IL TRACCIATORE DELL'ESPERIMENTO CMS

- Linee guida del progetto
- Stato della costruzione:
  - moduli
  - integrazione

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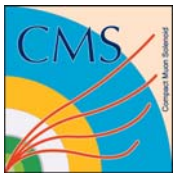
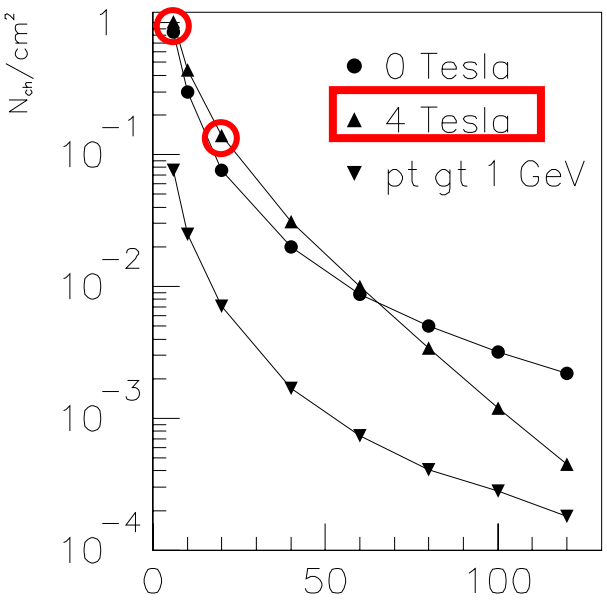


Tracking a LHC

- Alla luminosità di 10^{34} $cm^{-2}s^{-1}$
  - 20 eventi minimum-bias per bunch crossing (Δt=25 ns)



O(1.0) cm^{-2} r=10 cm

O(0.1) cm^{-2} r=25 cm

misura coordinate precisa $|\eta|<2.5$

- buona risoluzione su p_t
  - $\Delta p_t / p_t \approx 0.1 p_t$ per $|\eta|<1.6$ (p_t in TeV)
- capacità di tag di b/τ (IP,SVX)
  - $\varepsilon(b)\approx 60\%$ per $\varepsilon(u)=1\%$

✓ ≈10 punti/traccia

✓ occupanza 1-2%

risoluzione 20-30 μm

(NB: sagitta≈200 μm per p_t=1 TeV)

granularità spaziale e temporale

Il Tracker di CMS: R&D

- APV25
  - CMOS 0.25 μm, radiation-hard fino a 20 Mrad (D_{max}=10 Mrad)
  - "deconvoluzione": filtro numerico (APSP)
    CR-RC con τ=50 ns $\rightarrow$ FWHM=27 ns

    ENC_{dec}=396+59.4/pF P=1.8 mW/ch

- Rivelatori a μ-strip di silicio:
  - radiation-hard ($\Phi_{max} \approx 1.6 \times 10^{14}$ 1 MeV n-eq/cm^2):
    <100>, metal-overhang, DS=SS x2
  - 20 <r<60 cm: sensori corti (ℓ=12 cm) e sottili (d=320 μm)
    60<r<110 cm: sensori lunghi (ℓ=19 cm) ma spessi (d=500 μm)

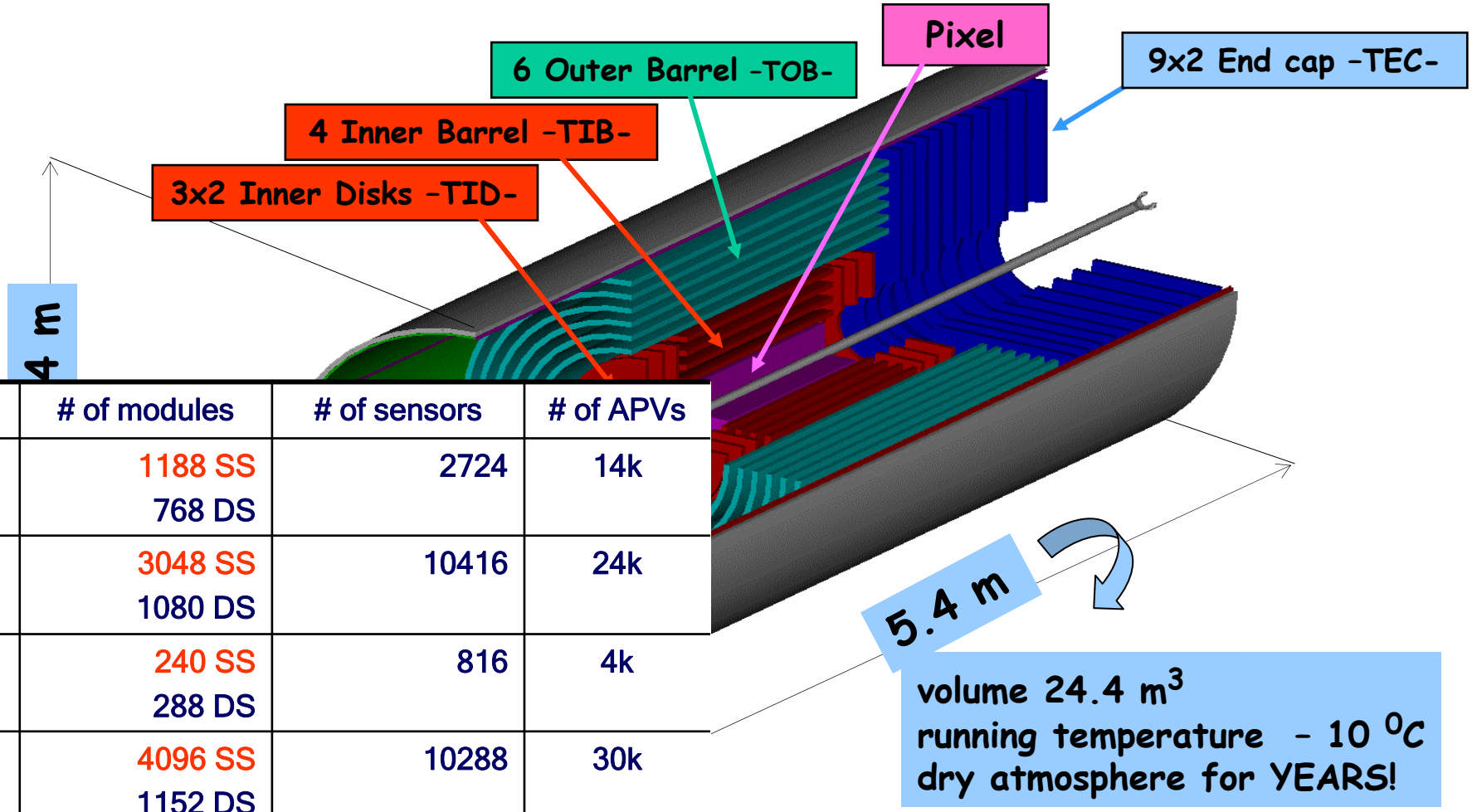
    ☠□♓♦♏ ✪ C_d ✪ ℓ ♦♓♑■♋● ✪ d

    scelta di geometrie con C_d(320 μm)/cm = C_d(500 μm)/cm

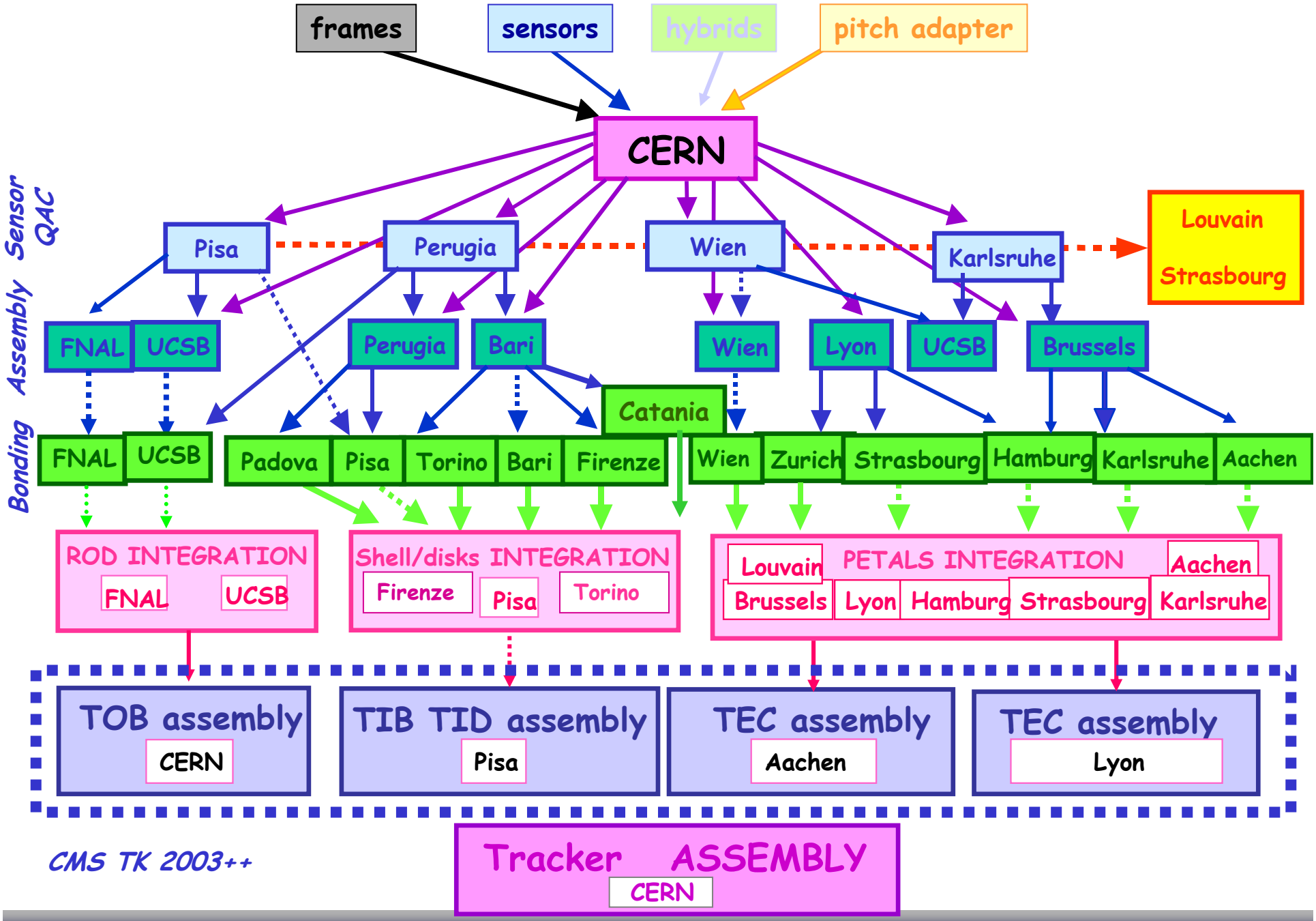
    ♦/☠ ≥12 per tutta la durata di LHC

    pitch 80-120 μm (TIB), 122-183 μm (TOB)
  - wafer 6"

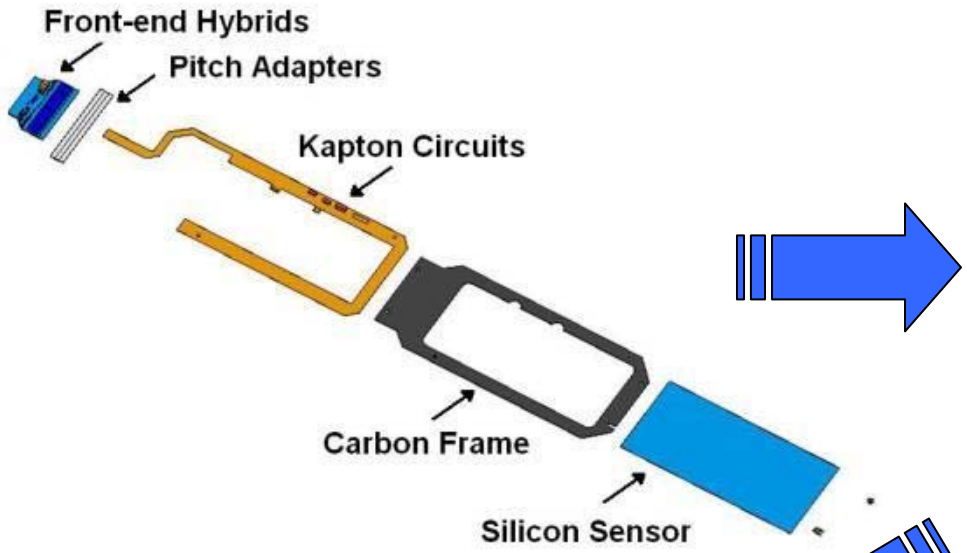
Layout del Tracker



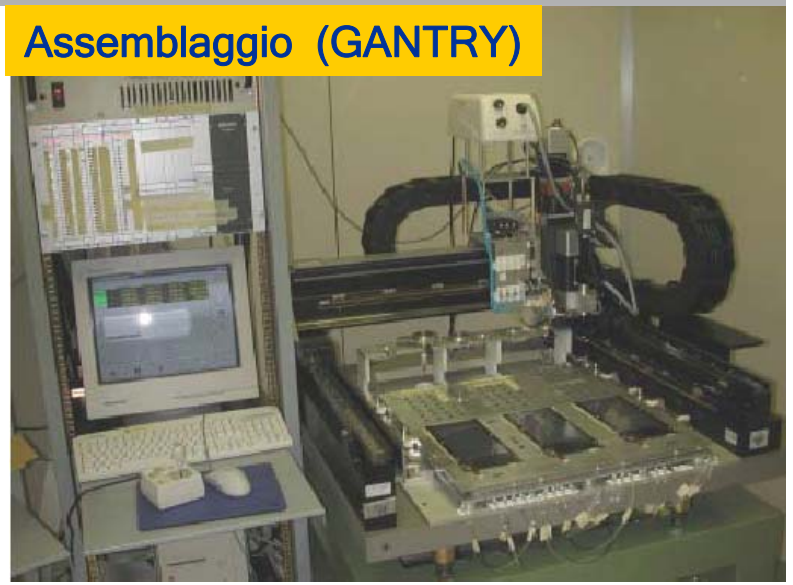
	# of modules	# of sensors	# of APVs
TIB	1188 SS 768 DS	2724	14k
TOB	3048 SS 1080 DS	10416	24k
TID	240 SS 288 DS	816	4k
TEC	4096 SS 1152 DS	10288	30k
TotTK	8572 SS 3288 DS	24244	73k


frames
sensors
hybrids
pitch adapter
CERN
Sensor QAC
Assembly
Bonding
Pisa
Perugia
Wien
Karlsruhe
Louvain
Strasbourg
FNAL
UCSB
Perugia
Bari
Wien
Lyon
UCSB
Brussels
Catania
FNAL
UCSB
Padova
Pisa
Torino
Bari
Firenze
Wien
Zurich
Strasbourg
Hamburg
Karlsruhe
Aachen
ROD INTEGRATION
FNAL
UCSB
Shell/disks INTEGRATION
Firenze
Pisa
Torino
PETALS INTEGRATION
Louvain
Aachen
Brussels
Lyon
Hamburg
Strasbourg
Karlsruhe
TOB assembly
CERN
TIB TID assembly
Pisa
TEC assembly
Aachen
TEC assembly
Lyon
CMS TK 2003++
Tracker ASSEMBLY
CERN

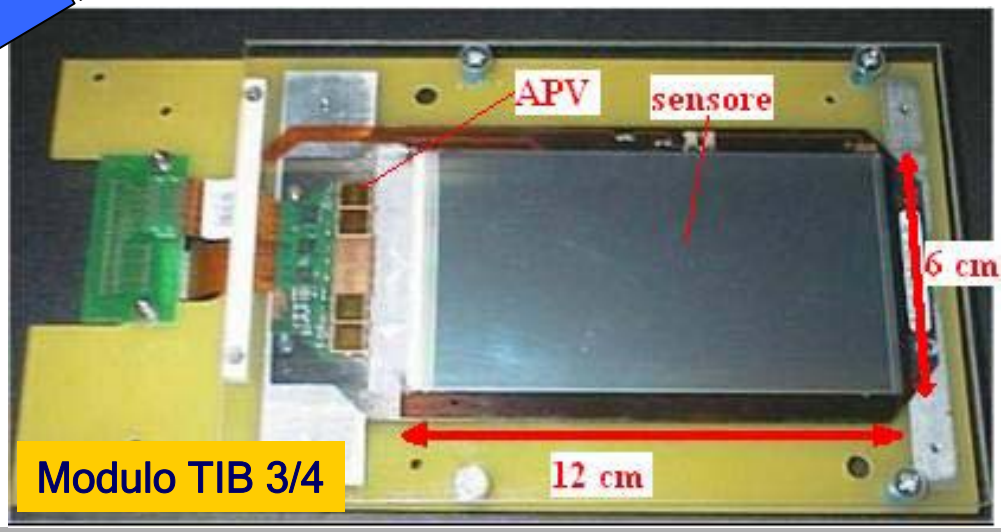
La produzione dei moduli



Assemblaggio (GANTRY)

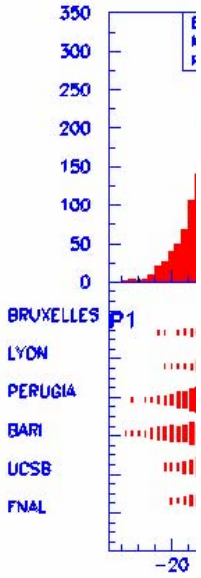


Bonding & Test

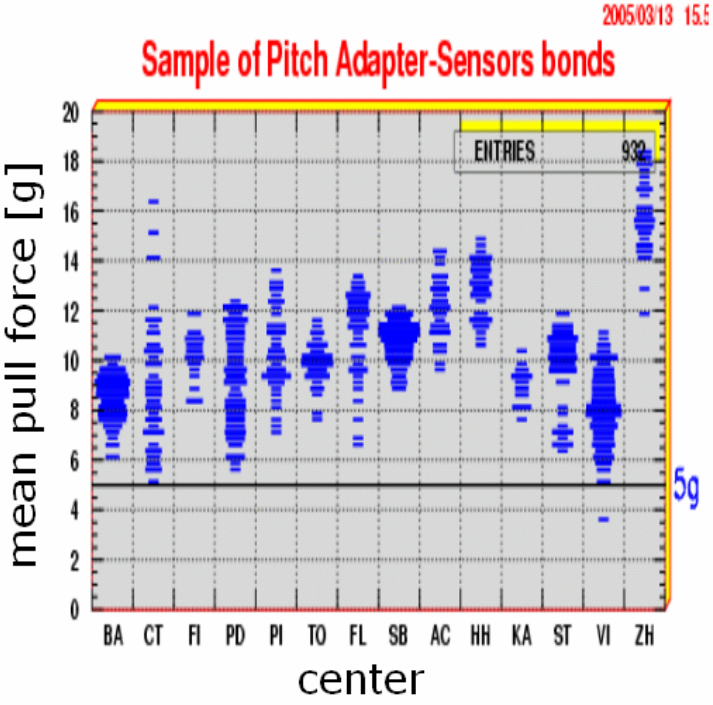


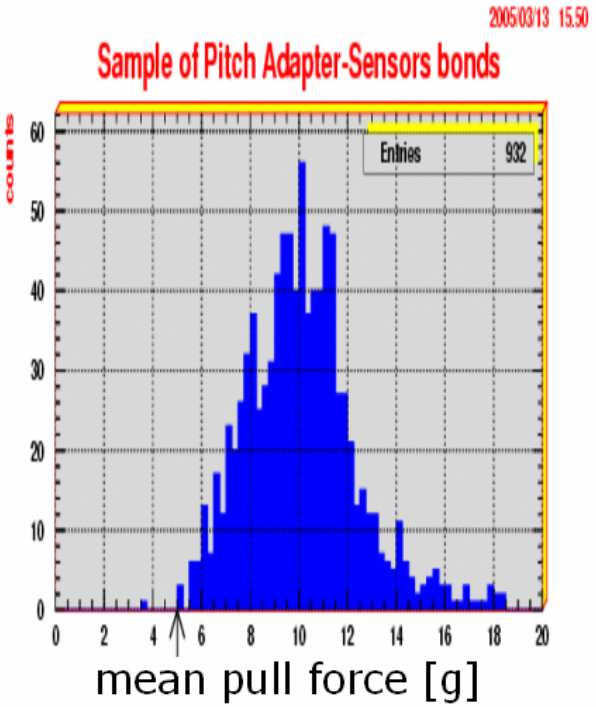
Modulo TIB 3/4

Mean pull forces *[spec: >5g]*



March 15

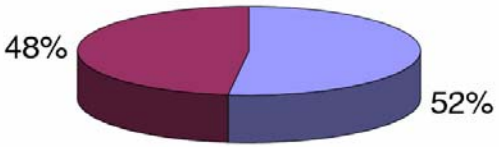




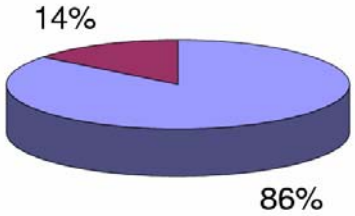
- Precisione meccanica: ±39 μm coordinata di misura
  ±65 μm coordinata perpendicolare
- Bonding robusto (>5g)
- Buona IV, pochi canali cattivi (1% grade A, 2% grade B)

Quantità e qualità dei moduli

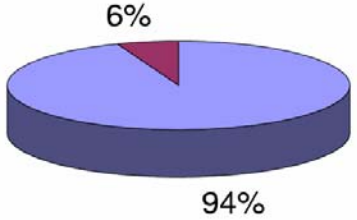
- Finora prodotti ≈3000 moduli



TIB+TID



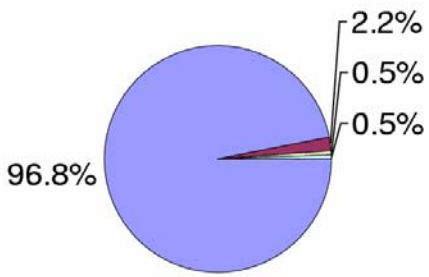
TEC



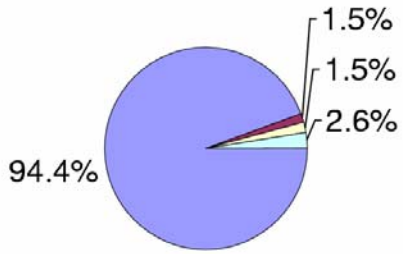
TOB

no 10% contingency

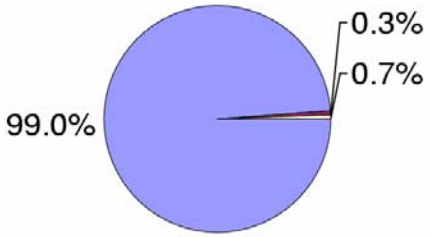
- Qualità buona→ottima a seconda del tipo



TIB

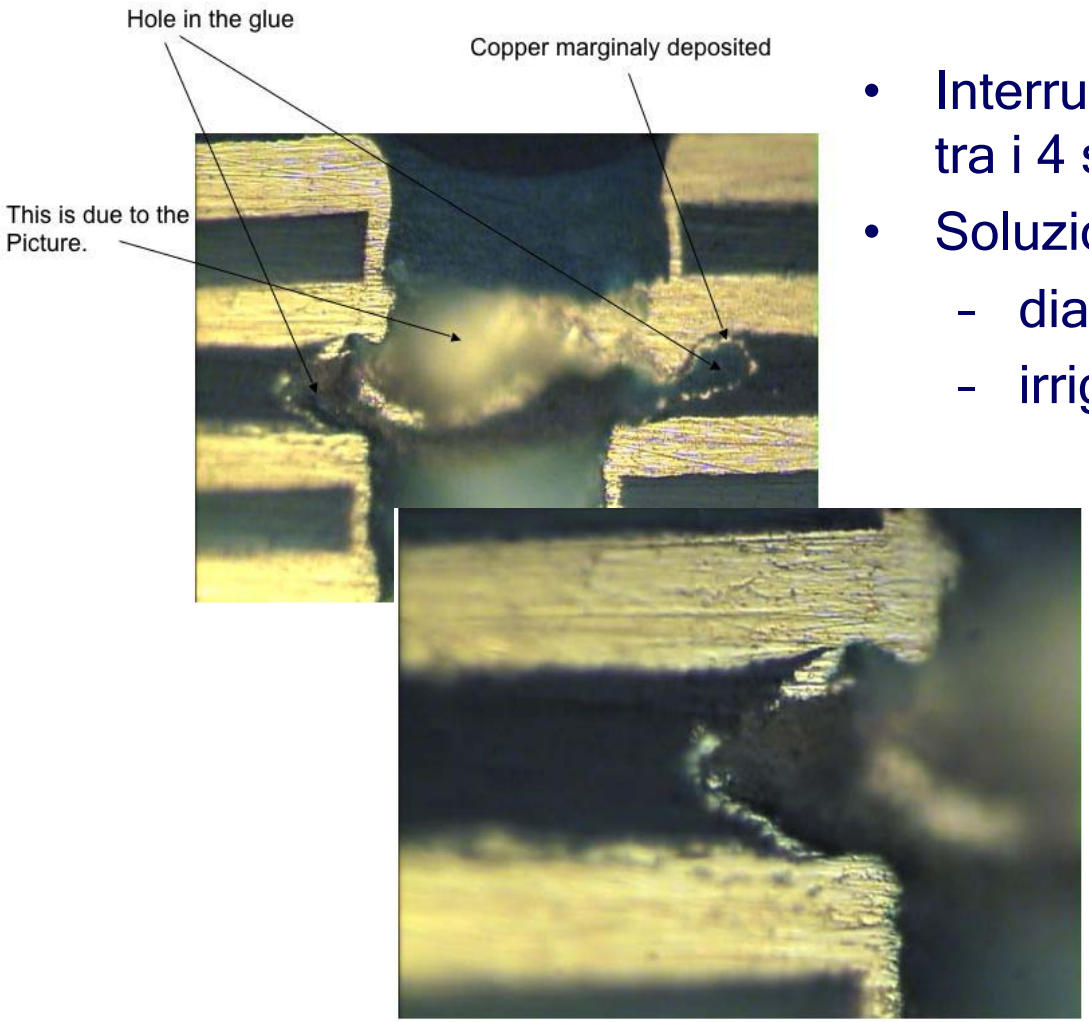


TEC

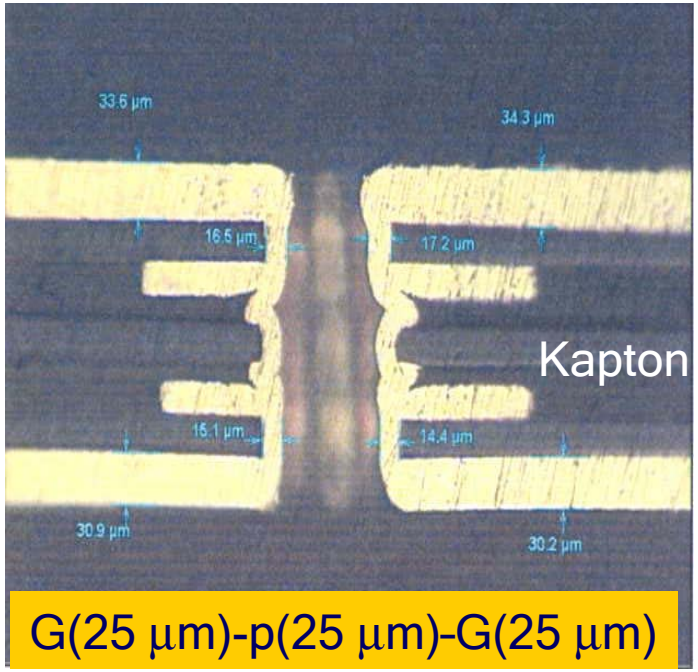


TOB

Gli ibridi di front-end



- Interruzioni nelle “viæ” di connessione tra i 4 strati degli ibridi
- Soluzione
  - diametro fori: 100 μm→250 μm
  - irrigidimento del supporto



G(25 μm)-p(25 μm)-G(25 μm)

Ritardo di 1 anno! (1/3 ibridi tot)

I sensori spessi (500 μm)

- Fabbisogno Tracker CMS
  - 6052 sensori 320 μm/bassa ρ (1-3 kΩcm)
  - 18192 sensori 500 μm/alta ρ (4-8 kΩcm)

- Fornitori: STM ed HPK

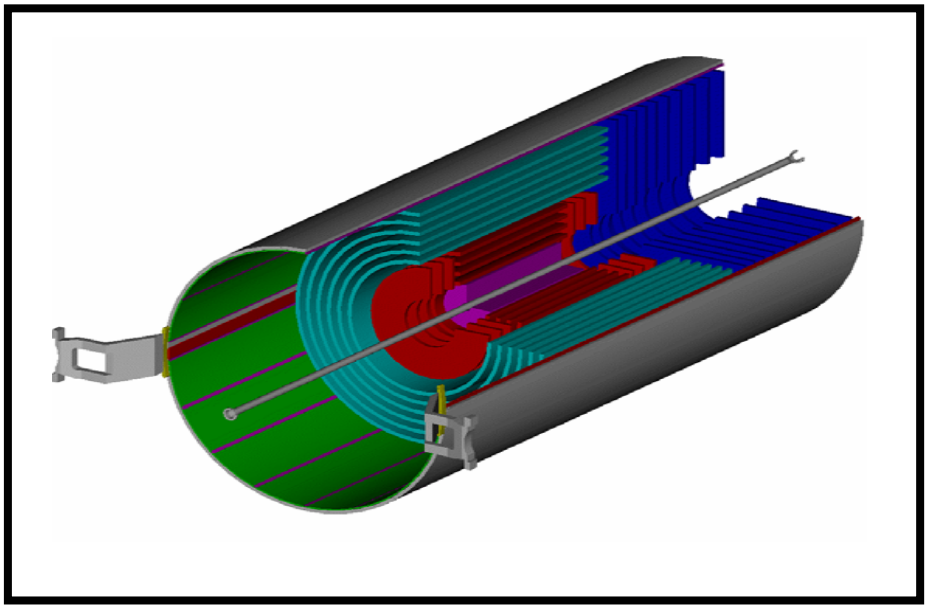
- Qualità produzione:
  - STM: instabile
    (i_{lk}@450V>10 μA, V_{fb}>5V, R_{int}@20V<1 GΩ, macchie…)
  - HPK: ottima (100% accettati)

	2001	Mar 04	Jul 04
320 μm	100% HPK	100% HPK	100% HPK
500 μm	100% STM	60% STM/40%HPK	15% STM/85% HPK

L'integrazione dei sottorivelatori

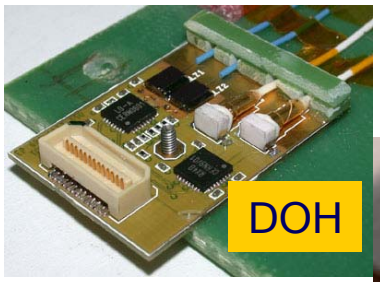
LV,HV
15 kA

digital
controls



cooling

analog
outputs

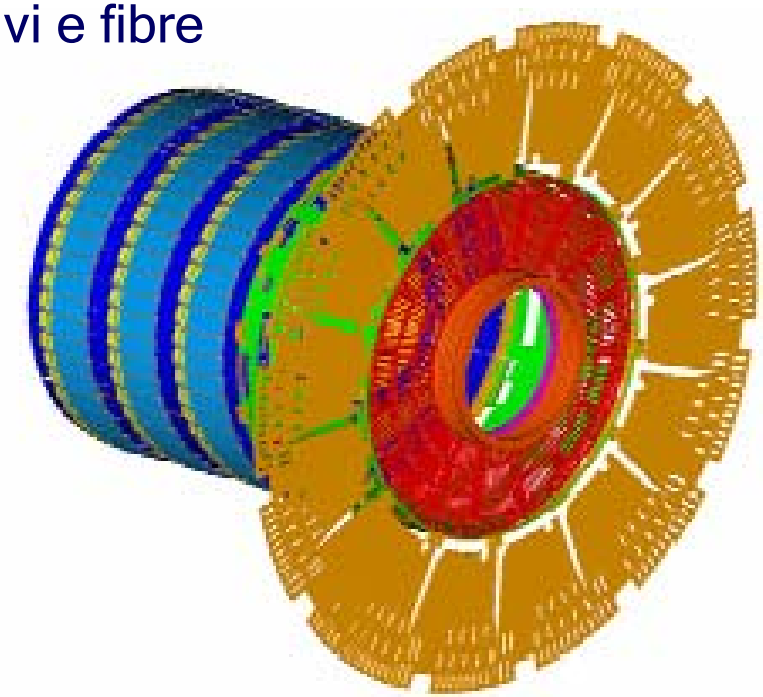


Integrazione del TIB/TID (I)

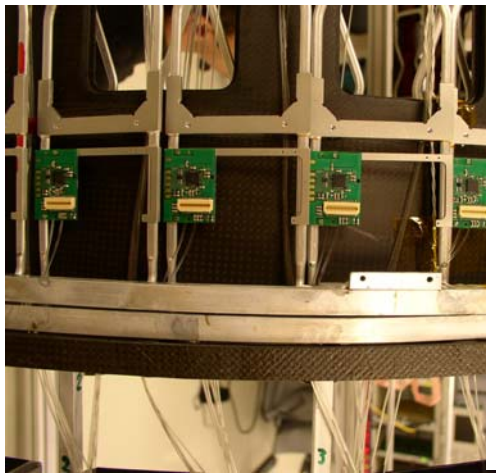
- 2 sottorivelatori: (TIB/TID)+ & (TIB/TID)-
- Per ogni sottorivelatore:
  - 4 cilindri composti da 2 shell l'uno
  - 3 dischi composti da 3 anelli l'uno

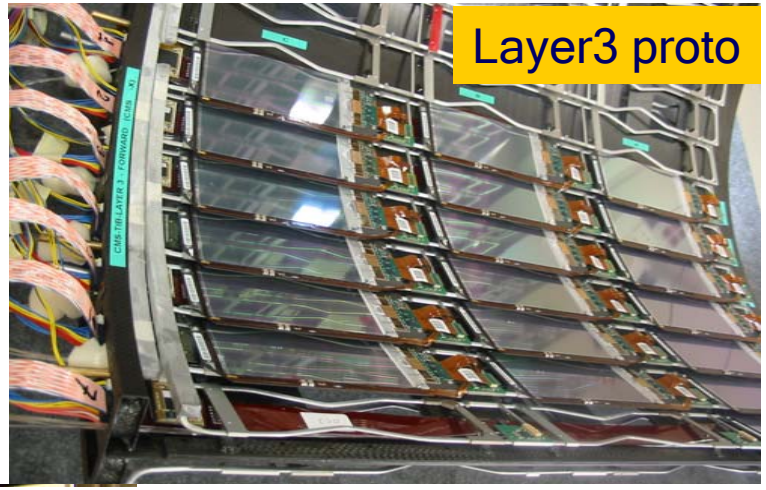
  "service cylinder" di supporto

  "margherita" di appoggio di cavi e fibre
- Integrazione effettuata in Italia (2xPI+FI+TO)



Integrazione del TIB/TID (II)





Sequenza di montaggio

1. Cooling pipes ed elementi di precisione sulle strutture di CF
2. DOHM
3. AOH e dispiegamento OF
4. mother cables
5. moduli
6. burn-in

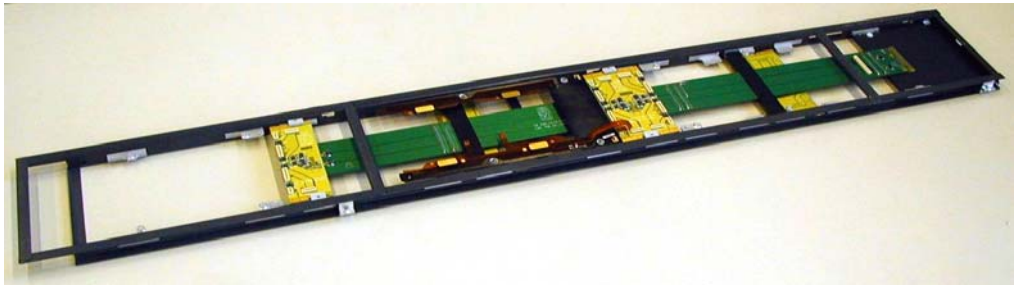
Rate integrazione

- L1/2: 3 mod/day
- L3/4: 7 mod/day
- TID: 7 mod/day

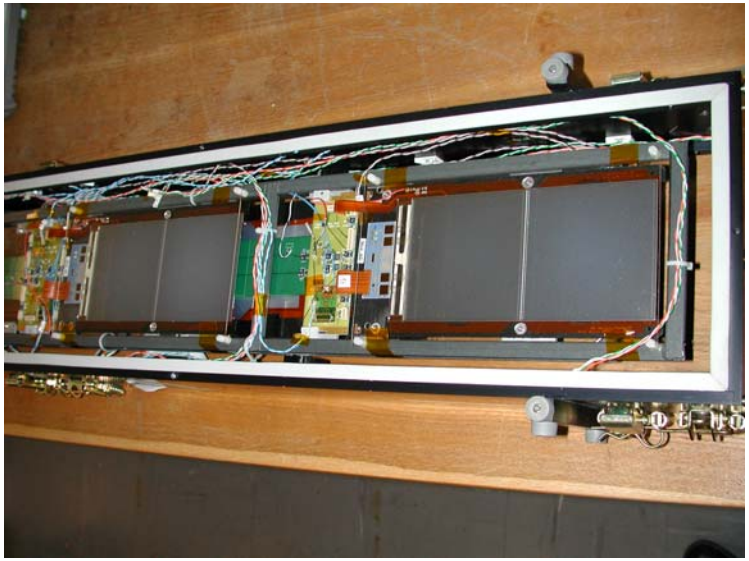
Attualmente “pronti” i moduli per allestire TIB+ (TIB/TID)+ 31Aug05

Integrazione del TOB

- Unità strutturale: “rod” (CCU, AOH, moduli) montata su “wheel” (DOH)
- 6/12 moduli per rod
- 2 rod: +z, -z
- 688 rod in totale



1. Produzione frames delle rods
2. Cablatura rod (CERN)
3. Montaggio moduli su rod e burn-in (US)



370/688 rod cablate
≈75% Layer5&6

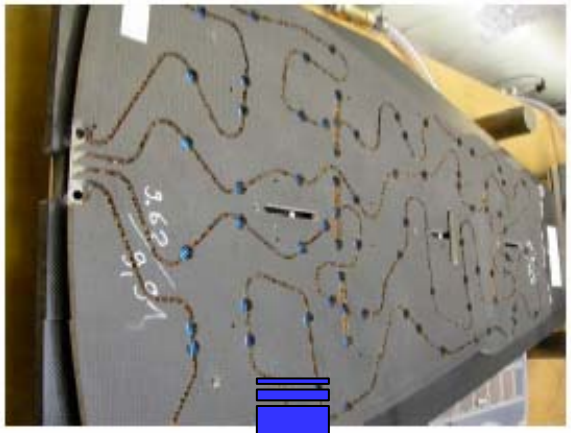
TOB+ Dec05

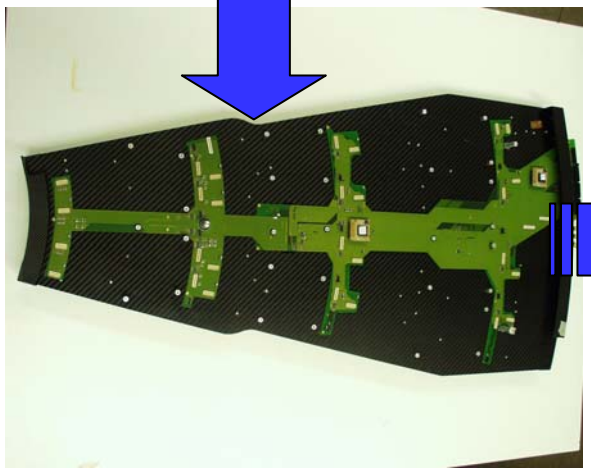
Integrazione del TEC

- Unità strutturale: “petalo” ($\Delta\phi$=22.5°)
- Settori (in z) di 9x2 petali
- 2x144 petali

1 petalo/wk per PIC
(50% LT test)

TEC+ Nov05





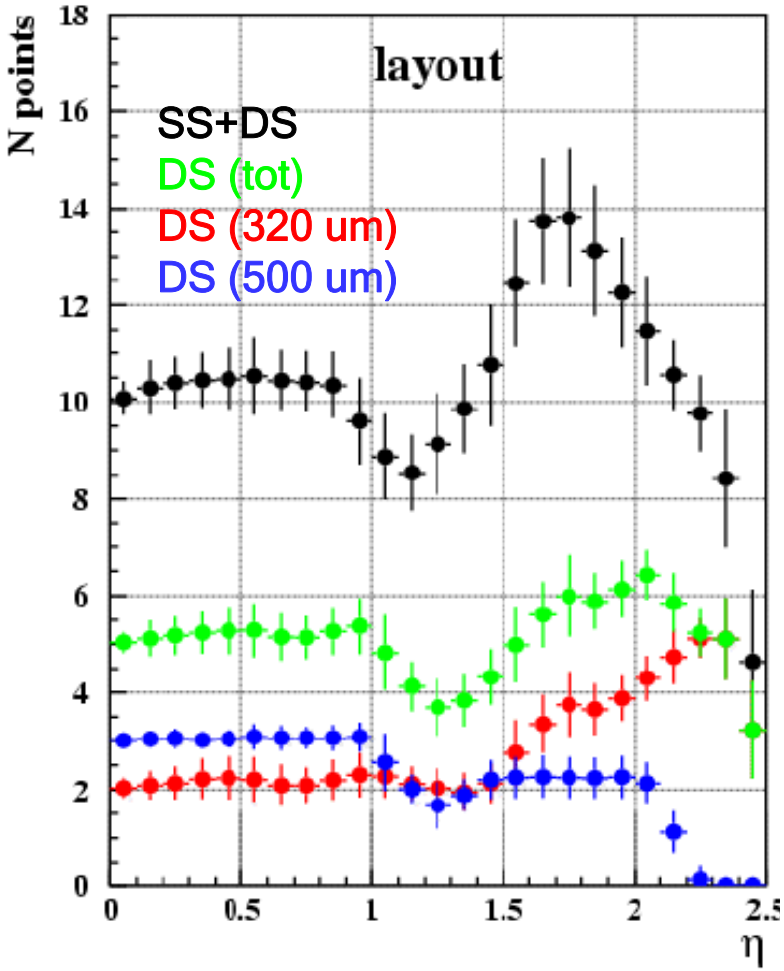
Conclusioni

- Tracker sulla critica/buona strada per CMS

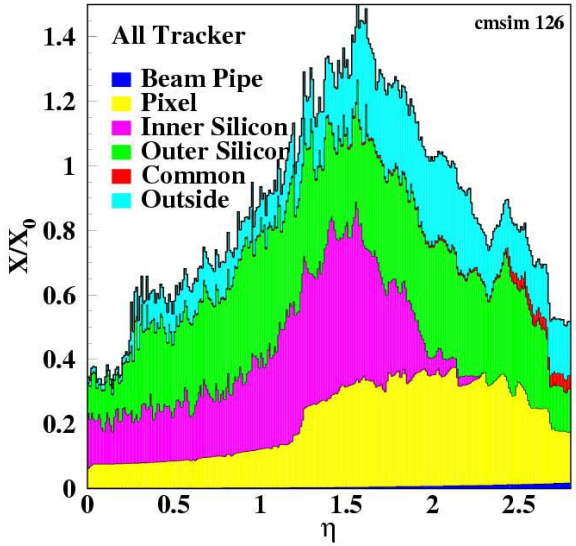
- Capacità di produrre rivelatori a μ-strip
  - su vasta scala (3000 moduli fatti finora ≈25 m^2)
  - di ottima qualità
  - con una produzione diffusa in molti passi/centri
- Sistemi complessi testati per intero in test beam

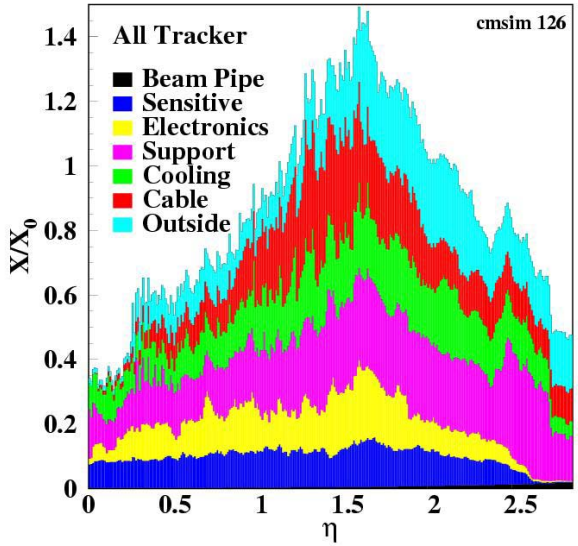
EXTRA SLIDES

Layout del Tracker



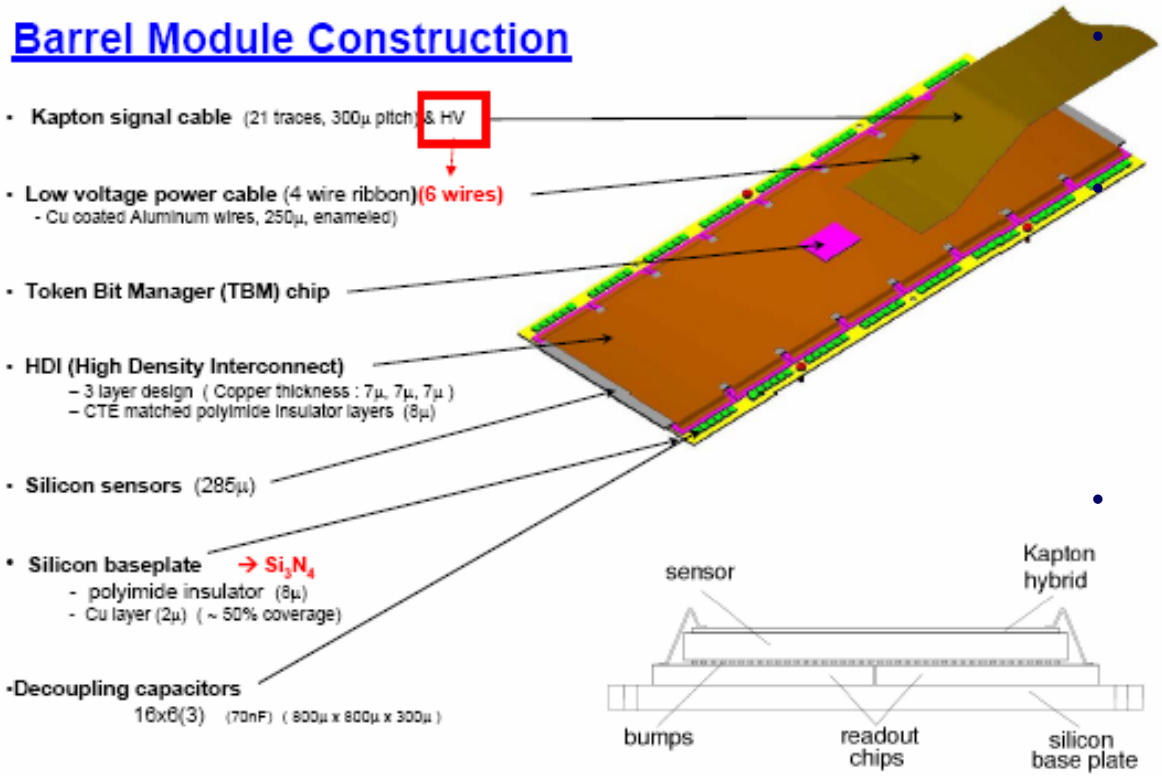
No pixels





Pixel

- 2 barrel layers
  - r=4.3, 7.2 cm
  - r=7.2, 11.0 cm
- 2 (x2) “turbine blade” end disks



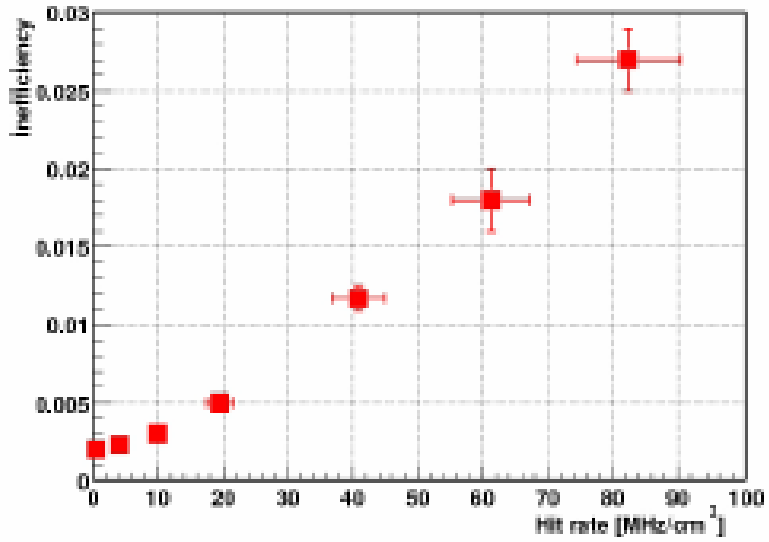
- 150 x150 μm^2 (θ_L=32°)
  ROC: 100x150 μm^2

  Pre-produzione del 10% dei sensori (*n*-in-*n* ox-Si con *p*-spray) dei layer 1&2 del barrel
  $\Phi=10^{15}/cm^2$ (TDR:$\Phi=6x10^{14}/cm^2$)

  V_{bkdn}>600 V
- Verifica funzionamento di moduli con chip bump-bonded su fascio al PSI

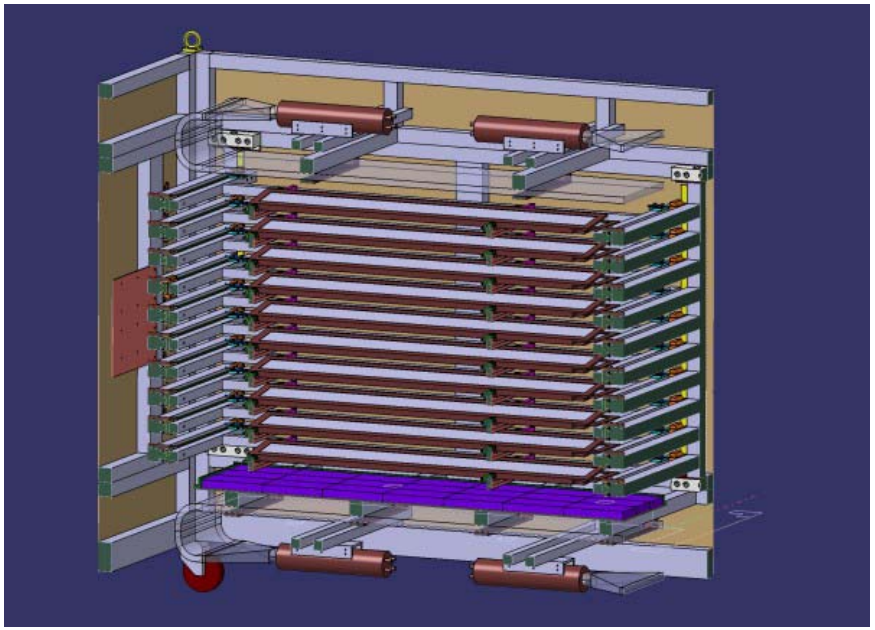
  π p=350 MeV, 25MHz/cm^2 $\leftrightarrow$LHC r=4 cm
  eff=99%

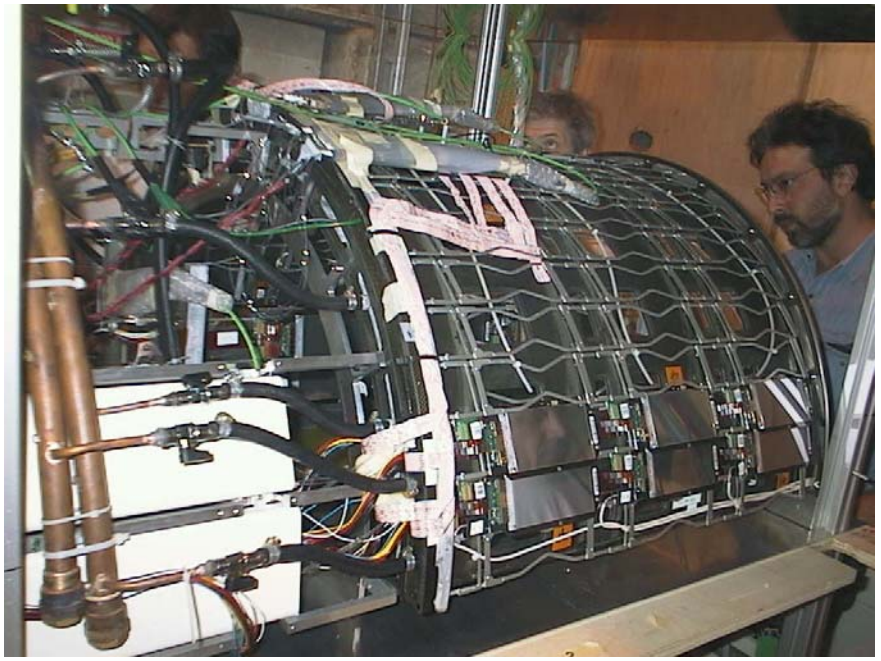
Pixel


Inefficiency
0.03
0.025
0.02
0.015
0.01
0.005
0
0
10
20
30
40
50
60
70
80
90
100
Hit rate [MHz/cm^2]

Test Beam

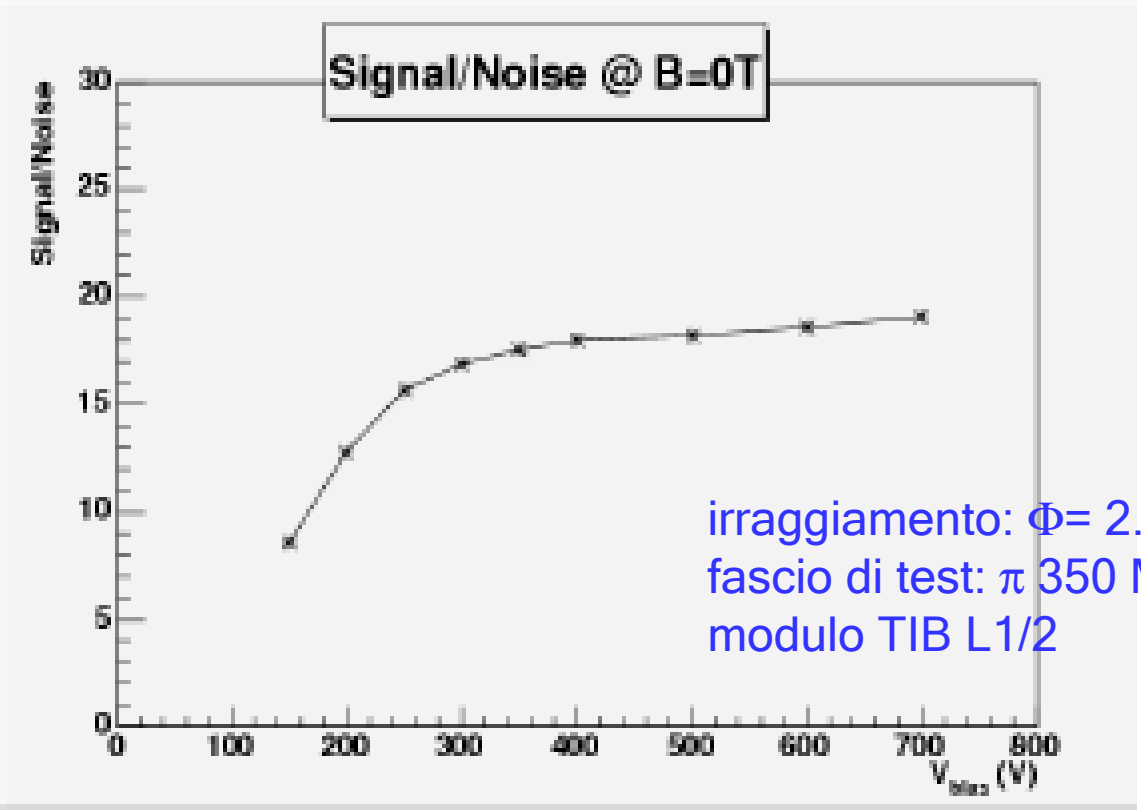
- Test di strutture:
  - C(osmic)RACK :20 rod del TOB
  - Prototipo TIB layer 3





Test Beam

- Test su moduli di produzione irraggiati (PkOn)

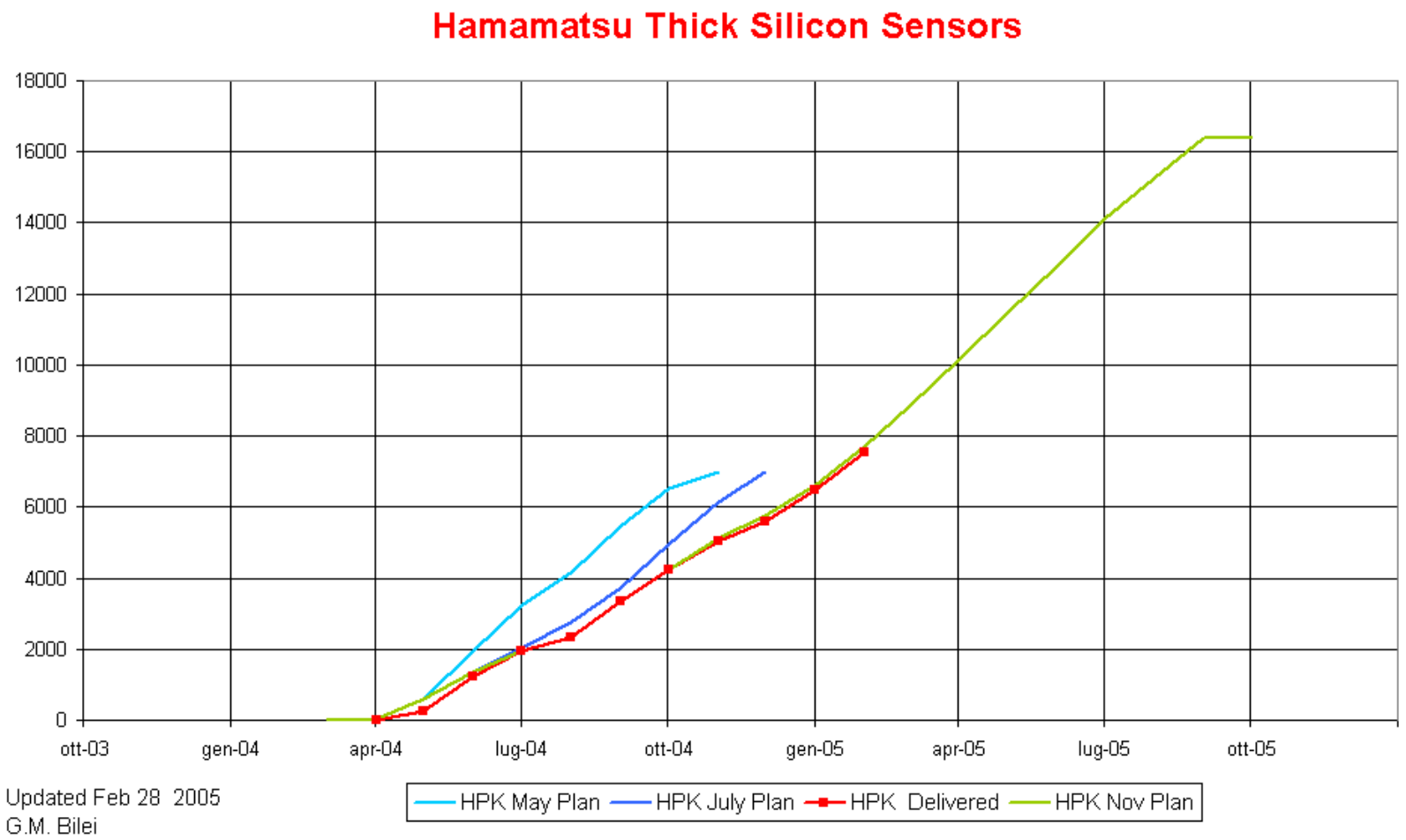


irraggiamento: Φ= 2.0 10^{14}n/cm^2 (10 yr@LHC)
fascio di test: π 350 MeV
modulo TIB L1/2

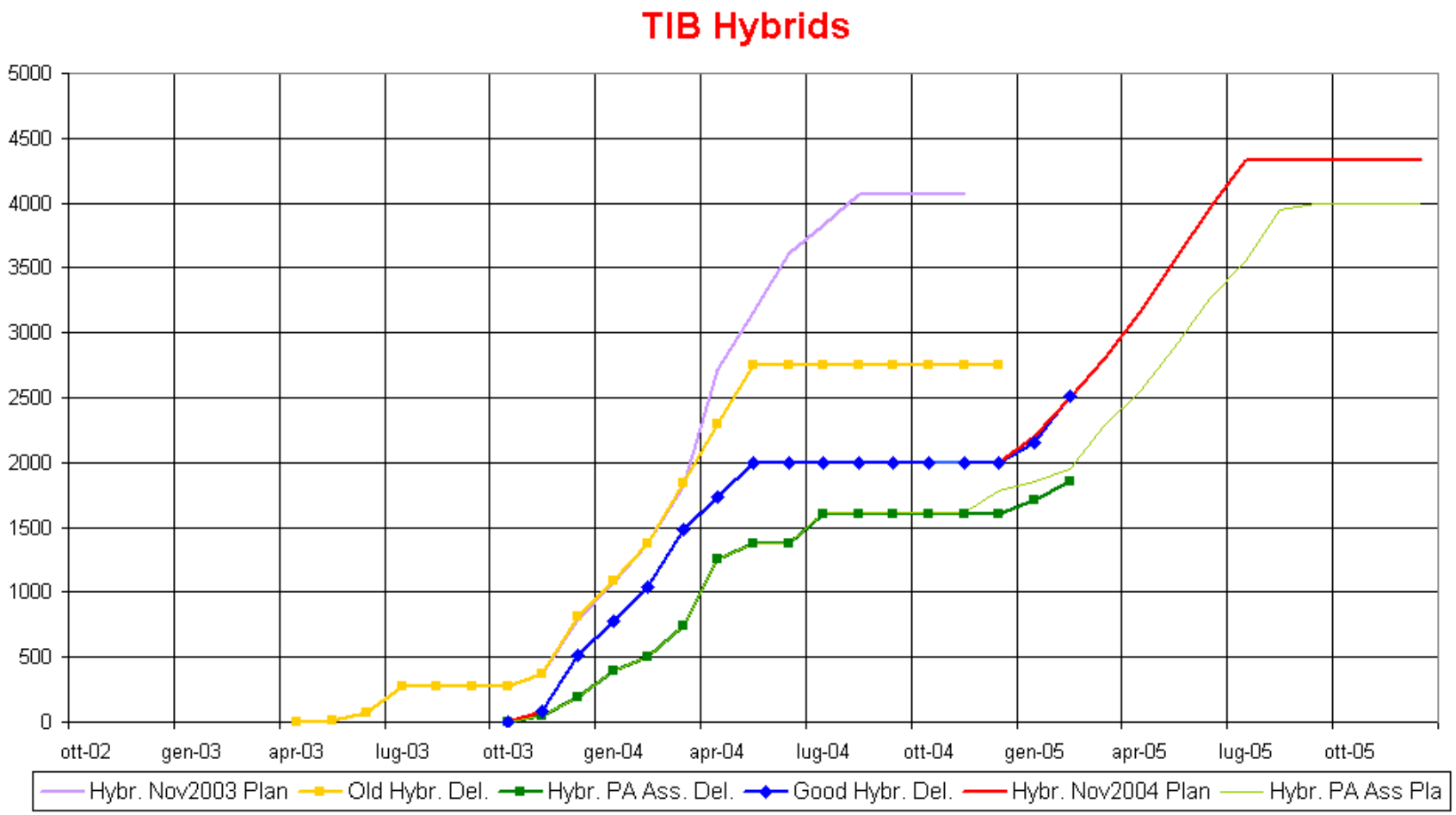
Gli ibridi di front-end

- Ritardo di 1 anno nella “schedule” di produzione
- Attualmente (week 11)
  - 5500 ibridi funzionanti (kgh): 1/3 dei necessari
    3300 “vecchi” + 2200 “nuovi”
    300 kgh/wk $\rightarrow$ 400 kgh/wk
- Composizione per tipo di modulo
  - TIB : 2400 (60%)
  - TOB: 1600 (28%)
  - TEC: 1500 (22%)

Schedule (I)


Hamamatsu Thick Silicon Sensors
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
ott-03
gen-04
apr-04
lug-04
ott-04
gen-05
apr-05
lug-05
ott-05
Updated Feb 28 2005
G.M. Bilei
HPK May Plan
HPK July Plan
HPK Delivered
HPK Nov Plan

Schedule (II)

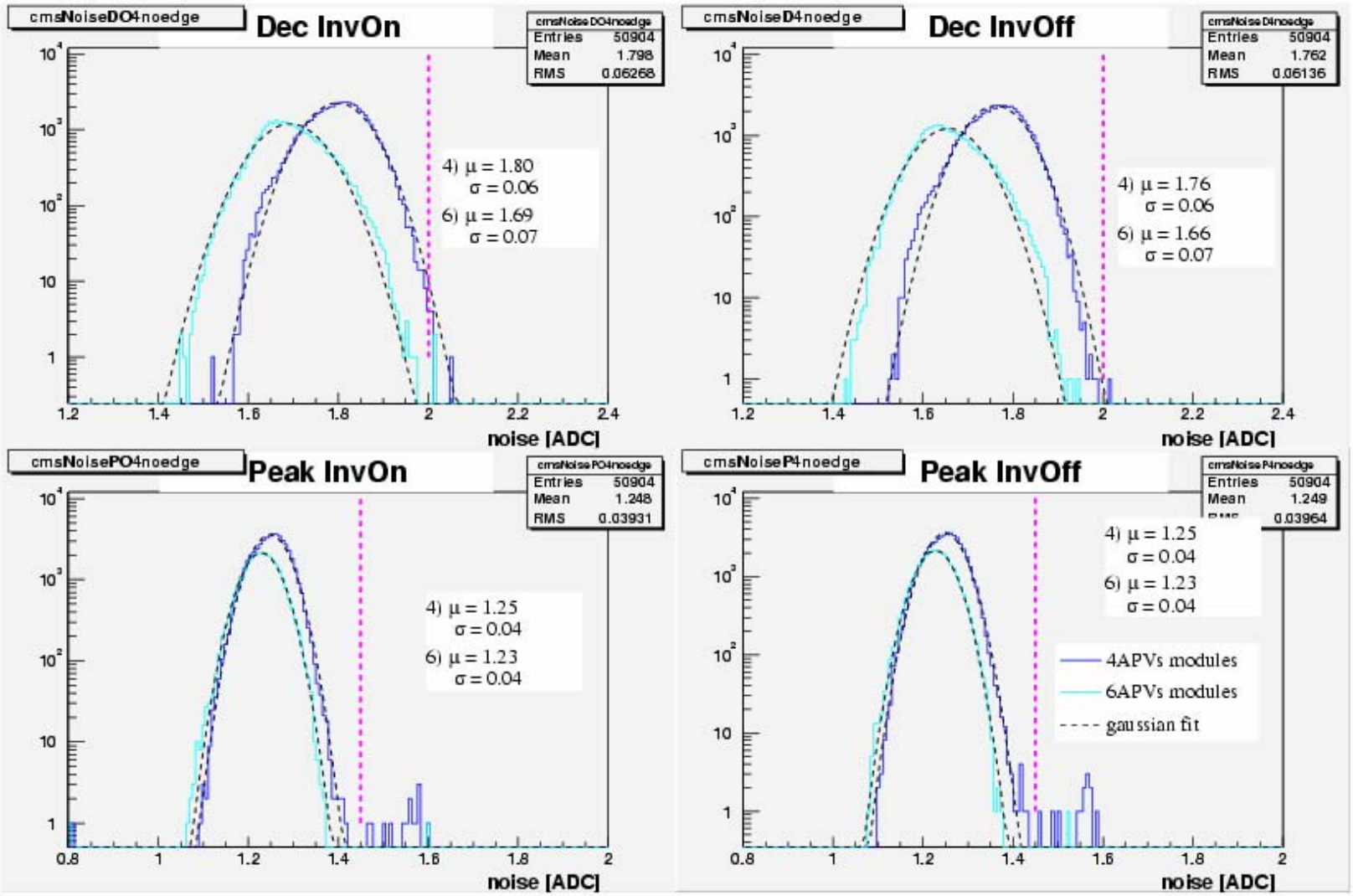


Updated Feb 28 2005
G.M.Bilei

Qualità dei moduli (I)

$CMN_{dec} \approx 0.45$ ADC

$CMN_{pk} \approx 0.3$ ADC



Qualità dei moduli (II)