Front-End Hybrids
for the
CMS Silicon Tracker

- Technology Choices and a some History
- New Developments in Rigid-Flex and Full-Flex Technology
- Next Steps and
- Preparation of Industrial Production and Testing (FHIT)
- Conclusions

Laboratories:

IReS & LEPSI, Strasbourg
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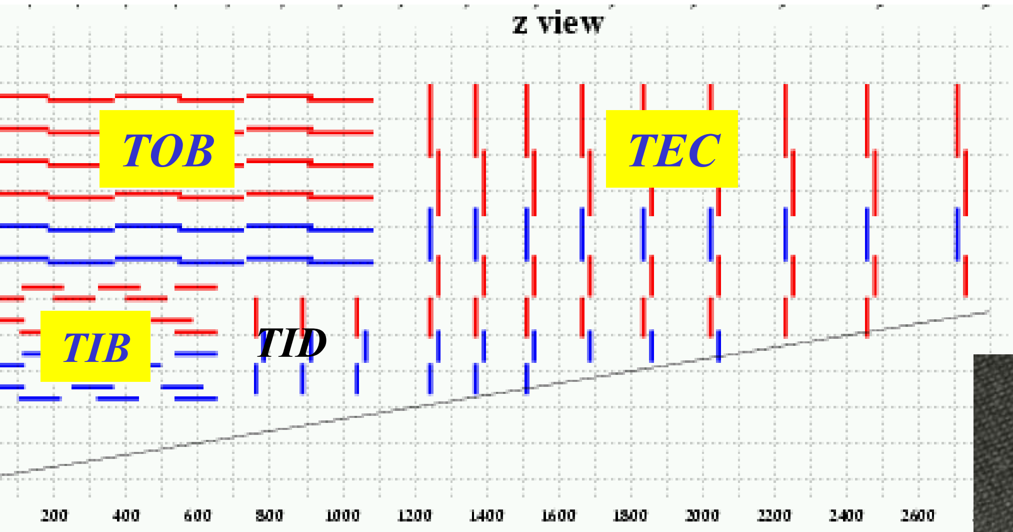
Contributing

Aachen I, Bari, CE
IC-London, Karlsru
Pisa, Vienna

Technology Choice
and
some History

- Start in 2000
  - Option for fully industrial production
  - Technology choice without validated proto-types: thick film on ceramic
- 2000-2001/2
  - Prototyping in this technology ca. 180 FE-hybrids (CERN, Dorazil, Mipot)
  - Many design changes to adapt to detector-module integration
  - Development of an automatic test-station (FHIT) for industrial production
  - Identification of industrial partners
- 2001
  - ASIC change: MUX, PLL, DCU -> packaged chips (LPCC)
  - New technology options (FR4 and/or kapton, Flex-Rigid, Full-Flex)
- 2002
  - Electrical system tests
  - Revision of initial technology choice, but no final choice (no valid prototypes)
  - Start of industrial production planned

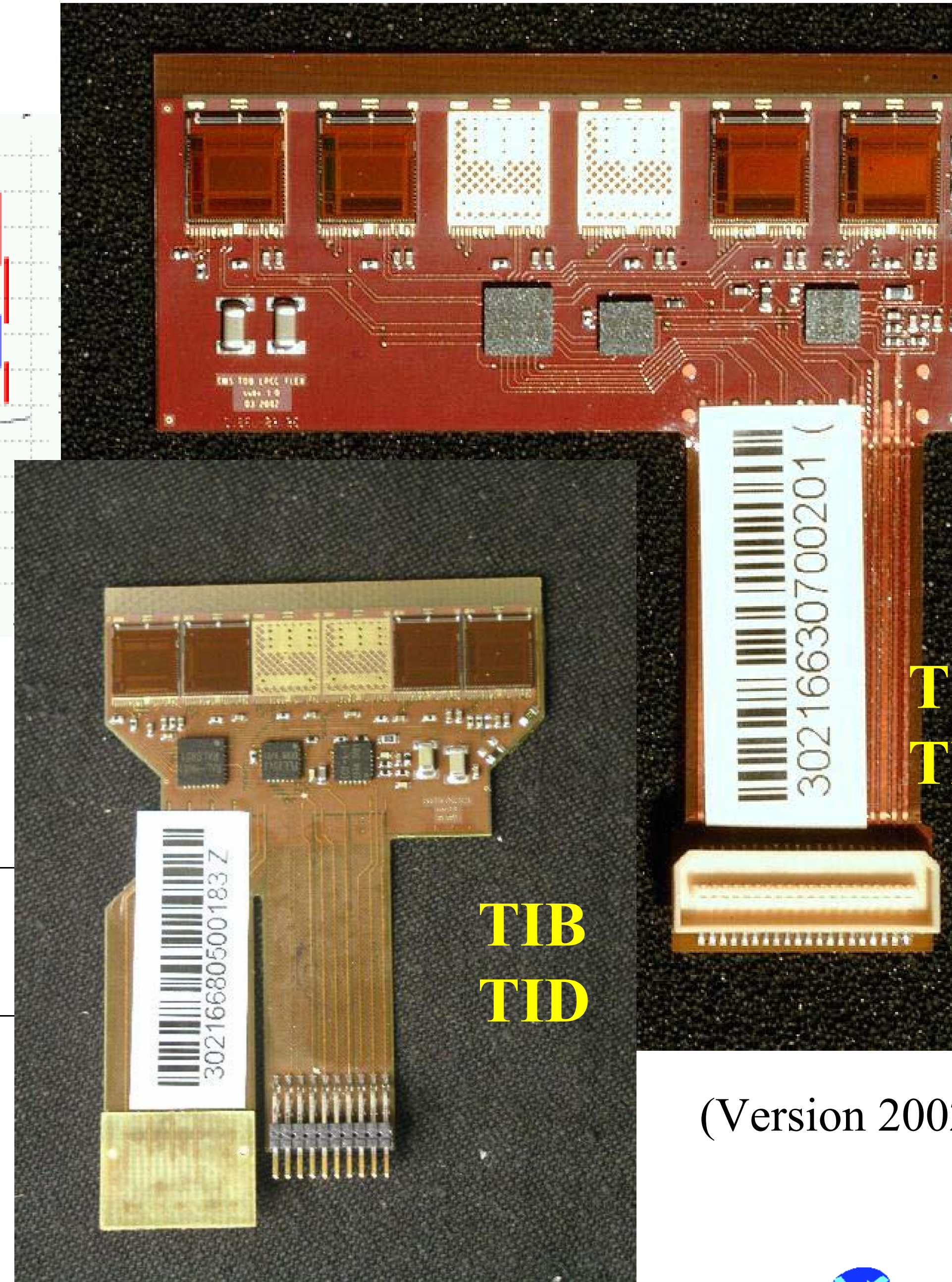
Modularity and Geometries



FE-hybrid types

	TIB/TID		TOB		TEC	
	R-Φ	stereo	R-Φ	stereo	R-Φ	stereo
PV	1056	1056	1680	-	1152	1152
PV	1428	-	2448	1080	4096	-
al	**2484**	**1056**	**4128**	**1080**	**5248**	**1152**
	3540		**5108**		**6400**	
al			**15048**			

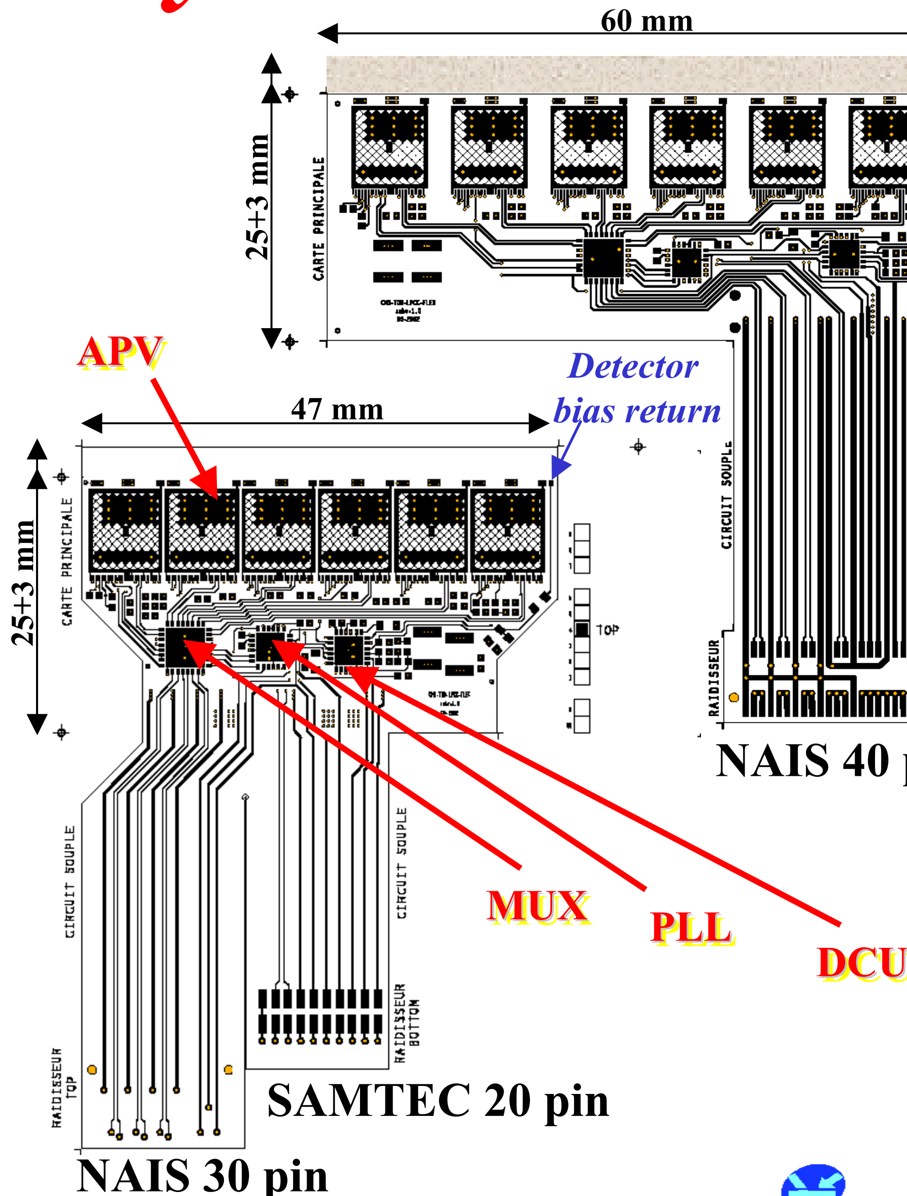
⇒ Need industrial production!



(Version 200

Definition of FE Hybrid (I)

- **Electrical functionality (2002):**
  - Analogue read-out chips
    4 or 6 APV25
  - Power lines, grounding, decoupling
  - Auxiliary chips: MUX, PLL and DCU
  - Measurements (with DCU-chip) of :
    - Supply voltages and currents,
    - Temperatures on hybrid and detector (with internal and external thermistors)
    - Detector bias return current
    - No HV on hybrid
  - Open issues (see JD.Berst):
    - I2C termination
    - Detector return bias resistors
    - Voltage divider for DCU
    - Decoupling capacitors



Definition of FE Hybrid

Iulti-layer board

- Mechanical parameters
  - Two geometries
  - Heat transport to frame (◉ 3 Watt)
  - Support of pitch-adapter
  - Thickness limitations, less than one mm without components
  - No connector on the hybrid
  - Rigid and flat within 100 μm
  - Operation at -10° to -20 °C
  - Radiation hardness
- Electrical parameters (2002)
  - 4 metal layers
  - Via: Ø 100/300 μm
  - Line width: 120 μm
  - Separations (line/via): 180/90 μm
  - Bias line resistance: 20-50 mΩ

Kapton cable

- 1 or 2 connectors (NAIS and SAMTE
- Bending radius of 1-1.5 mm (180° tur

SMD components

- Minimal height
- R and C of type 0402 and 0603
- LPCC (since 2002): MUX, PLL, DCU

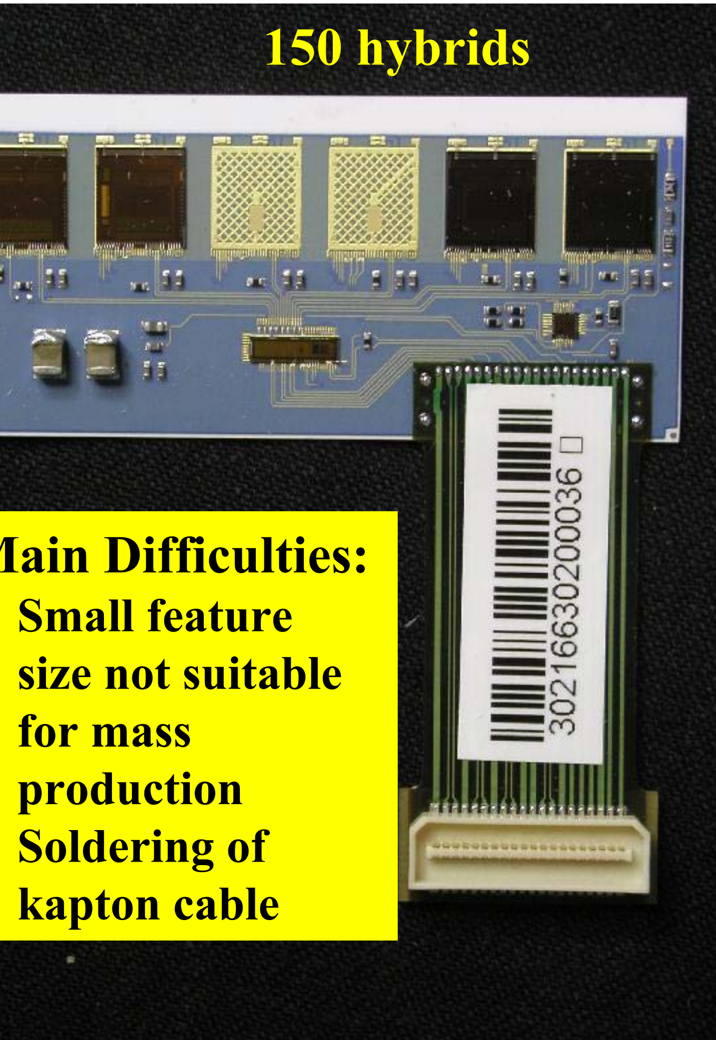
Naked die ASICs to bond

- 4 or 6 APVs, alignment ± 30 μm
- (MUX-PLL)
- (DCU)
- Glob-top cover for bonds?

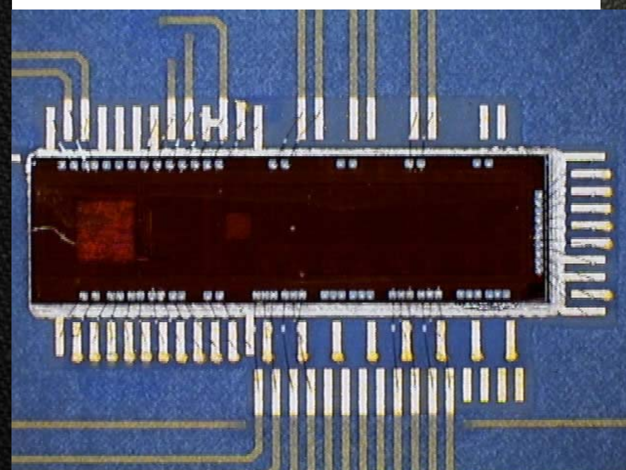
(Radiation hardness ?)

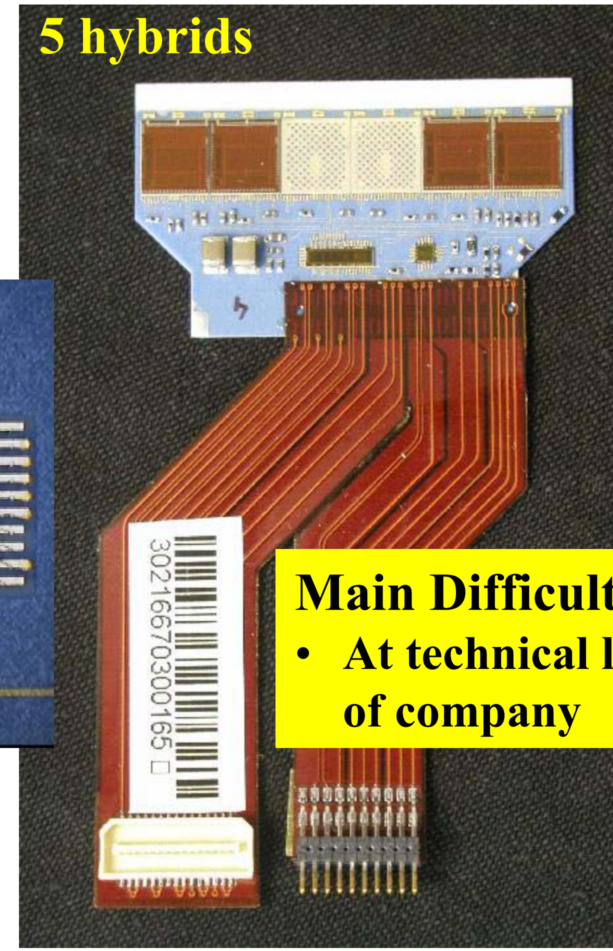
Dorazil and MIPOT Ceramic Hybrids

After a market survey (MS2991) only two companies agreed to produce hybrids for CMS Tracker M200 Milestone at reasonable price



- Yield about 80%
- 103 at CERN
- ca. 20 at IReS





Summary on Ceramic Hybrids

n total about 180 ceramic hybrids were produced

- Yield about 80% (we did not repair everything)
- About half will be used for prototype Si-detector modules until December
  - Assembly procedure
  - Performance in test beam
- Different electronic and electrical and mechanical system tests for the configuratio TIB TOB and TEC.
- Temperature cycles
- Irradiation tests

eneral concept of FE-hybrid validated

everal changes requested (⇒ re-design of layout)

e-design with larger feature size necessary

ossible with new encapsulated control chips in 0.5mm pitch housings

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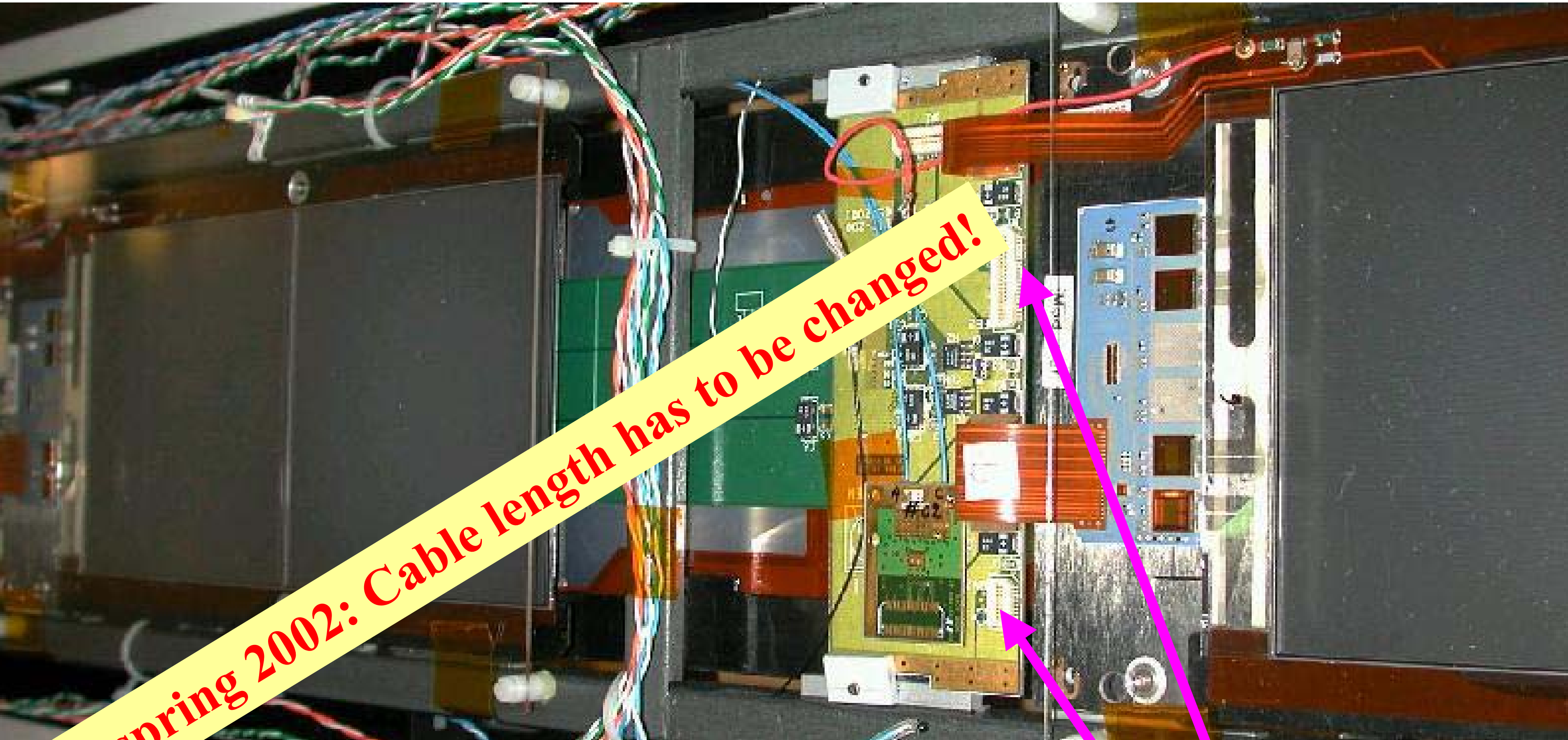
ow other potentially significant cheaper technologies available

New R&D and industry survey necessary at very late stage of proj

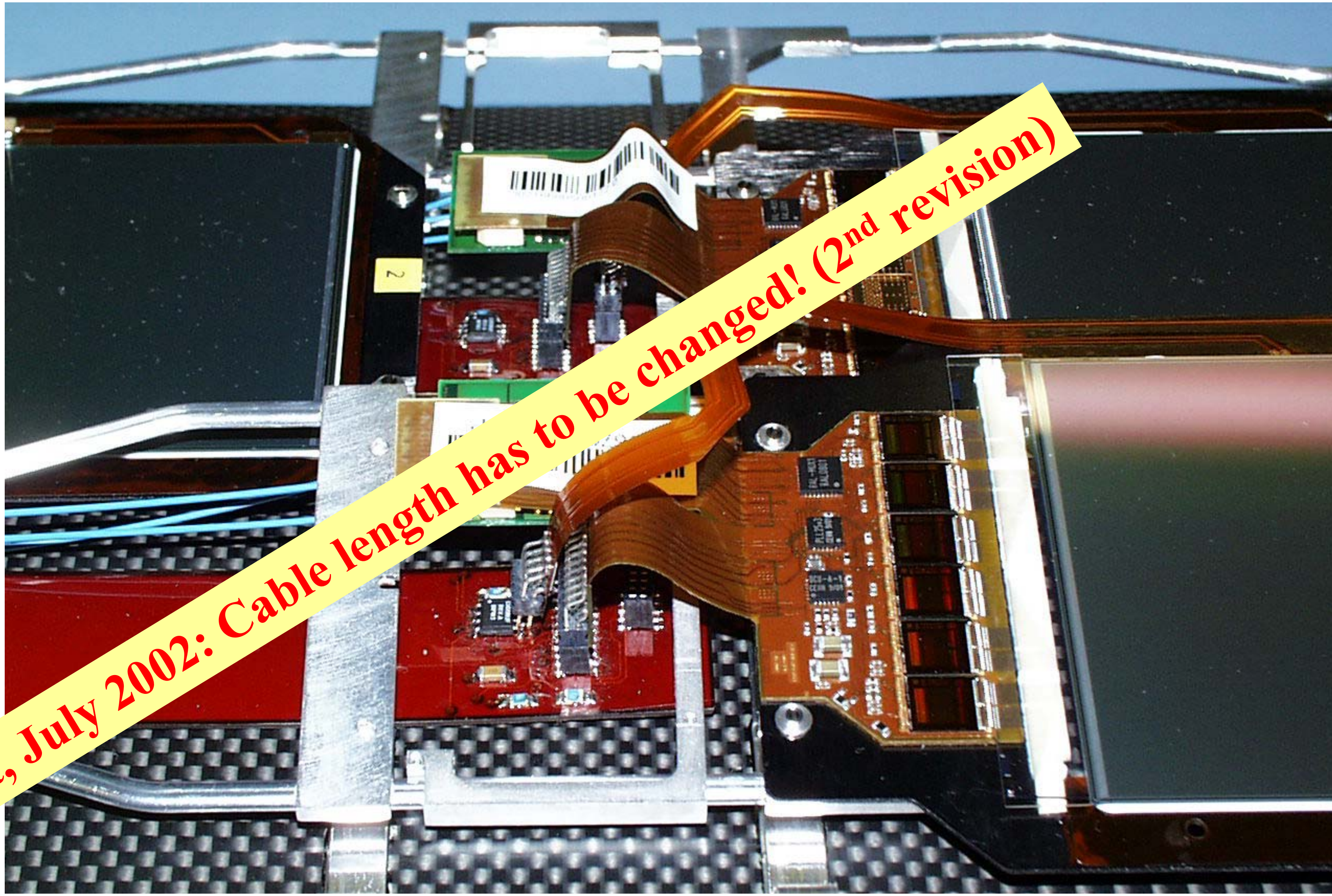
Loaded TOB Rod with Si-Detector Modules



esult, spring 2002: Cable length has to be changed!

Used for double sided modu

TIB Shell loaded with Si-Detector Modules



esult, July 2002: Cable length has to be changed! (2nd revision)

Technology choices

Thermo-mechanical properties

- Heat (max. 3 Watt) has to be transported to detector frame
- CTE compatibility with module frame material:
  - Hybrid will be glued on frame (carbon fibre or graphite)
  - Deformation
  - Lift-off
- Many simulations and tests to validate concept and substrate-material

Suitable for automatic mounting on Gantry

- Flatness
- Rigidity

Integration of cable and connector(s) ?

Material	CTE ppm/°C	Thermal Conductivity (W/mK)	Xo (m
Al2O3	7.0	24.0	75.
FR4/G10	12-16	0.2-0.3	19
Carbon Fibre	< 1.0	200-400 ‖ 1 ⊥	25
Graphite E779	7.4	65.	18
Polyimide	45.0	0.2	28
Cu	17.0	390.0	14.
Au	14.0	318.0	3.3

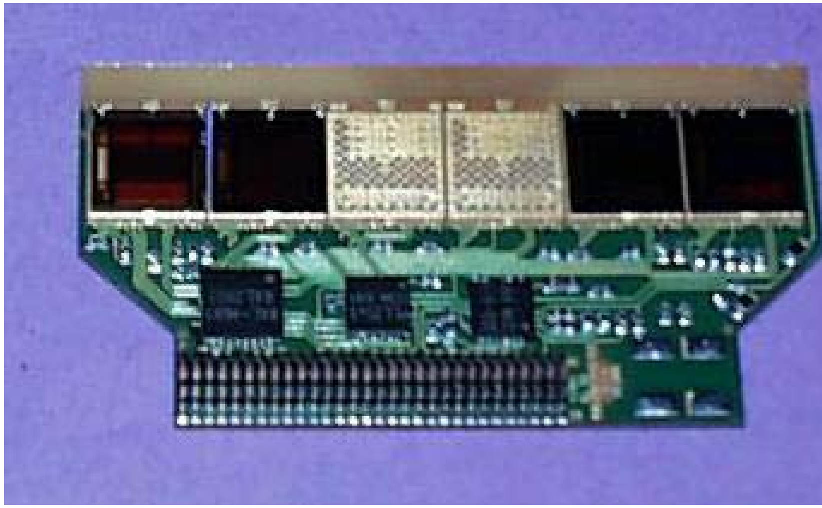
New Technological Choices

Prototyping I
Dec 2001-Jan 2002

- **With new LPCC Control and Service ASICS**
  - **MUX, PLL, DCU**
- **Multi-layer board in "advanced" FR4 printed circuit board technology**
- **Could be very cheap in large quantities**
- **First circuits in January 2002**
- **Boards are correct**
- **Great difficulties to solder cable**

⇒ Only a few working proto-types

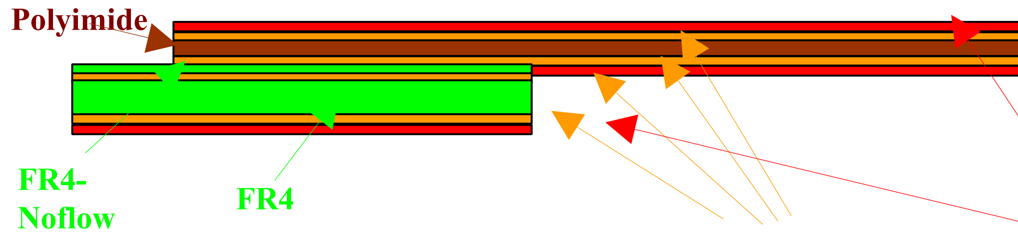
- **Next step was cable integration:**
  - **Go to Rigid-Flex hybrid**



FR4 board with connector

New Technological Choices

Prototyping II



Rigid(FR4) Hybrid:

Different companies with different technologies and quality

(CIBEL, GS-Precision)

- 2 bottom layers on rigid FR4
- 2 upper layers on polyimide

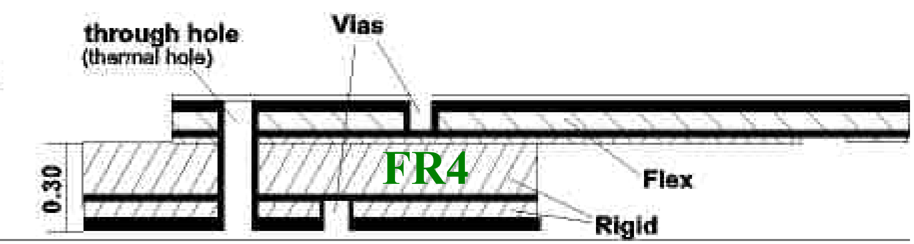
Tolerances in thickness up to 100 micron

Non-Flatness in the order of 100 micron before SMD montage, and we have seen more

Extend FR4 part under PA

FR4 thickness is limited by diameter/length ratio for blind via

Also GS Precision proposes new structure:



New Technological Choices (Full-Flex)

Prototyping III

ex-Flex (all Kapton) laminated on

Carbon-fibre substrate

FR4-substrate with thermal heat conducts

Mechanical properties to be explored

- Final rigidity?
- Final flatness < 100 µm?

oto-types available from CICOREL

30 TOB

- 12 laminated on FR4 with thermal via
- 20 laminated on CF

CICOREL

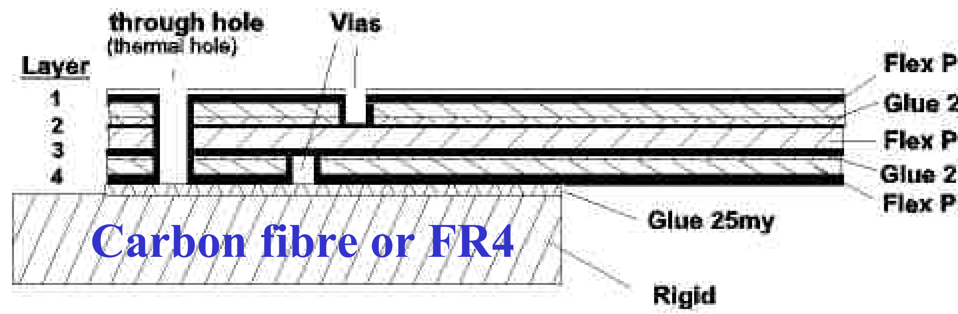
Layer	Thickness	Layer	Thick
Hybrid		Cable	
Vernis	20	Coverlay 25+25	
Cu 18+12	30	Cu 18+12	
PI	25	PI	
Cu	18	Cu	
Glue	25	Coverlay 25+25	
Cu	18		
PI	25		
Cu 18+12	30		
Coverlay 25+25	50		
Total	**241**		

CICOREL

New Technological Choices (Full-Flex)

Prototyping IV

GS Precision



x-Flex (all Kapton) laminated on

Carbon-fibre substrate

FR4-substrate with thermal heat conducts

proposal:

Have to keep 4-layer structure up to connector, cable thickness?

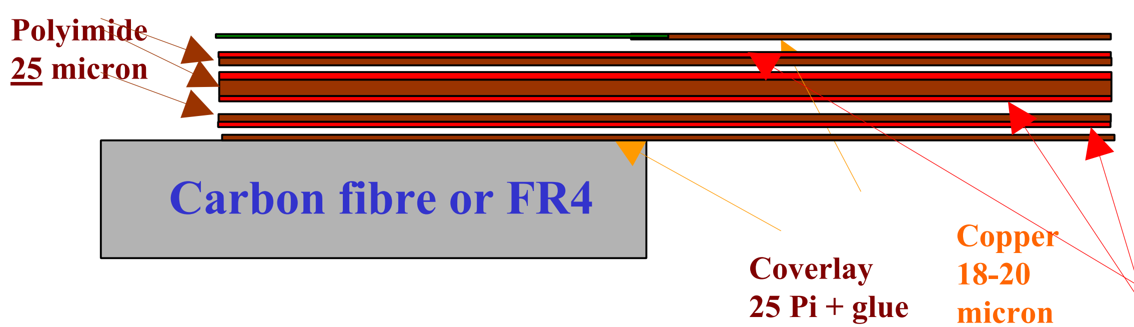
CONEX(?):

Different process,

Cable should use layers 2 and 3

Re-design of layout!(?)

DYCONEX



New Technological Choices Conclusions-Proposal!

I. **Pure FR4, not followed any further**

II. **Flex-Rigid in new structure of GS-Precision:**

- **Heat-transfer integrated into design, no further carrier**
- **Need valid prototypes to evaluate flatness and rigidity** **Nov02**
- **Order the 50 TIB hybrids in final geometry**
- **Evaluate assembled (by Hopp) hybrids** **Dec02**

III. **Full-Flex:**

- **Compare FR4 and CF carriers**
- **Load with components and evaluate** **Nov02**
- **Order larger quantity at Cicorel** **Dec02**

IV. **Dyconex:**

- **Change layout, if interesting price estimate** **Oct02**

V. **Prototypes are needed to qualify assembly companies!!!**

Industrial Production of FE-Hybrids

- **Large quantities (more than 15000) can only be produced reliably in industry**
- **Numbers will help to achieve uniformity throughout production**
- **Industry will also be charged with the final acceptance test before delivery**
- **Preferably only one manufacturer or consortium, delivering final product**
- **Technical specifications have to be well defined before tendering**
  - **Careful evaluation and system tests mandatory!**
- **Qualification of manufacturer by proto-type runs**
- **Quality assurance during production:**
  - **In depth test/characterisation of random samples**
  - **Some temperature or other cycles in industry before final acceptance test**
  - **Rely on industrial standard during mass production**
- **Duration of production will be about one year**

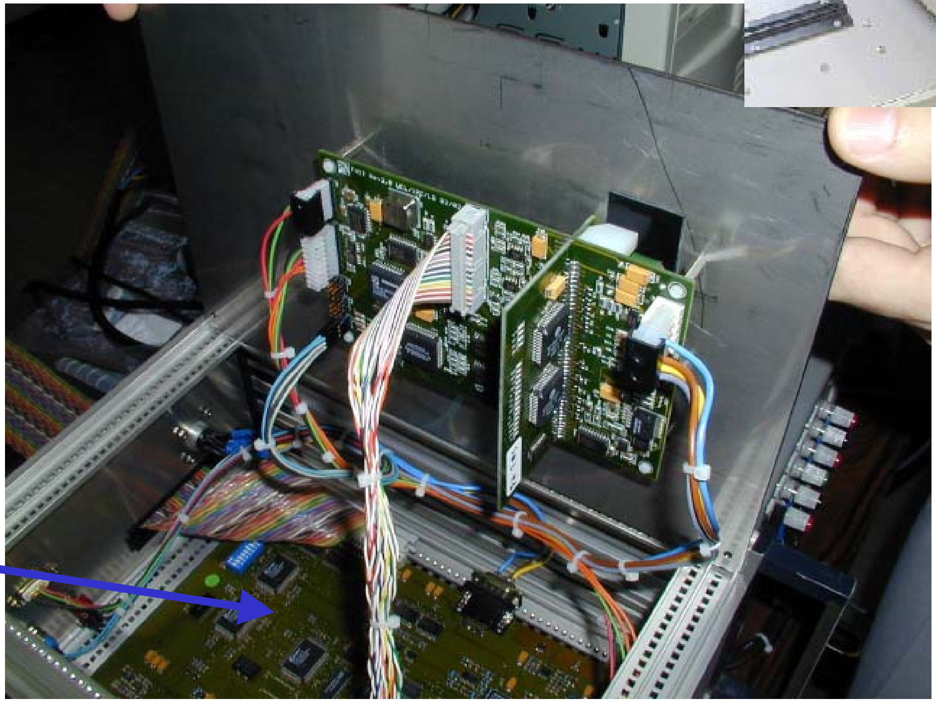
Front-End Hybrid Industrial Tester (I)

sk: **Simple acceptance test of hybrid in factory**

mponents:

Mechanical structure
Transition board (FEHC)
FHIT: electronic circuit including switching matrices
Active component, a connection to ARC and fast Controllers
ARC Read-out system
Power supplies
PC
Barcode reader
Software

ARC board



Front-End Hybrid Industrial Tester (II)

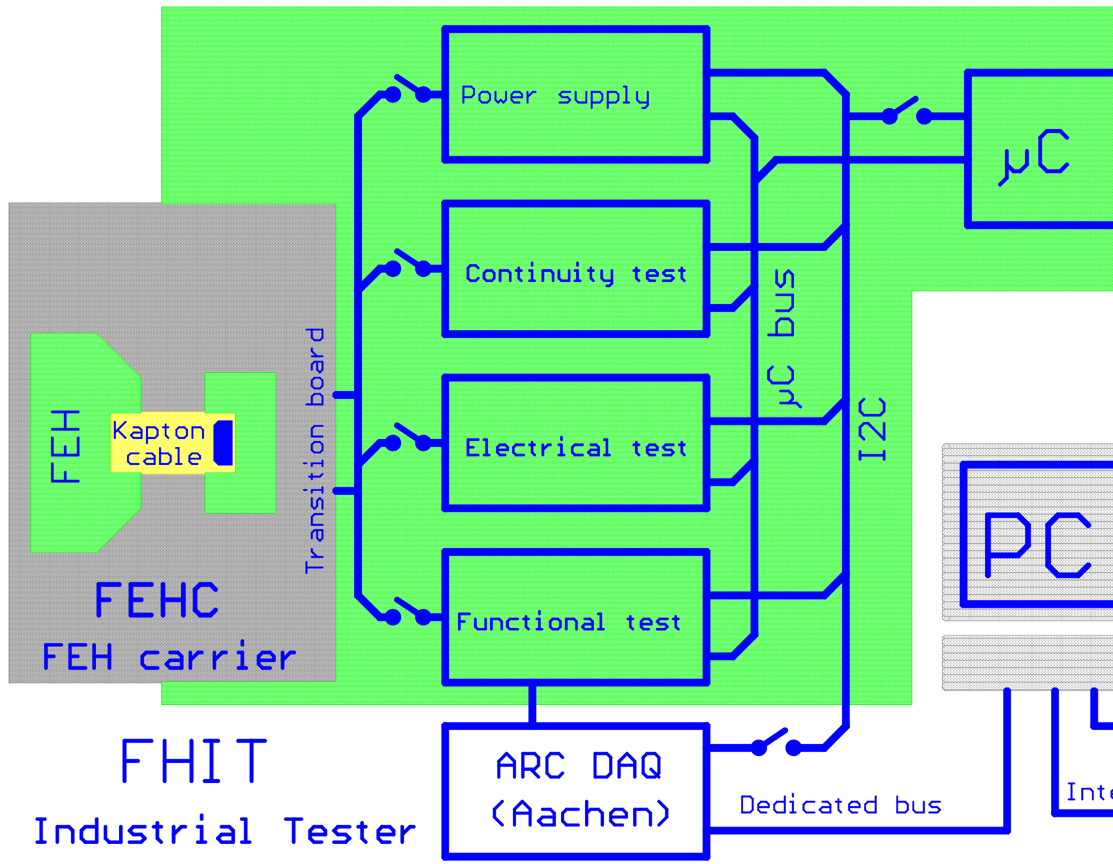
Test sequence:

→**Power supply control**
→**Barcode scanning, recognition of hybrid type**
→**Continuity test**
→**Electrical test, including I2C scan**
→**Functionality test (read-out of APVs)**
→**Log file creation + error file + hybrid identification file**
  → **XML (*CMS database*)**

Response (simplified for operator!):

green or red light

Block diagram



http://www.fynu.ucl.ac.be/themes/he/cms/activities/tracker/hybrids.html

LOUIS PASTEUR STRASBOURG

Summary and Conclusions

- Successful development of FE-hybrids for the CMS-tracker
- In total we have produced over 200 hybrids in different technologies
  - Required performance achieved!
  - Many modifications implemented to help system integration!
- New technologies (FR4, flex-rigid, full-flex) are being explored
  - Proto-types in industry are still in progress
  - They will determine the final technical specification and the choice of substrat
  - We still do need prototype runs to evaluate and to qualify the technology! Minimum 3 months!!
- Use these prototypes to set-up efficient module production to be ready when FE-Hybrids arri
- Full industrial production foreseen (duration is about one year)
  - Industrial tester (FHIT) has been developed for acceptance test

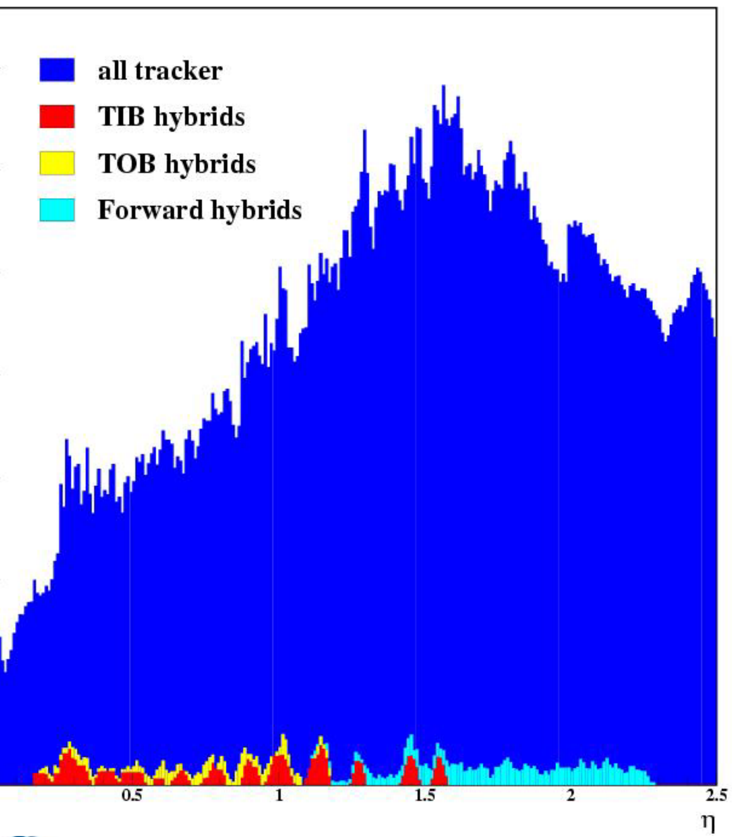
ireS LEPSI Laboratoire d'Electronique et de Physique des Systèmes

Technology choices (I)

ndustrial availability and price

o budget of tracker

adiation safety (no Ag)



Technology Candidates

	Material	Thickness(um)	% Xo	Total
*	Thick film on ceramic, metal: Au			
	Al2O3	380	0.50%	
	Isol	110	0.15%	
	Au 8 um	25	0.75%	1.40%
*	Cu on Kapton on carbon fibre			
	CFPC	500	0.20%	
	Kapt.+glue	150	0.05%	
	Cu 25 um	100	0.70%	0.95%
*	Cu on FR4			
	FR4	400	0.21%	
	Cu 25 um	100	0.70%	0.91%

(Very approximate figures!)

DCU

Digital Test: OK

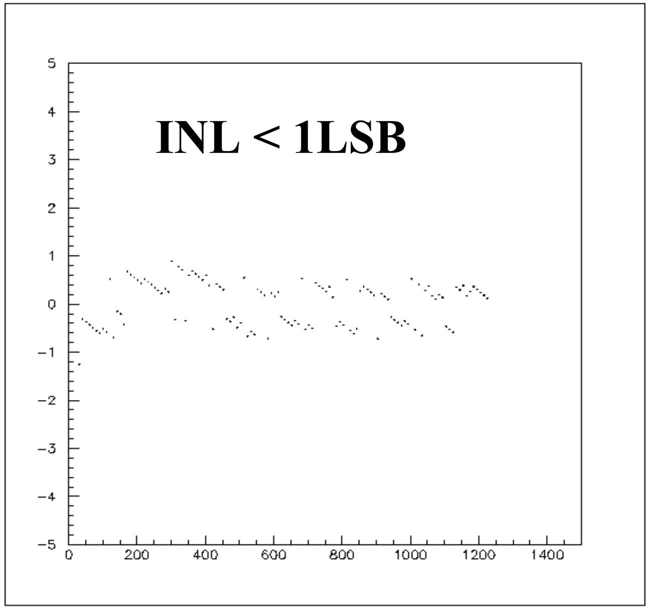
-1 LSB < DNL < 1 LSB

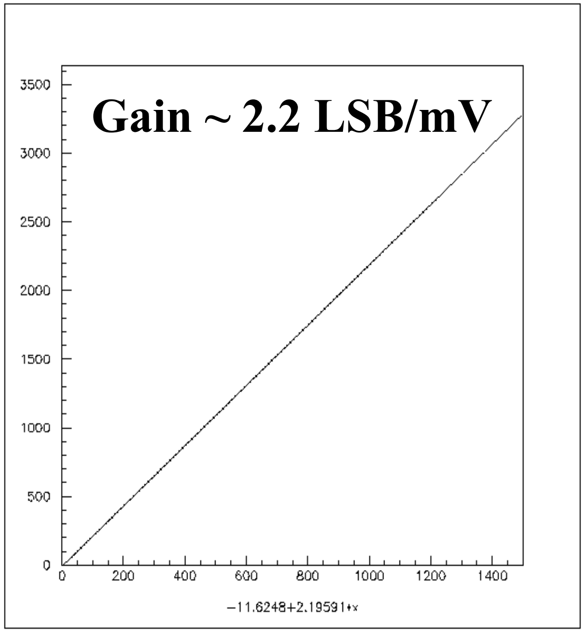
Transient noise RMS ~ 1/4 LSB

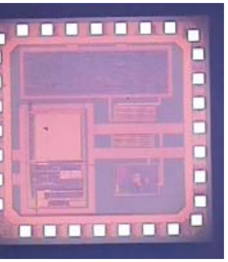
Power dissipation < 40mW

ADC Gain vs. X-ray dose: -0.4 %/Mrad

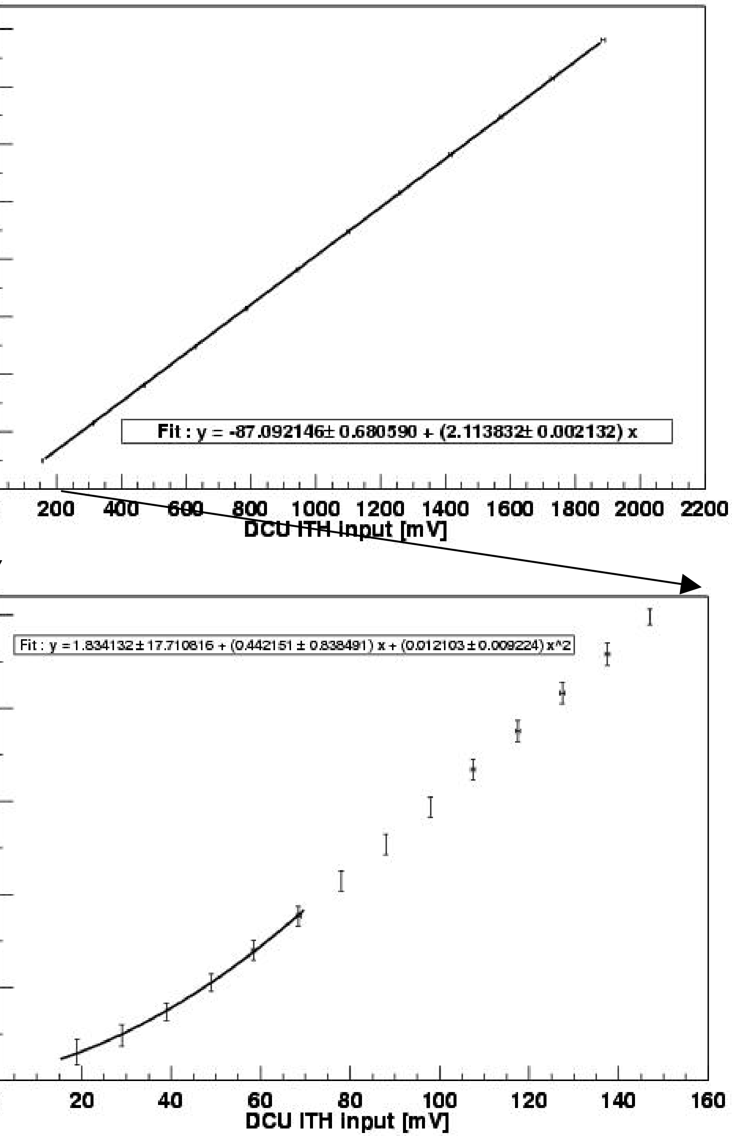
No evident changes in INL and transient noise RMS during and after X-ray irradiation



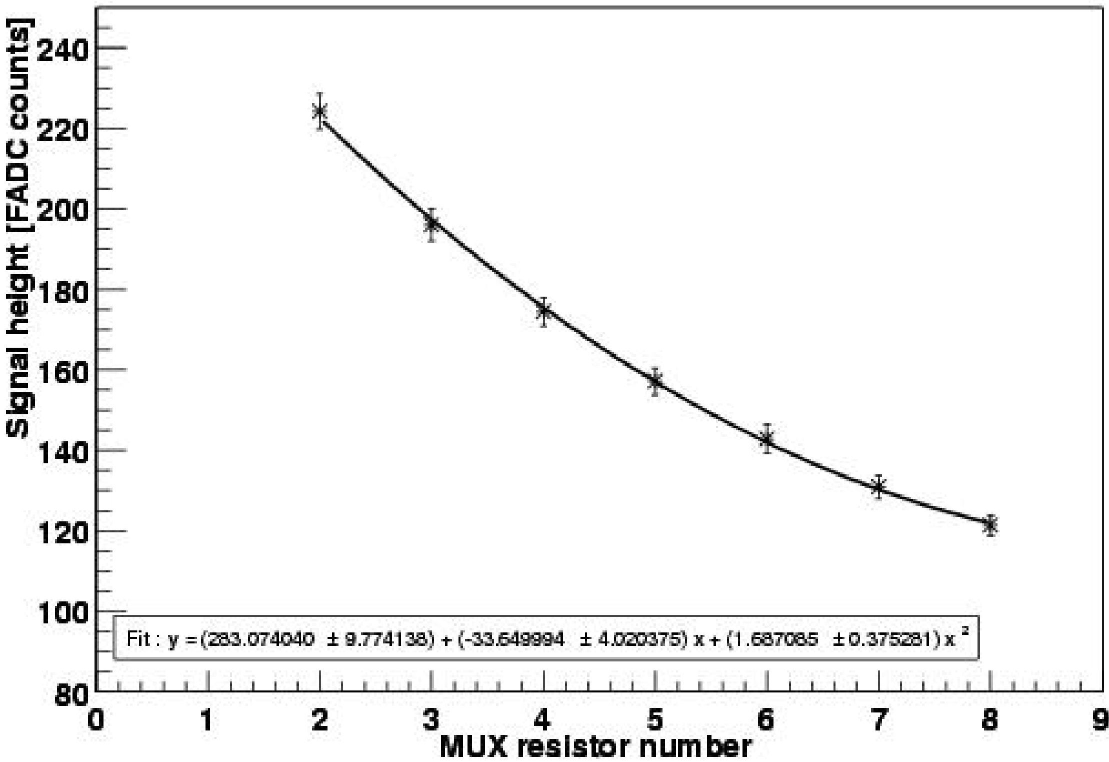


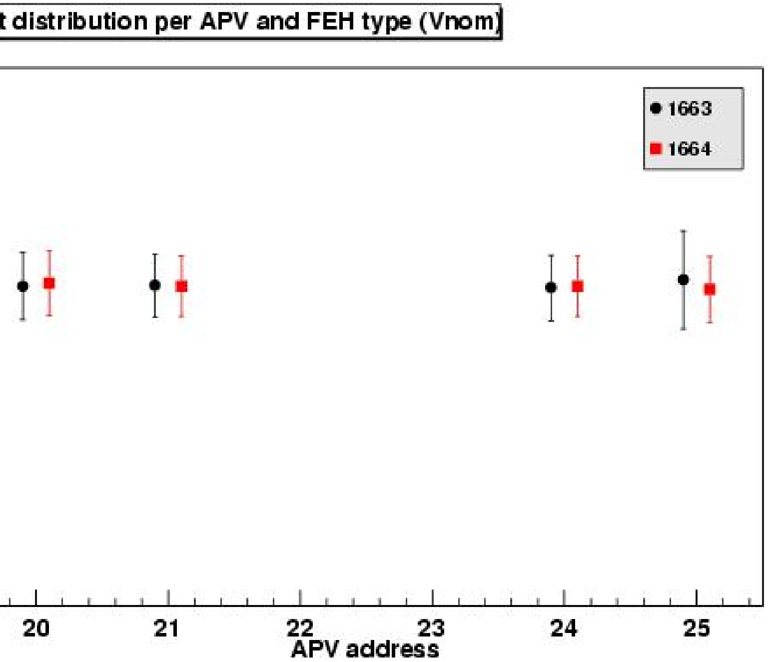


DCU ADC calibration



Signal amplitude as a function of MUX resistors being switched on





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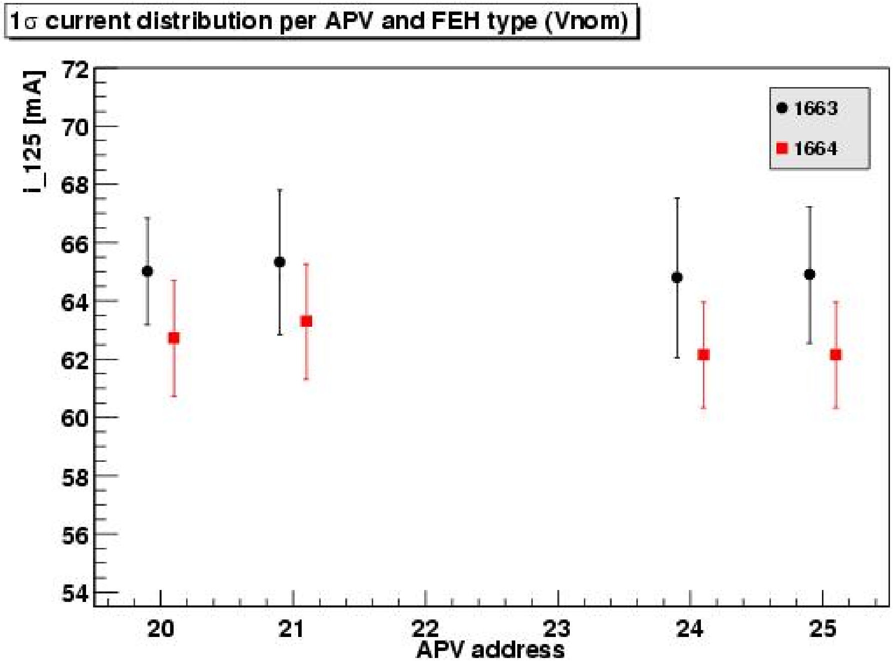

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APV current consumption distribution