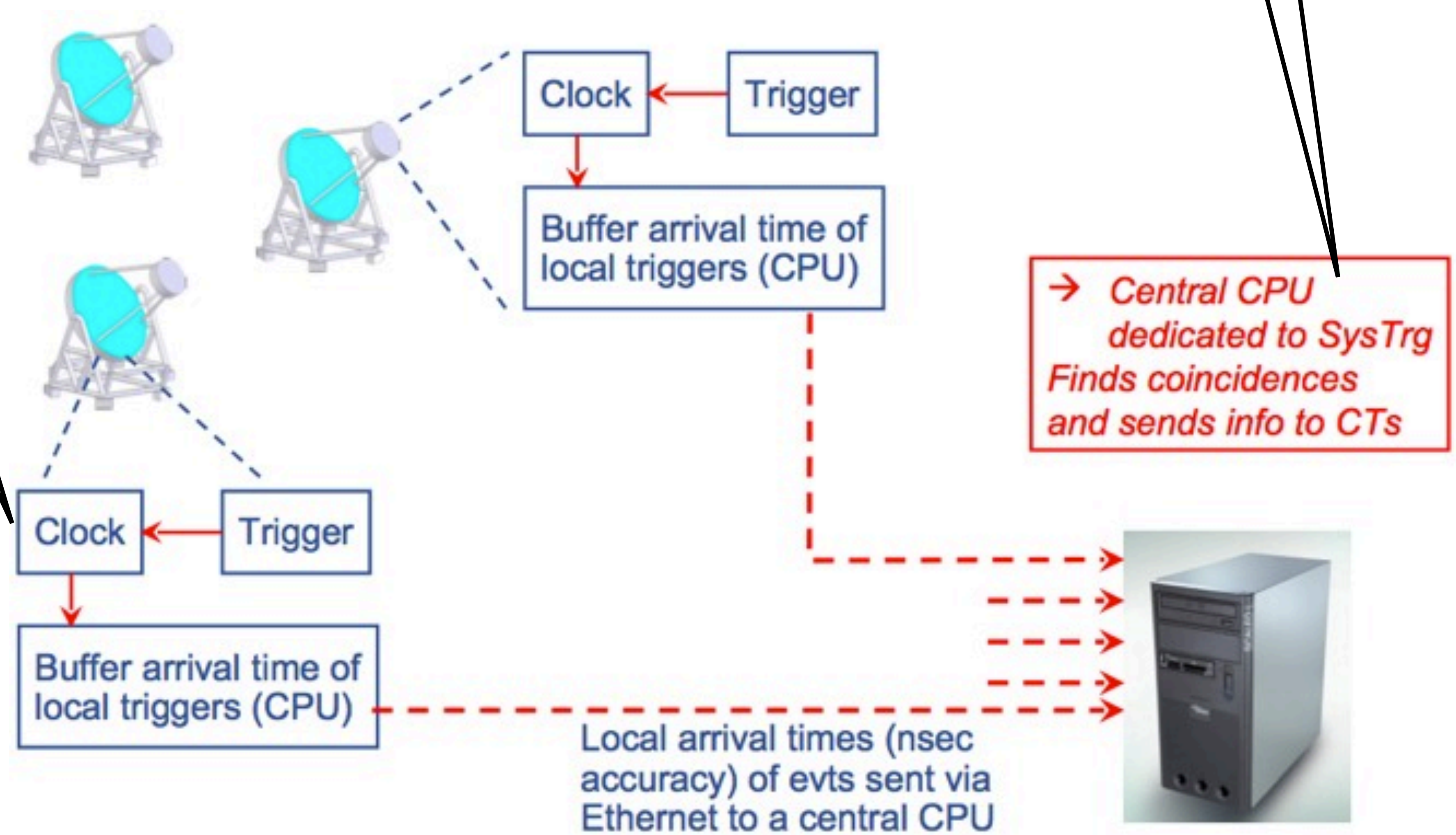
- SST:
  - SO and conventional trigger ideology can be the same.
  - Clustering of physical pixels will look different and implementation will depend on FE
  - Remember that SST events can be long... 200 ns
  - So a trigger system that allows clusters to be read out asynchronously (say within a long event) would be beneficial (each cluster would be centred on a different time within the image) - saves reading out 200 ns of data from the whole camera.
  - This is easy to implement with a dead-time free FE.... ie you don't have to, just readout the whole camera, then another part of the same image triggers the camera again.

Electronics
Central Trigger

- Hard
- Soft
- Soft with hard timing

APC working on this... 60-80 ms to analyse 1 s of triggers from 100 telescopes

Send 10 MHz global clock, with 1 GHz local counter. Possibly PXI over fibre. <1 E/ch



C.Bauer, C.Föhr, G. Hermann, W. Hofmann , T.Kihm, F.Köck- MPI für Kernphysik

Electronics
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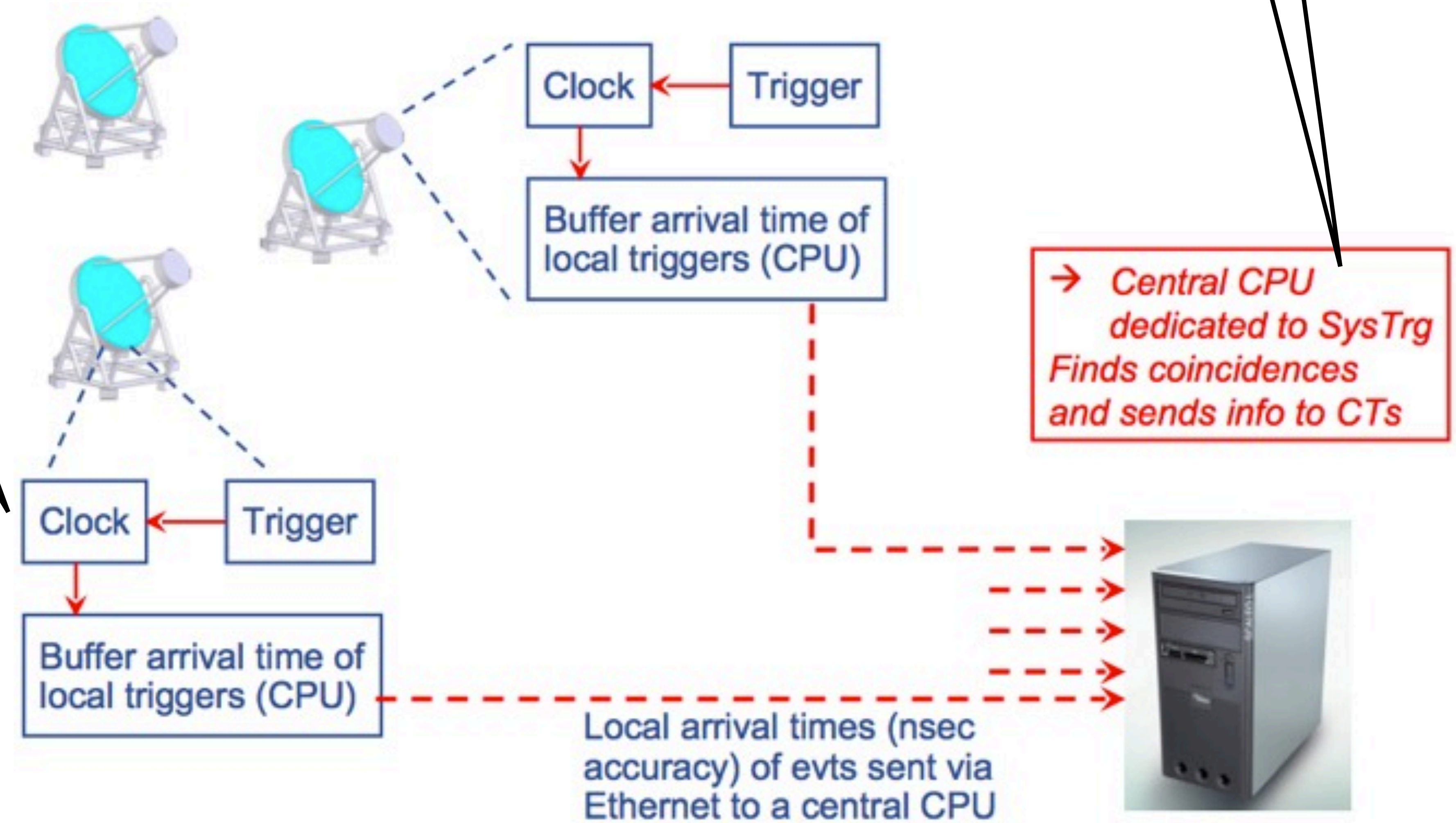
- For SST

APC working on this... 60-80 ms to analyse 1 s of triggers from 100 telescopes

Send 10 MHz global clock, with 1 GHz local counter. Possibly PXI over fibre. <1 E/ch
Do we need 1 ns for SST?



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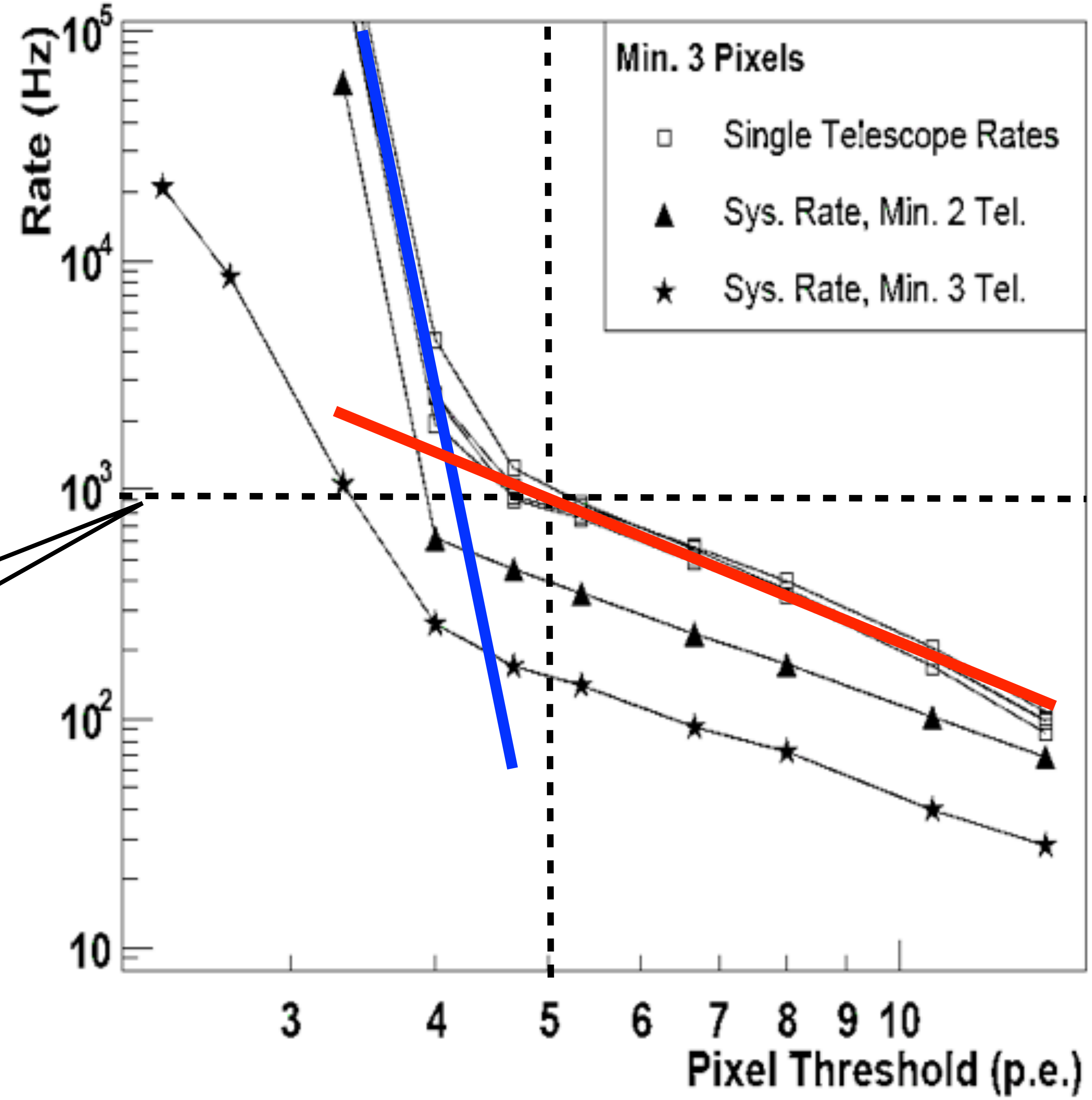
Electronics
Central Trigger

- Hard
- Soft
- Soft with hard timing
- For SST - Nothing?
  - At some SST size the camera rate is low enough to send all the data to one location...

For 5° MST, rate above 100 GeV is 1 kHz

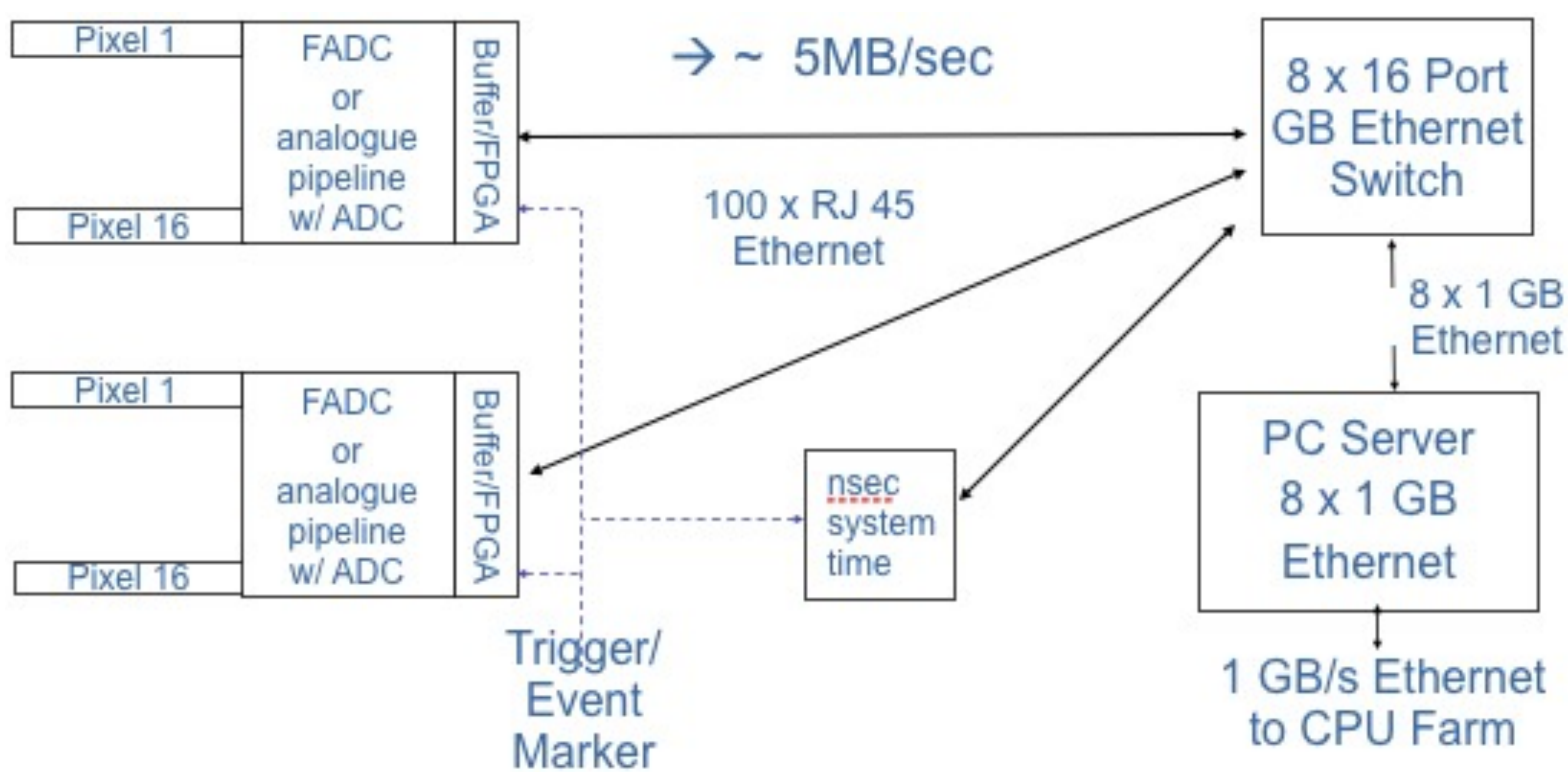
For 9° SST, rate above 1 TeV is 60 Hz



Electronics
DAQ

- Ethernet Based:
  - Implement in FPGAs at FE
  - Cascading switches
  - 1 x GB Ethernet from camera.

30 Byte / pixel / evt (20 nsec @ ~ 800 MHz x 2 gain)
2000 channels
10 kHz camera triggers
To Camera CPU 600 MByte/sec
To Central CPU 10 MByte/sec



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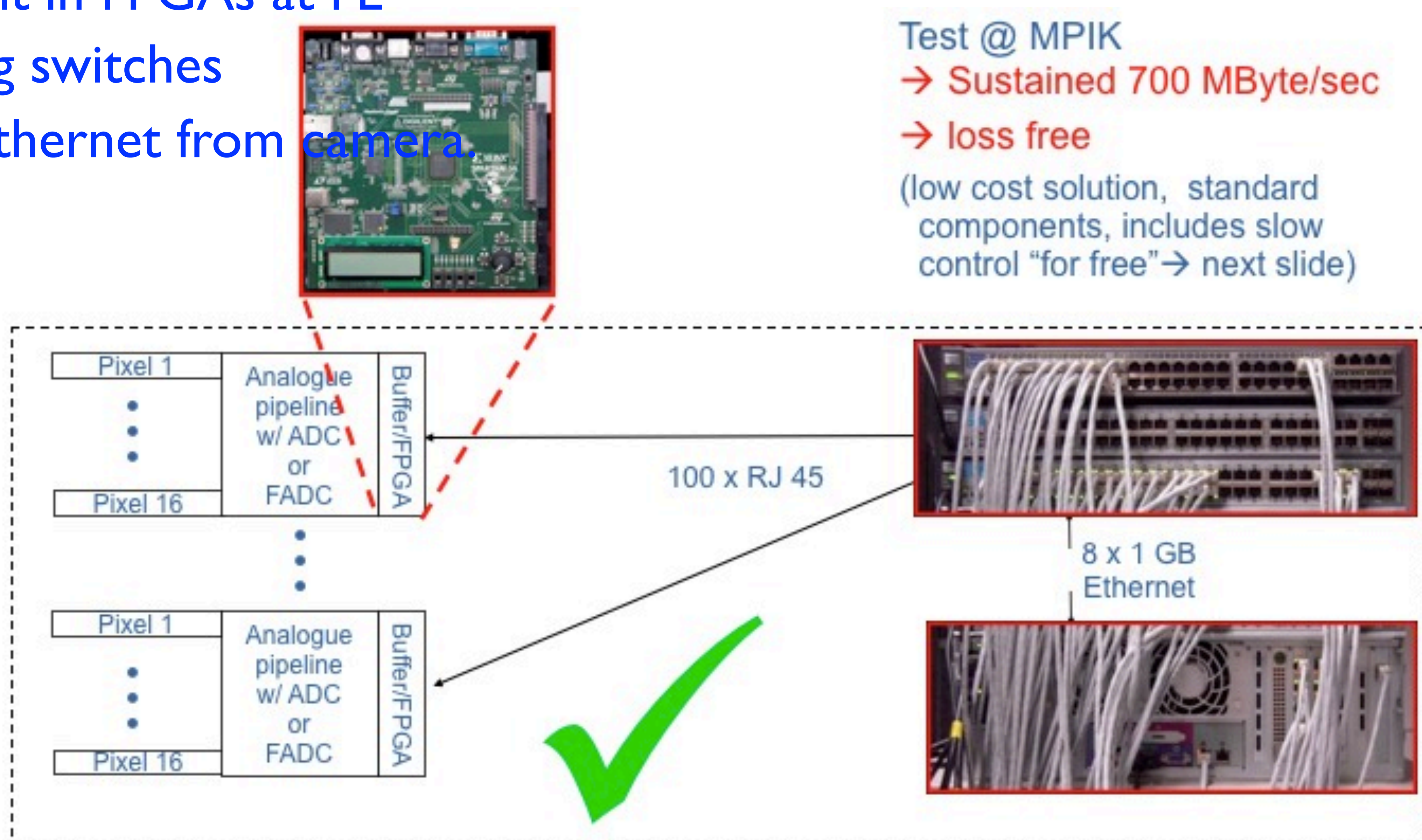

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Summary

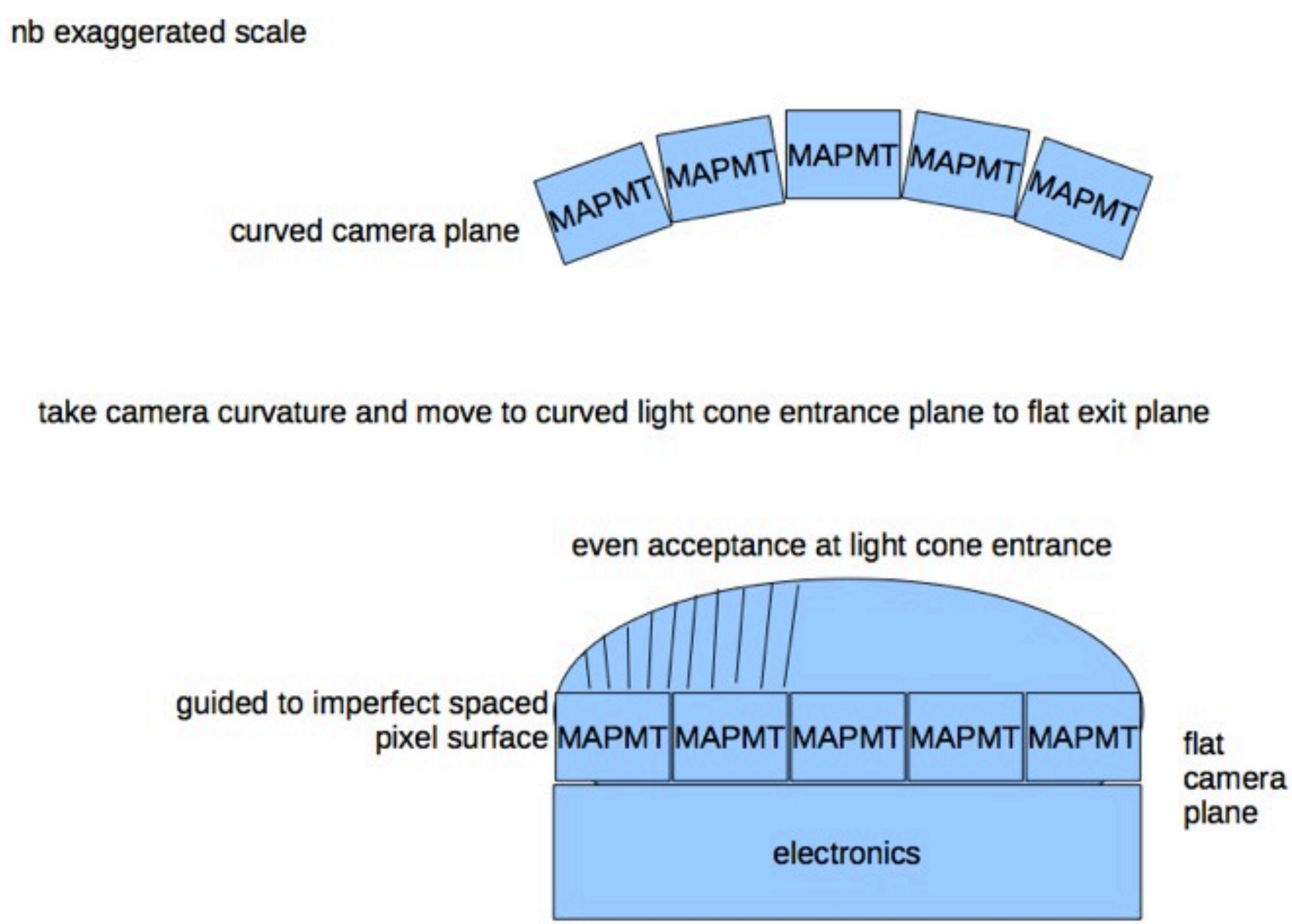
LIGHT GUIDES	MPI Munich	Zurich	Marseille	
PHOTOSENSORS	PMTS: Hamamatsu	PMTS: ETL	OTHER: MAPMTs	OTHER: SiPMs
HV	Hamamatsu	ISEG	DESY	
PREAMPS	NECTAR	DRAGON	AGIS	FLASHCAM
FRONT END	NECTAR (CEA/LPNHE/ LPTA/ICC-UB)	DRAGON (Pisa)	AGIS (TARGET) (SLAC)	FLASHCAM (MPIK, AIT, ETH, U. Zurich, AGH Krakow, Leeds)
TELESCOPE TRIGGER	ANALOGUE: L0 (IFAE)	ANALOGUE: L1 (Madrid/CIEMAT)	DIGITAL (DESY)	DIGITAL
CENTRAL TRIGGER / CLOCK DISTRIBUTION	APC	MPIK	Iowa State	
DAQ	Ethernet (MPIK)			

Summary

- We know what's under investigation
- What's been ruled out:
  - Very fast FADC - too expensive, too power hungry
  - Non-integrated cameras for the MST and LST
  - Analogue transmission over fibre
- What's not been ruled out... but maybe should be for the SST:
  - Sealed cameras with environmental control.
  - Lots of control and monitoring.
- What's not currently being focussed on by FPI/ELEC:
  - Links with MC... ie the specification motivation.
  - The SST

Pub-based ideas

Sub title



Michael Daniel