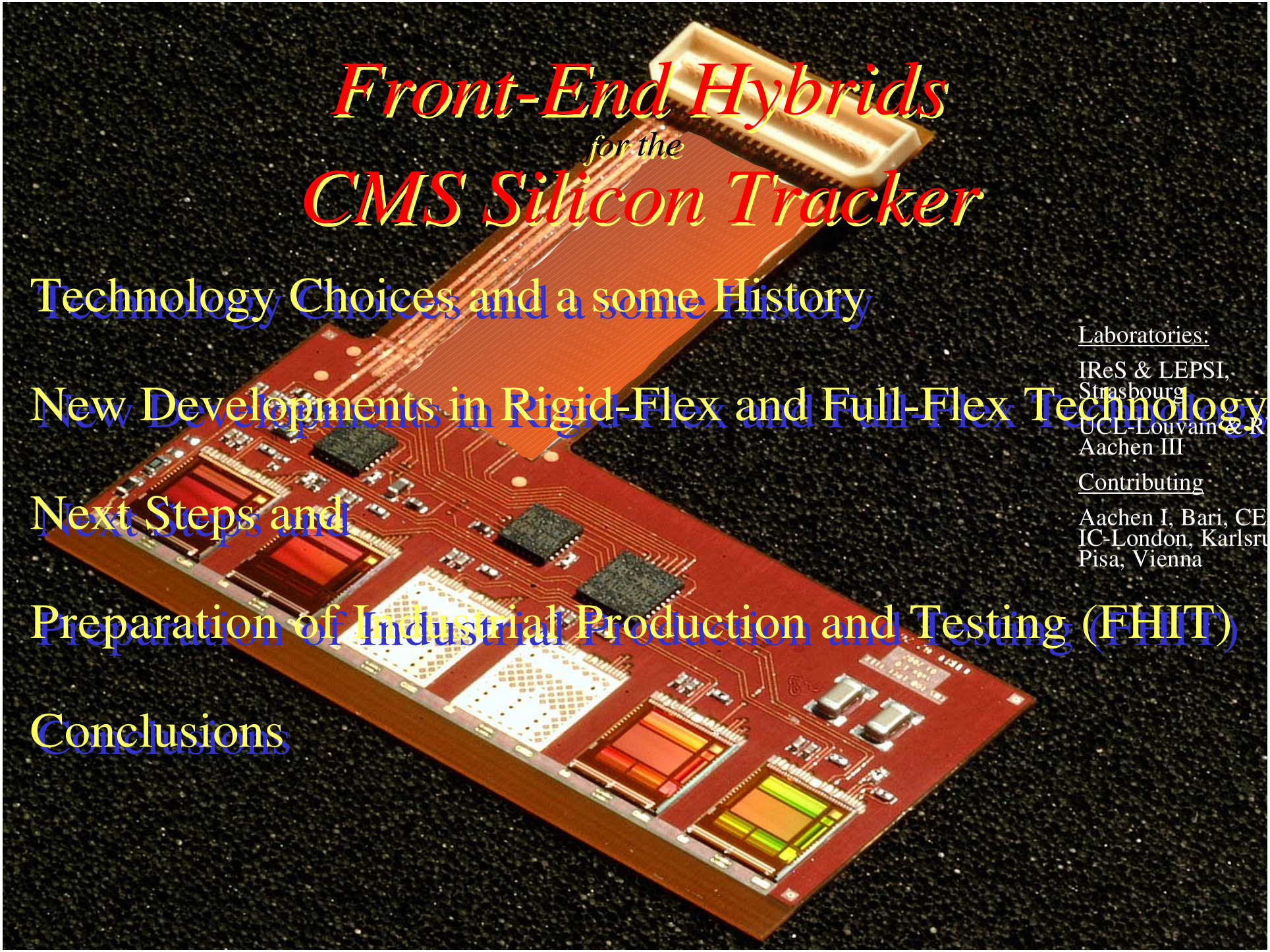
Front-End Hybrids
for the
CMS Silicon Tracker



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
UCL-Louvain & R
Aachen III

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)

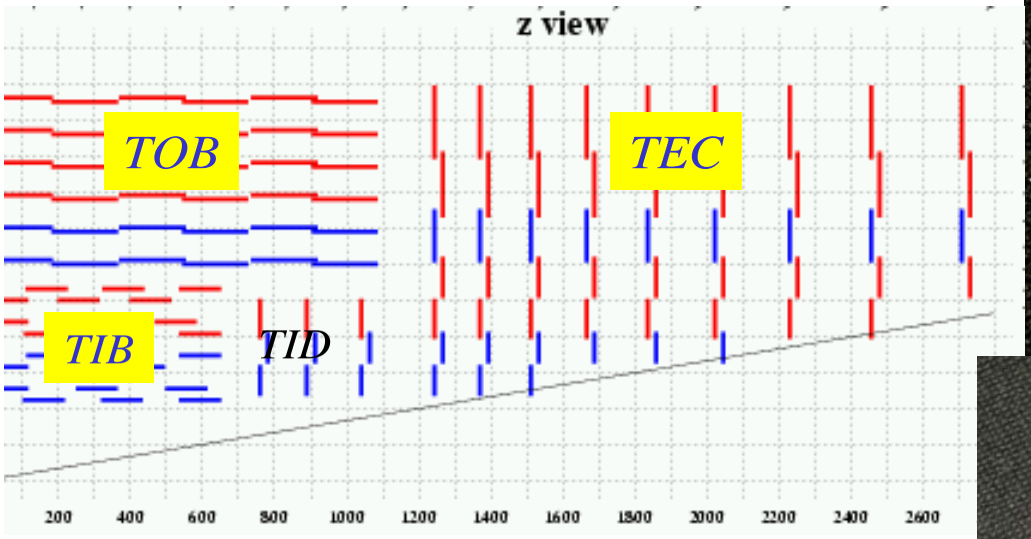
2002

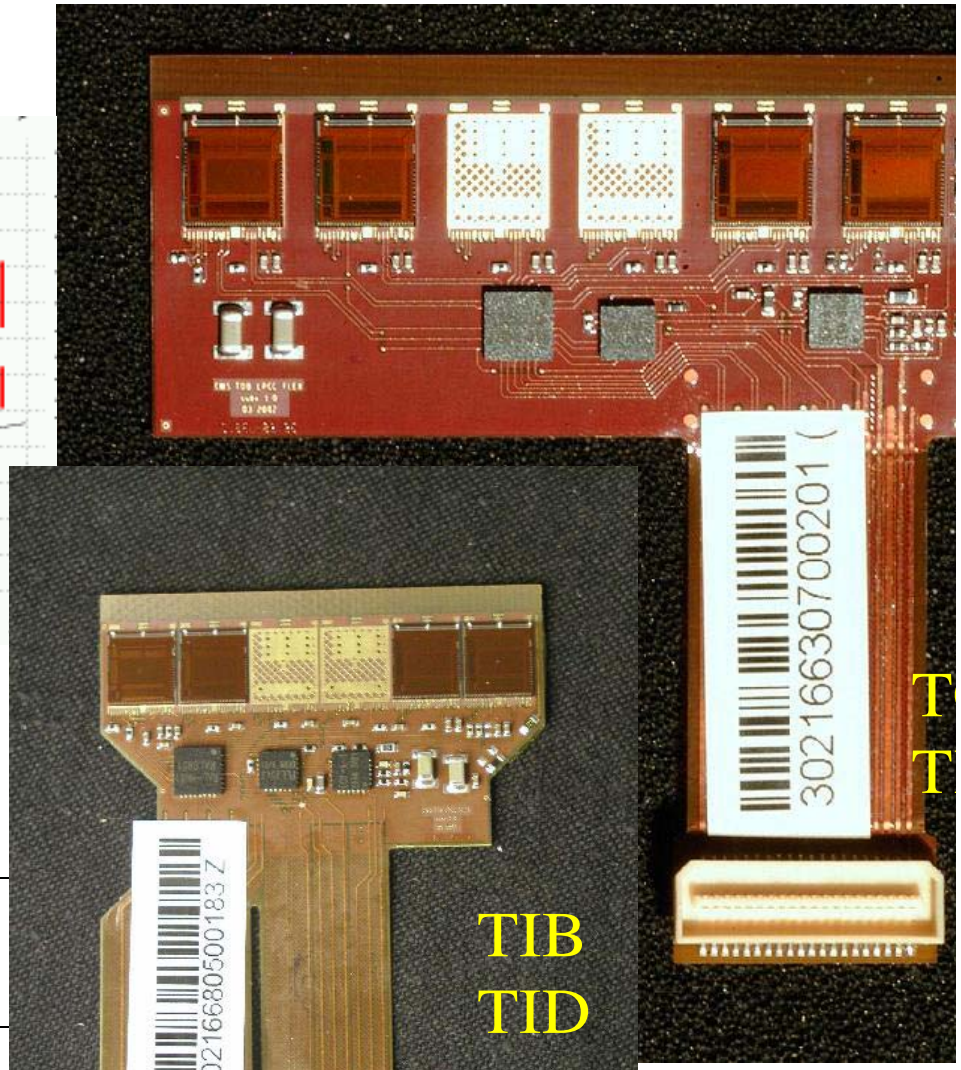
Electrical system tests

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-	stereo	R-	stereo	R-	stereo
PV	1056	1056	1680	-	1152	1152
PV	1428	-	2448	1080	4096	-
al	2484	1056	4128	1080	5248	1152
	3540		5108		6400	
al			15048			

(Version 200

Need industrial production!

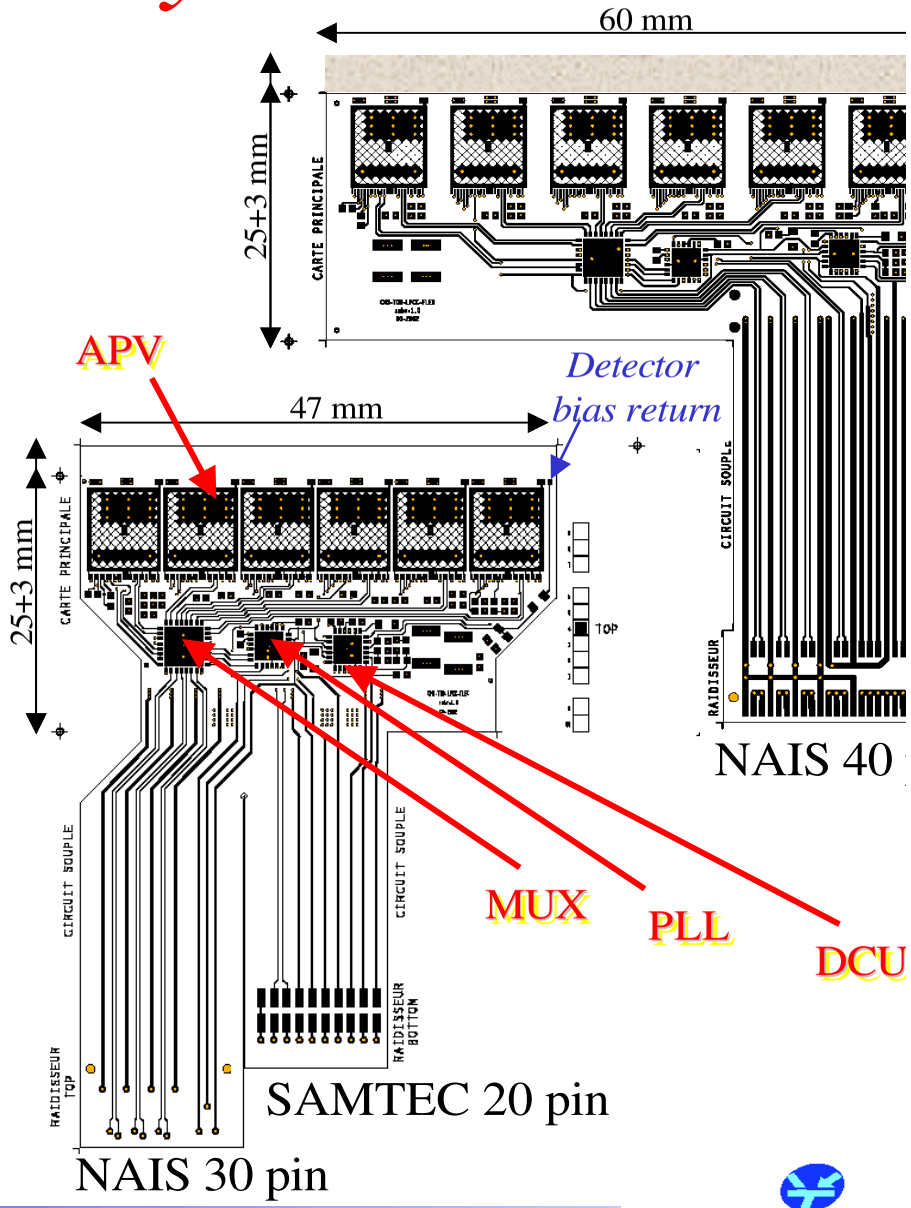
Definition of FE Hybrid (I)

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

Multi-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 m
- Operation at -10° to -20 °C
- Radiation hardness

Electrical parameters (2002)

- 4 metal layers
- Via: Ø 100/300 m
- Line width: 120 m
- Separations (line/via): 180/90 m
- Bias line resistance: 20-50 m

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 m
- (MUX-PLL)
- (DCU)

Glob-top cover for bonds?

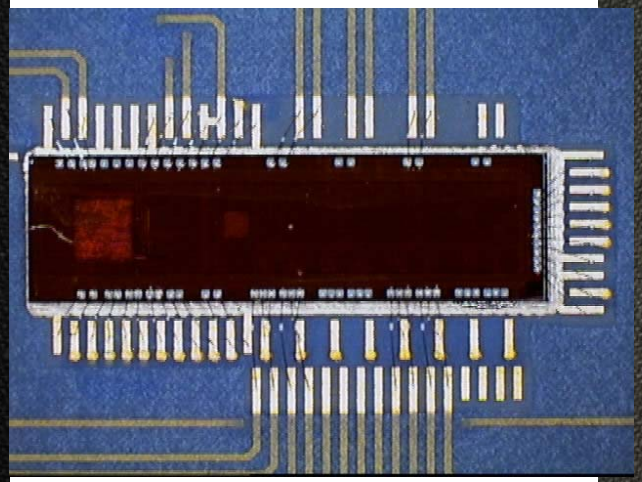
- (Radiation hardness ?)

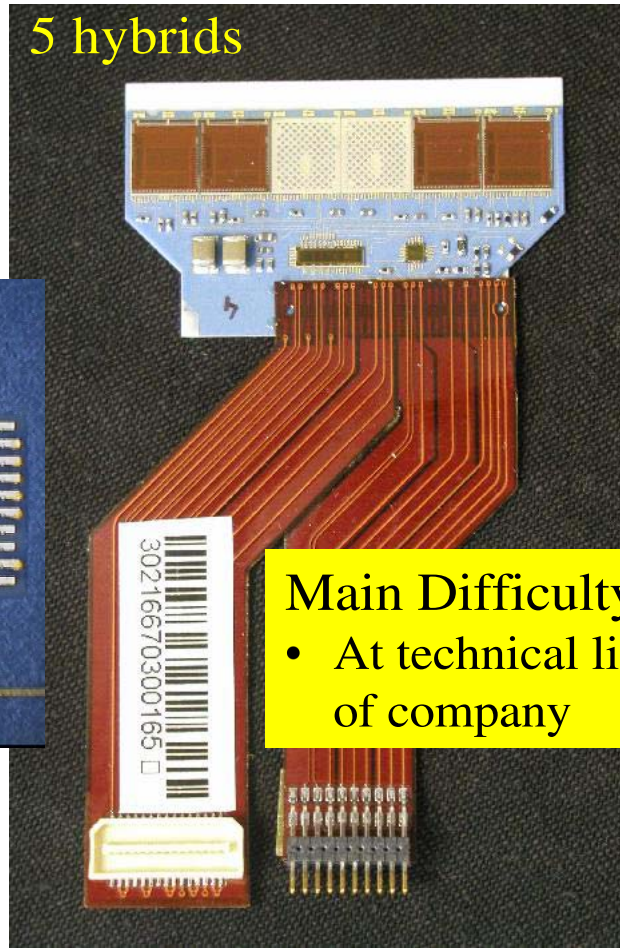
Dorazil and MIPOT Ceramic Hybrids

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

Main Difficulties:
Small feature size not suitable for mass production
Soldering of kapton cable

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





Main Difficulty
- At technical li
of company

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 configuration 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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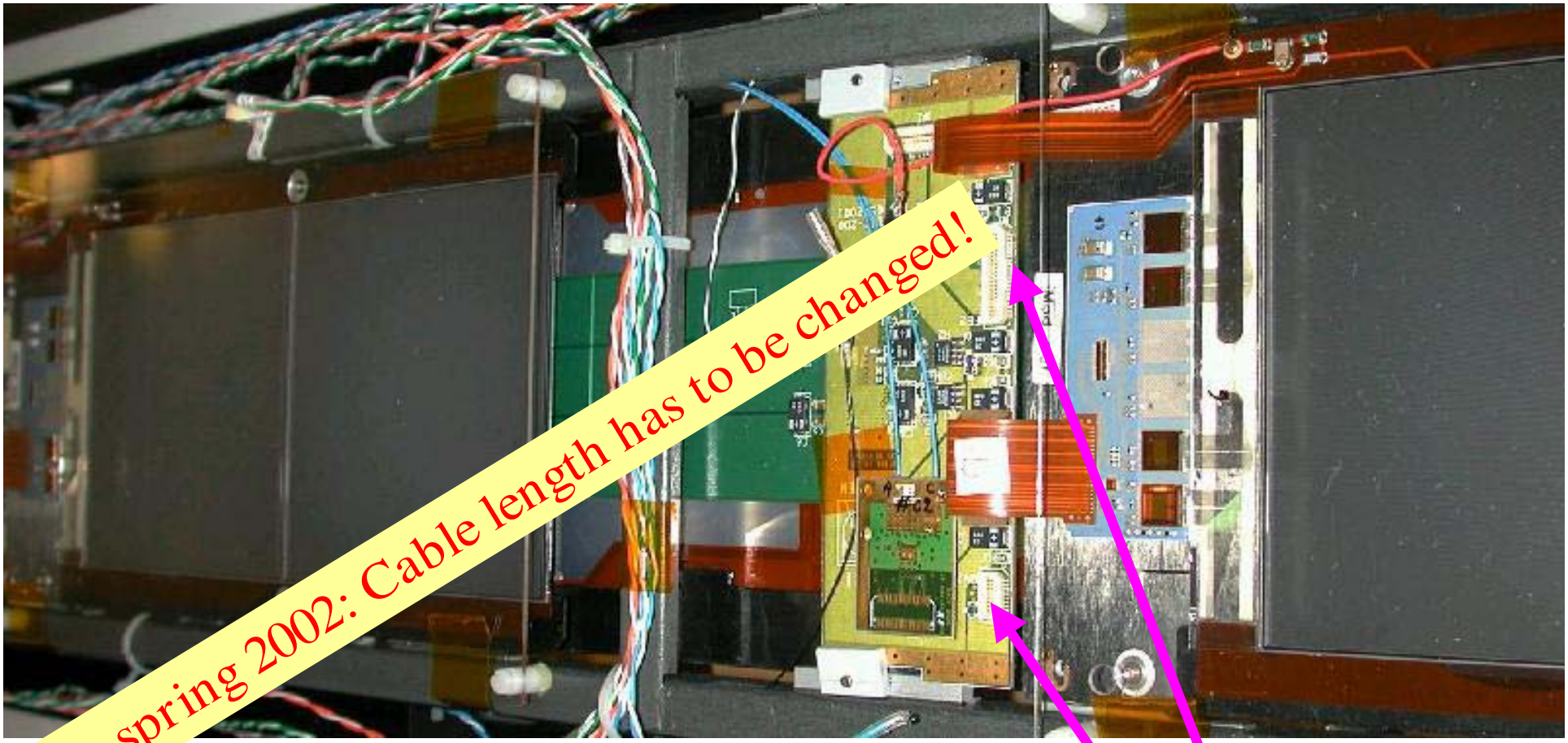
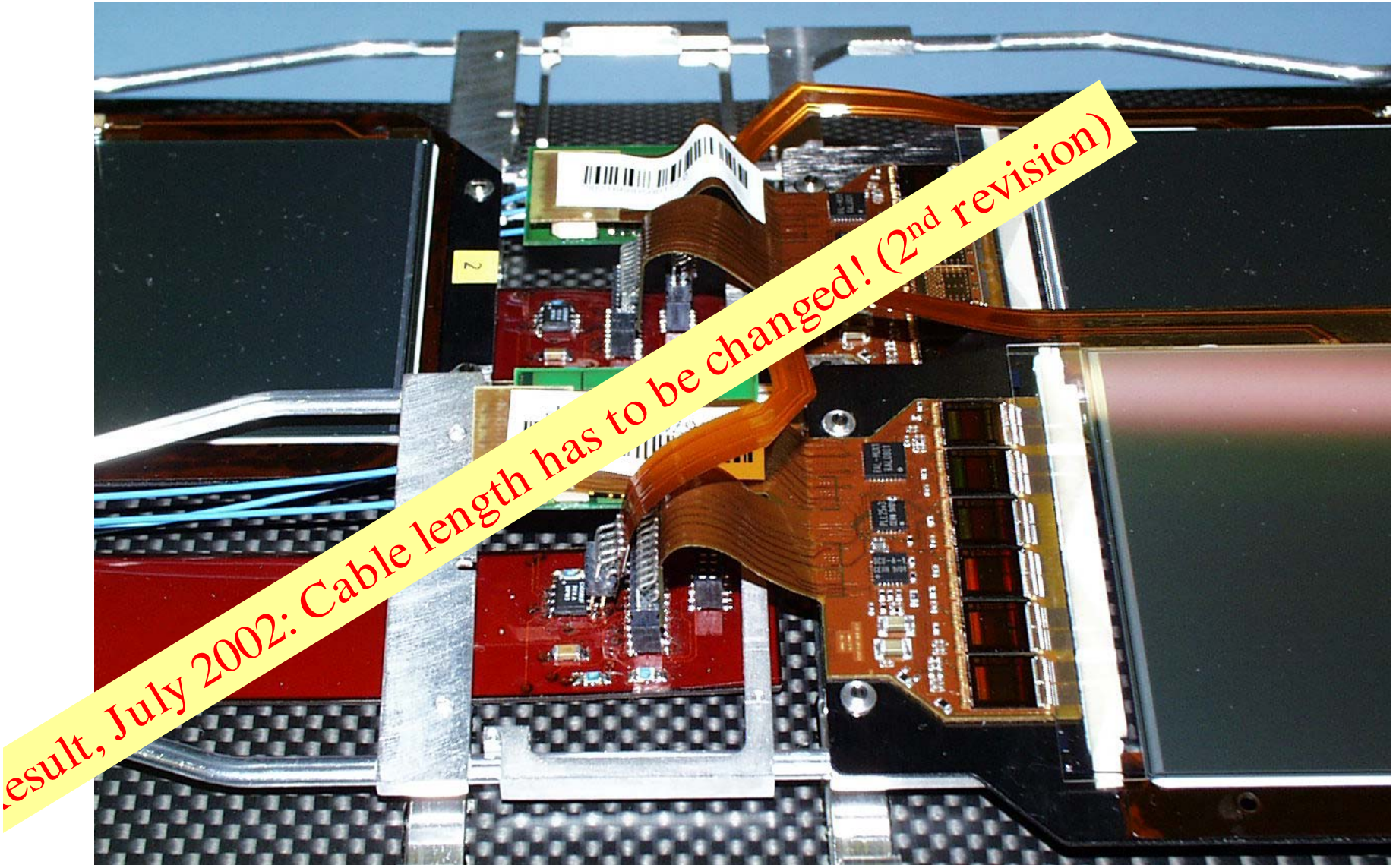
ow other potentially significant cheaper technologies available

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

Loaded TOB Rod with Si-Detector Modules



TIB Shell loaded with Si-Detector Modules



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

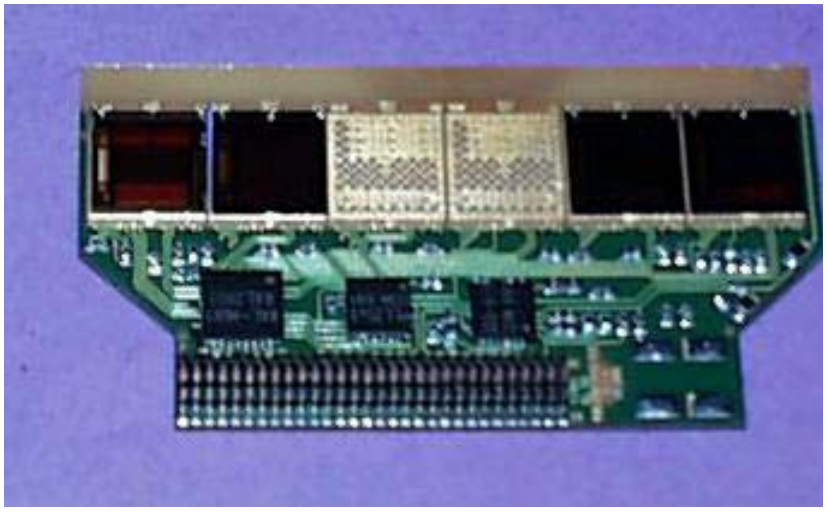
Boards are correct

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

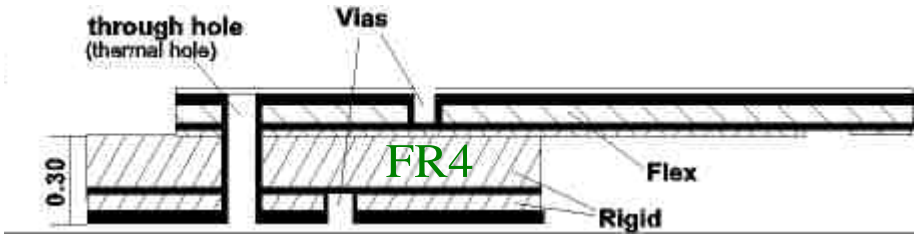
Tolerances in thickness up to 100 micron

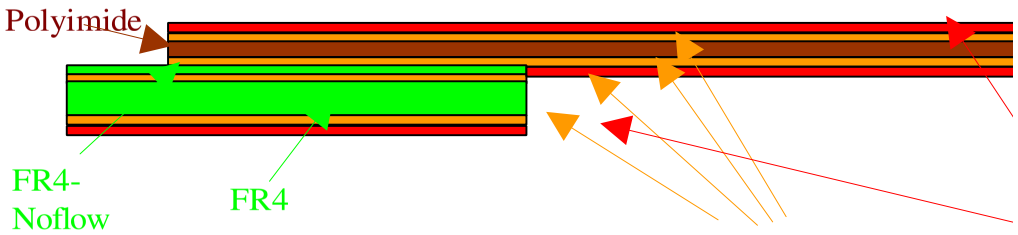
Non-Flatness in the order of 100 micron before SMD montage, and we have seen more

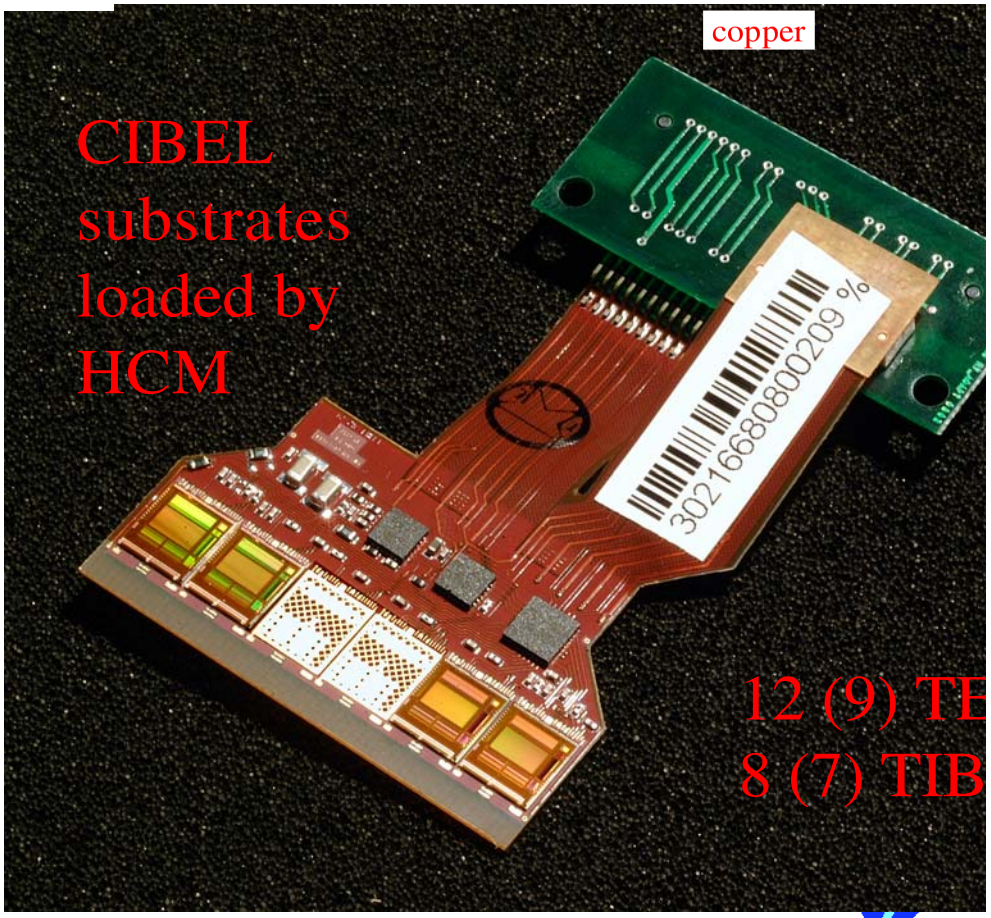
Extend FR4 part under PA

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 m?

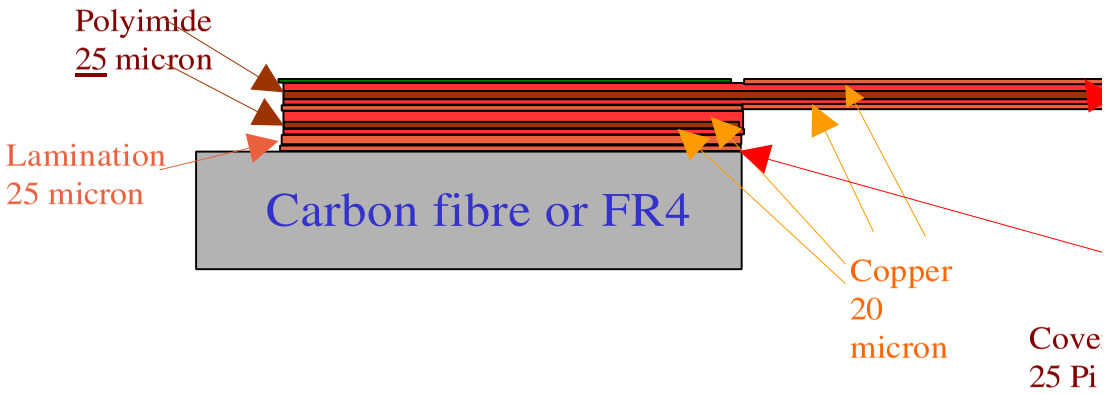
oto-types available from CICOREL

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

CICOREL

Layer Hybrid	Thickness	Layer Cable	Thick
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

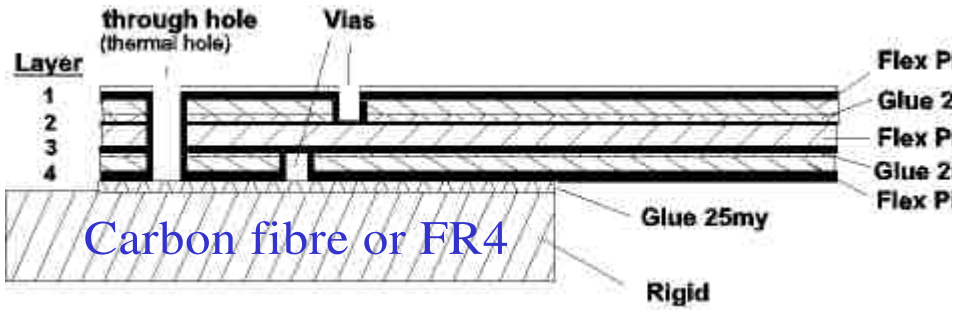
-Flex (all Kapton) laminated on

Carbon-fibre substrate

FR4-substrate with thermal heat conducts

proposal:

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



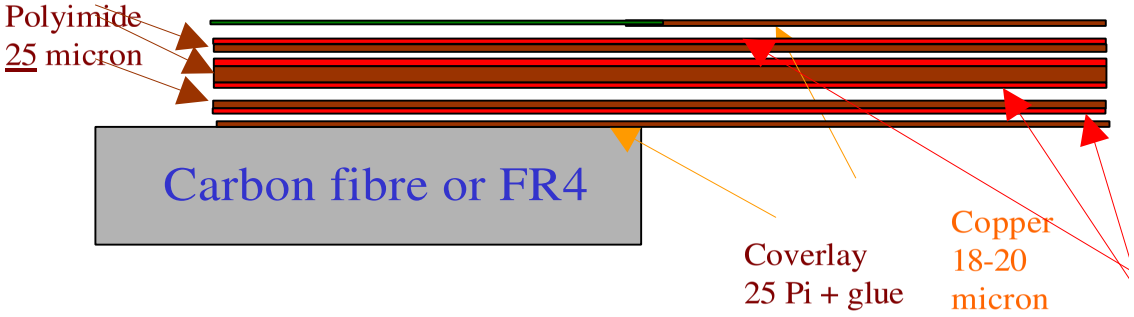
CONEX(?):

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

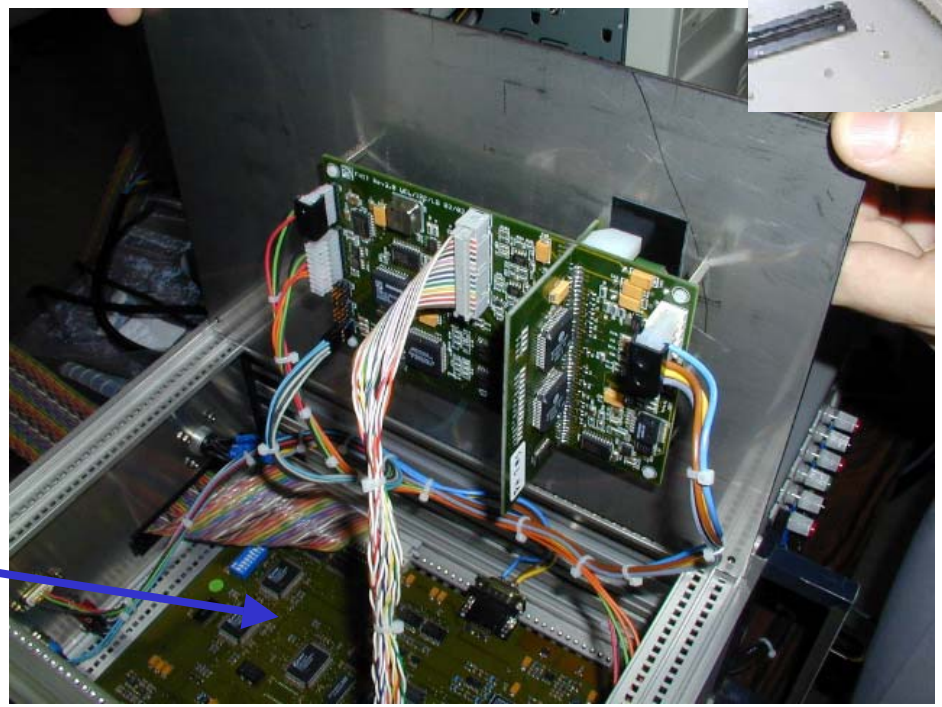
Duration of production will be about one year

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)

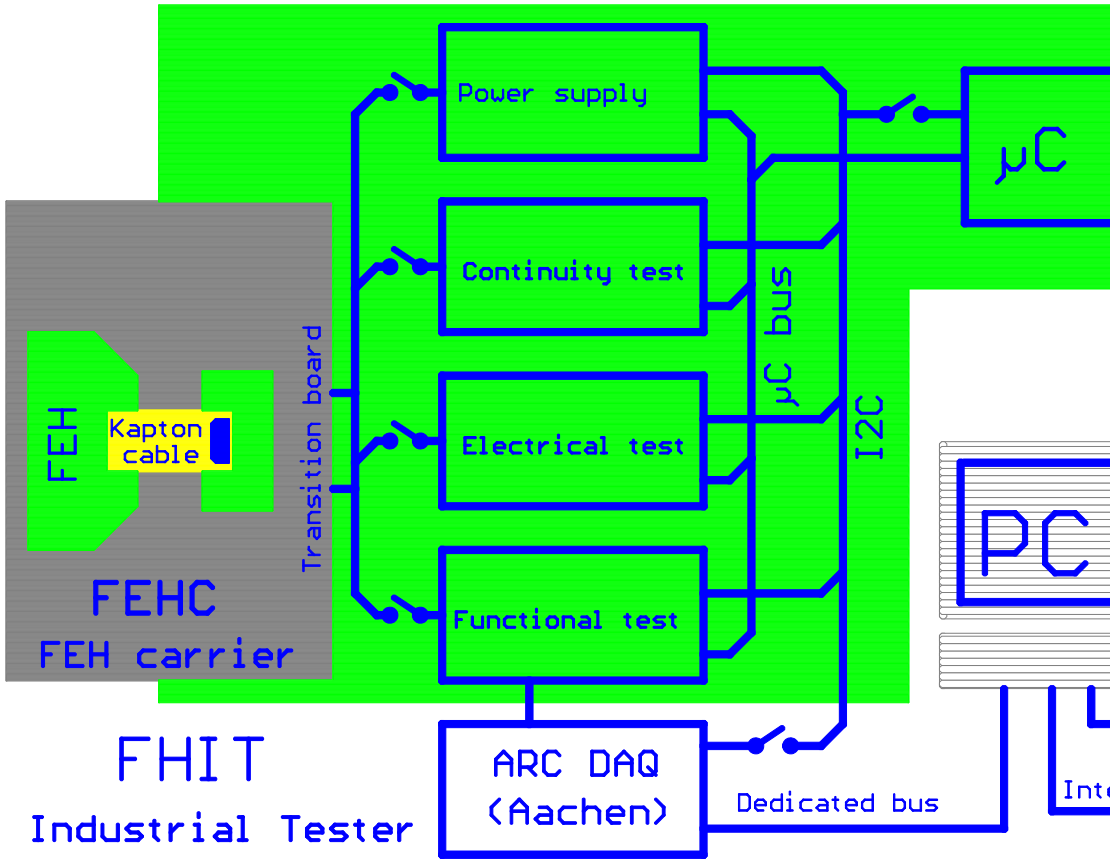
Test sequence:

- 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

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)

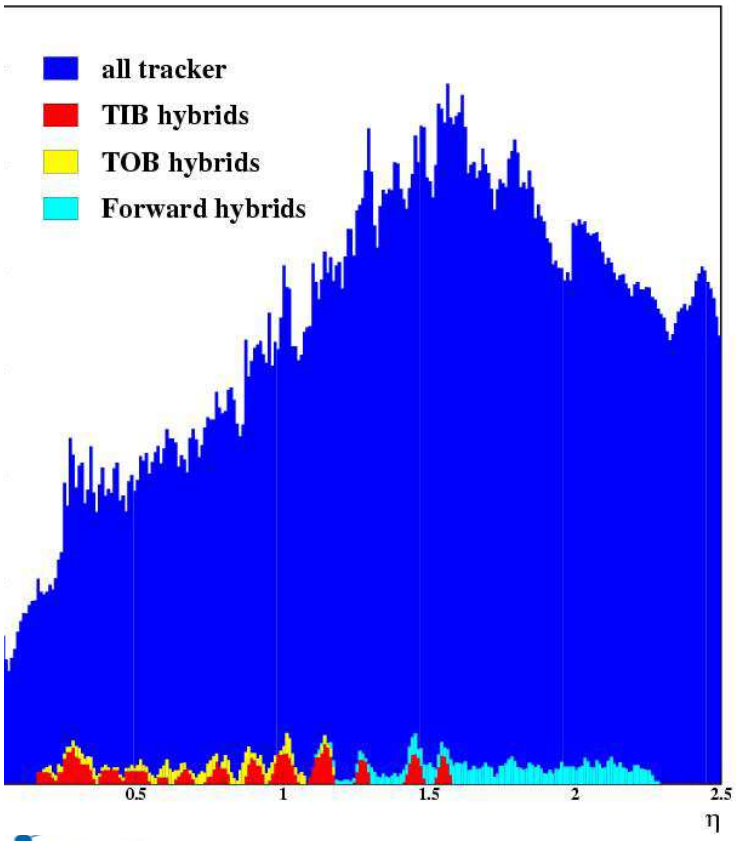
- Industrial tester (FHIT) has been developed for acceptance test

Technology choices (I)

ıdustrial 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

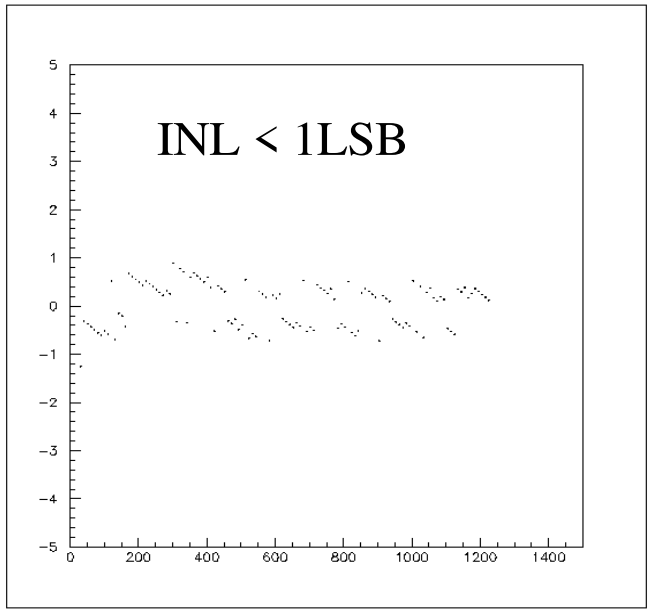
-1 LSB < DNL < 1 LSB

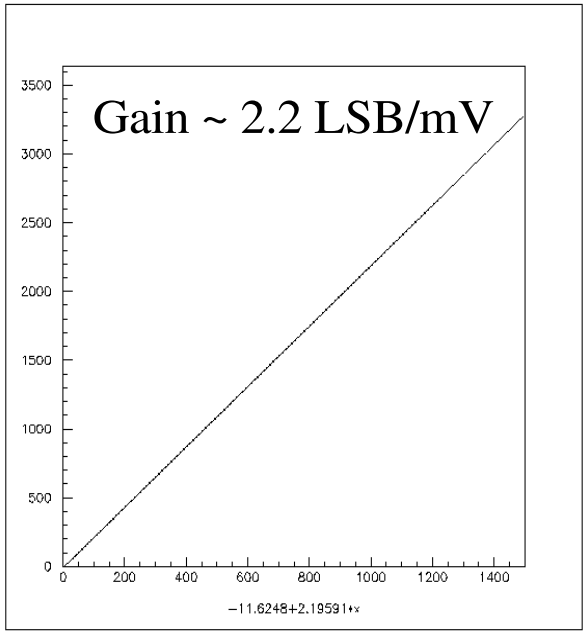
Transient noise RMS ~ 1/4 LSB

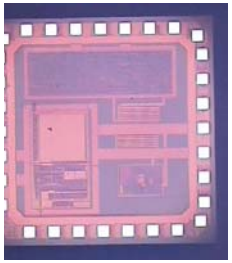
Power dissipation < 40mW

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

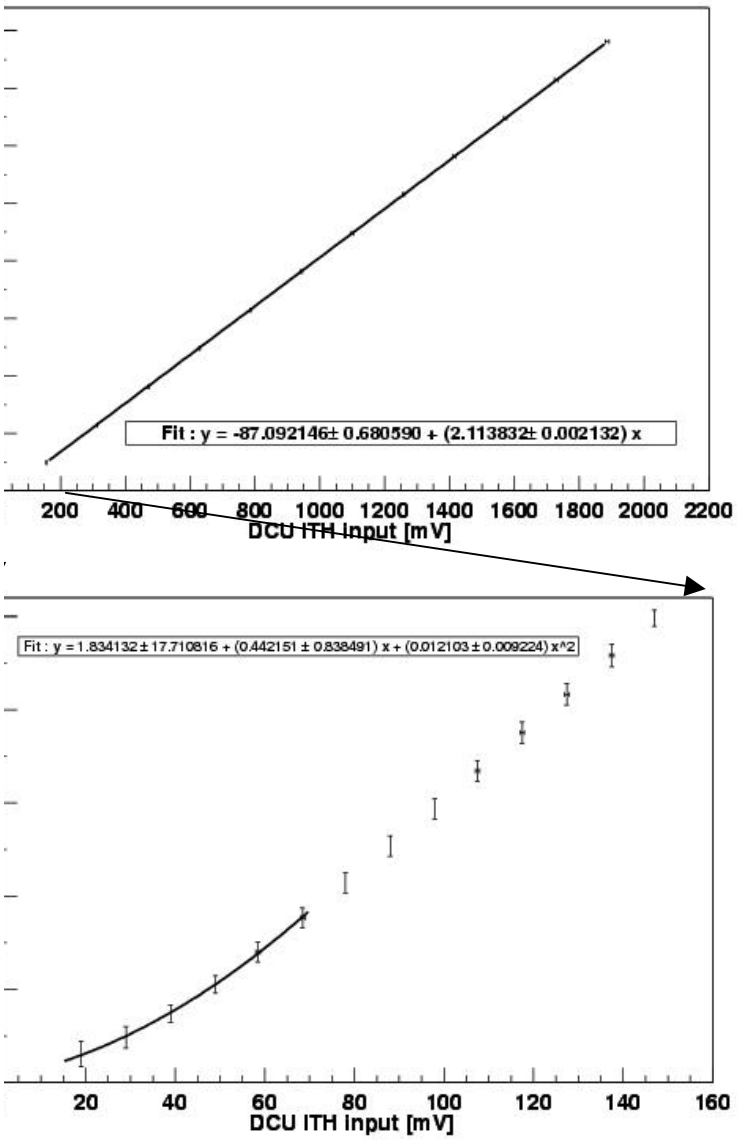
No evident changes in INL and transient noise RMS during and after X-ray irradiation



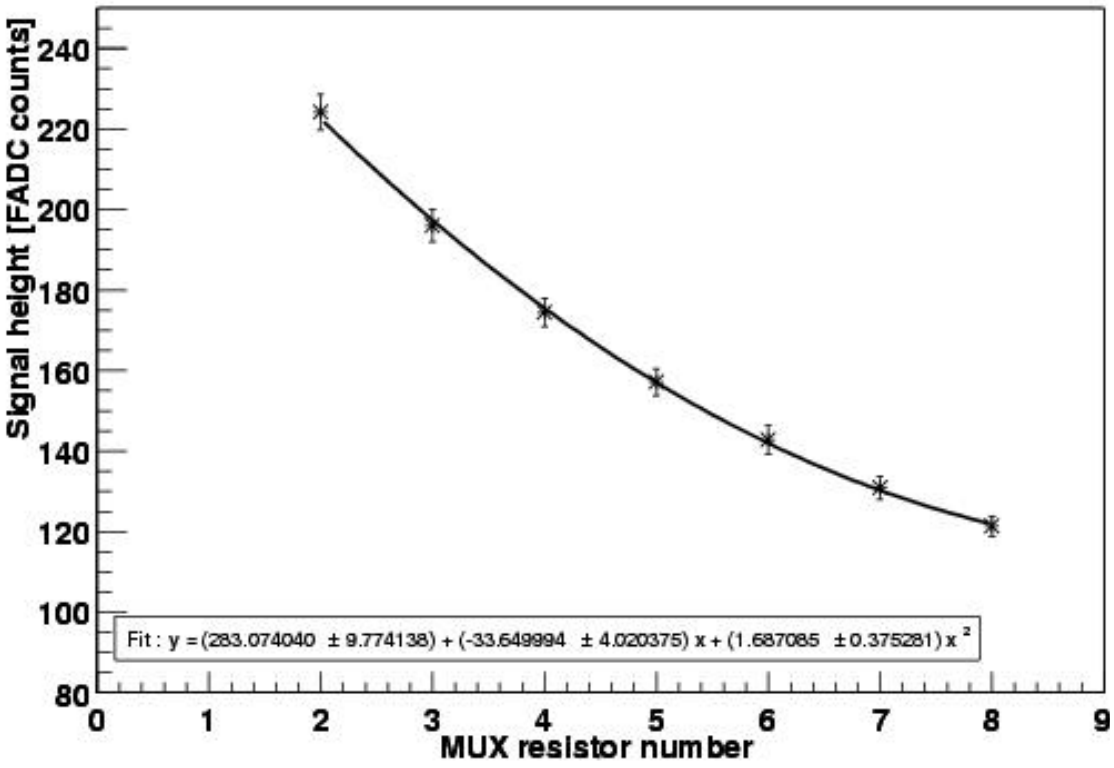


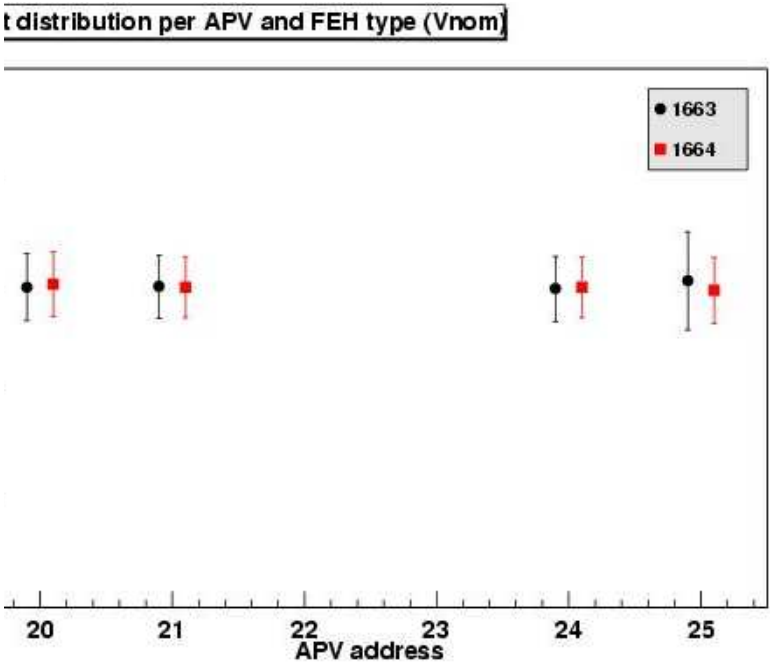


DCU ADC calibration



Signal amplitude as a function of MUX resistors being switched on





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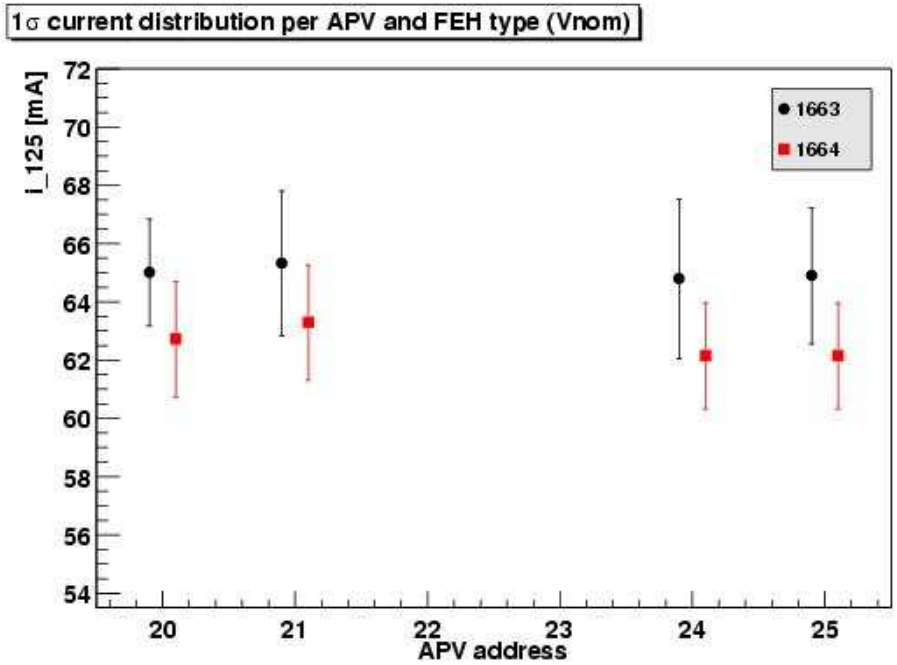

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APV current consumption distribution