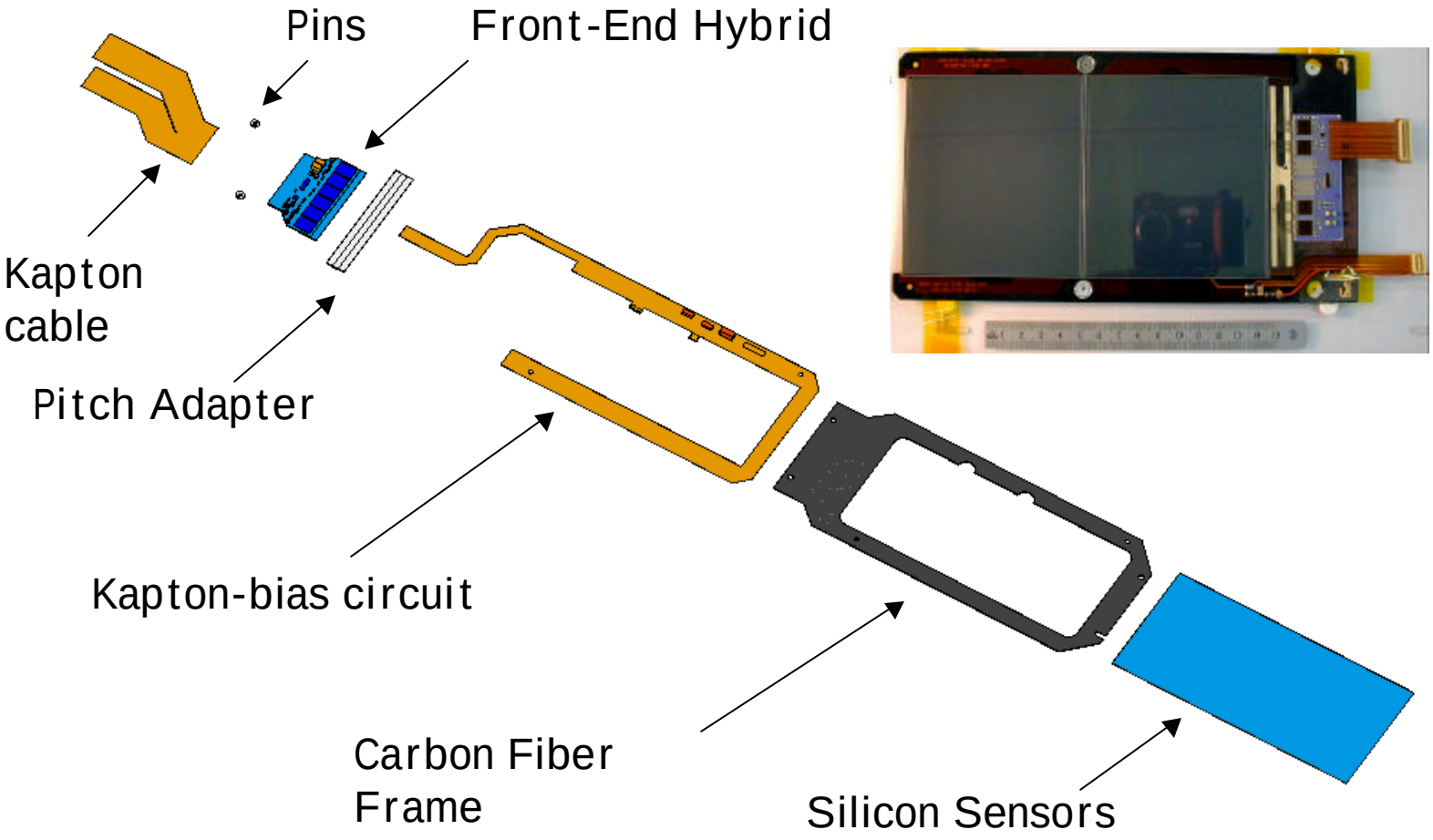
Tracker Outer Barrel Silicon

Slawek Tkaczyk

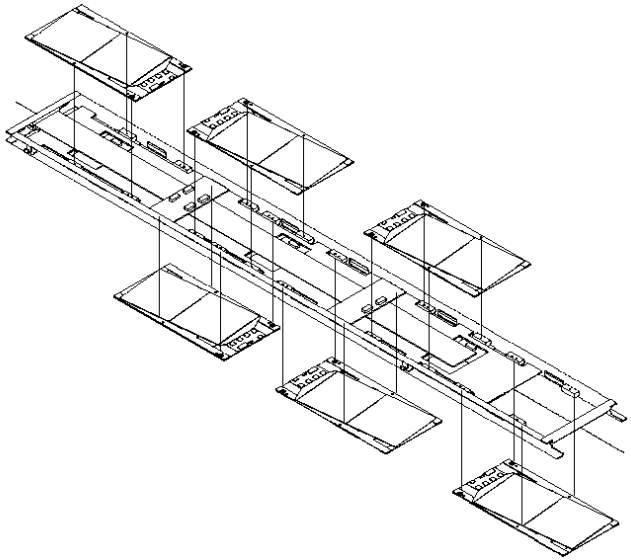
Fermilab

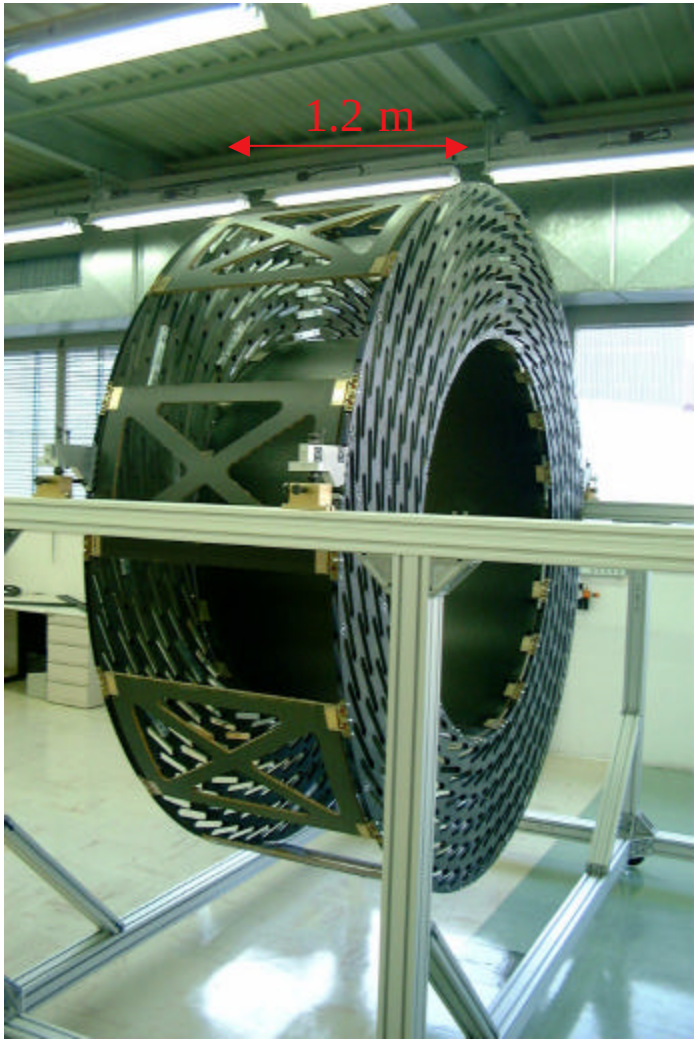
US CMS Silicon Tracker Project

Module Components

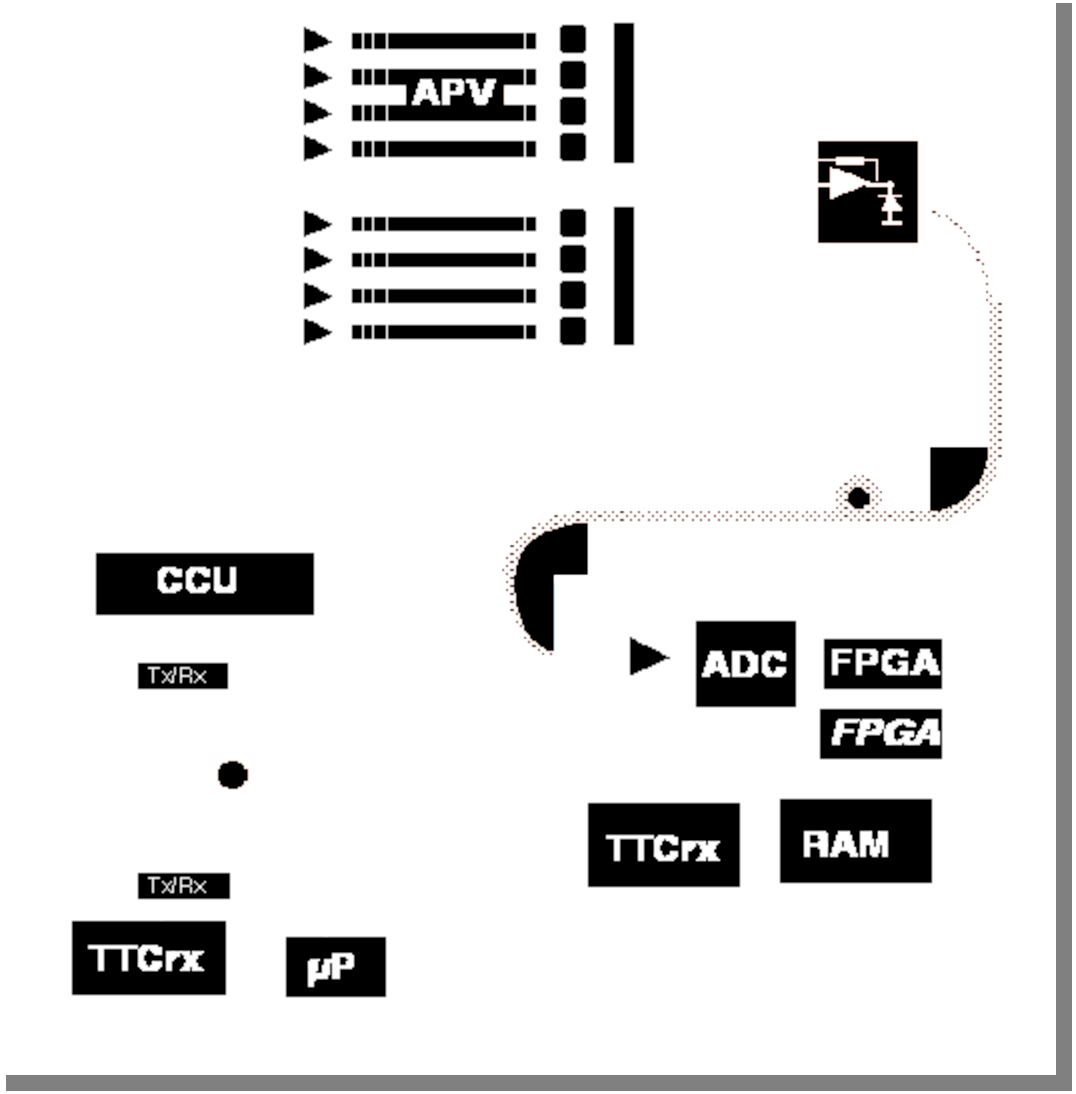


Rods





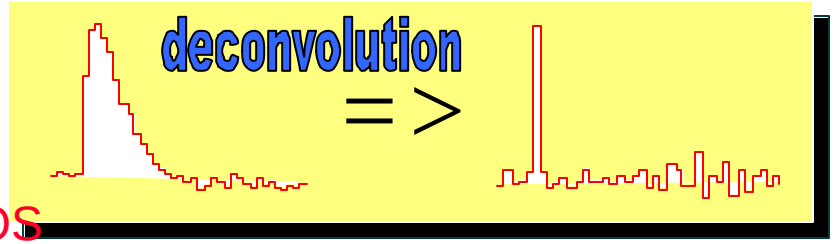
Tracker Readout System



APV History

Pre-history

- 1991… RD20 & deconvolution principle



1992 CMS LoI

1.2µm Harris AVLSIRA radiation hard CMOS

- 1993 - APV3 - 32 channel pipeline chip implementing CR-RC shaping and 3-weight deconvolution signal processing

1994 CMS TP

- 1995 - APV5 - 128 channels with addition of analogue multiplexer
- 1996 - APV6 - 128 channels with analogue multiplexer, bias generator, calibration control, and I^2C interface. Full CMS read-out functionality.
- 1998 - Development of APV6 into MSGC read-out chip, APVM

1998 CMS Tracker TDR

0.8µm DMILL radiation hard CMOS

- 1997-99 - APVD - development of DMILL versions

0.25µm CMOS

- 1998-2000 - development of APV25

1999 CMS all-silicon Tracker

Critical Path Items

- The Si-Tracker group is presently evaluating a recently discovered feature of the APV25.
- The ‘feature’ manifests itself in two related ways - see the next few slides.
- It is very unlikely that the APV25 will be re-designed at this point.
- A test beam study in mid-May should hopefully resolve the remaining concerns-data analysis in progress.
- **These higher order concerns should in no way detract from the otherwise superb performance of the APVs.**

Four chip TOB hybrid

HIPs and Pinholes

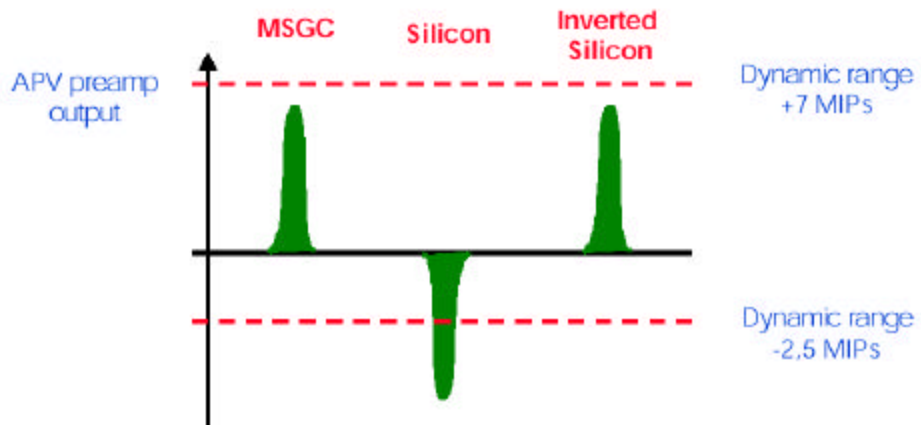
HIPs

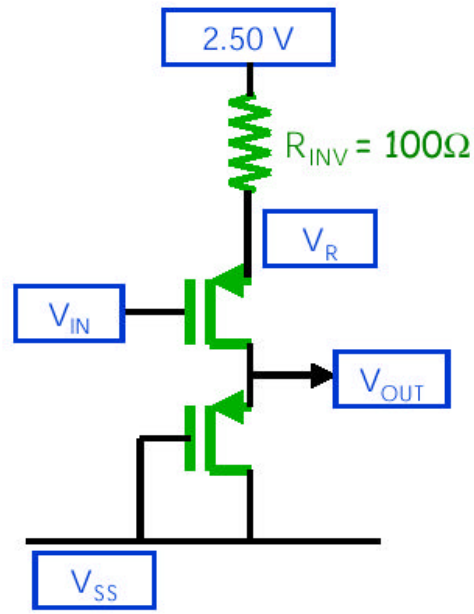
- Highly Ionizing Particle (1000X minimum ionizing) resulting from nuclear interactions in the silicon.
- These are rare events.
  - 3.9×10^{-4} per 500μ layer per incident pion.
- Rates confirmed in the recent exposure in the PSI test beam
- HIPs lead to large signals on a few strips.
  - This can saturate (disable) the entire APV (128 channels) for ~200 ns.

Pinholes

- Detector strips are capacitively coupled to the APV.
- The capacitors can occasionally be shorted (pinhole).
  - Leads to a DC current **into** the APV.
  - If enough pinholes are present the APV will be **permanently** disabled (until the pinholes are removed).

MSGC Legacy



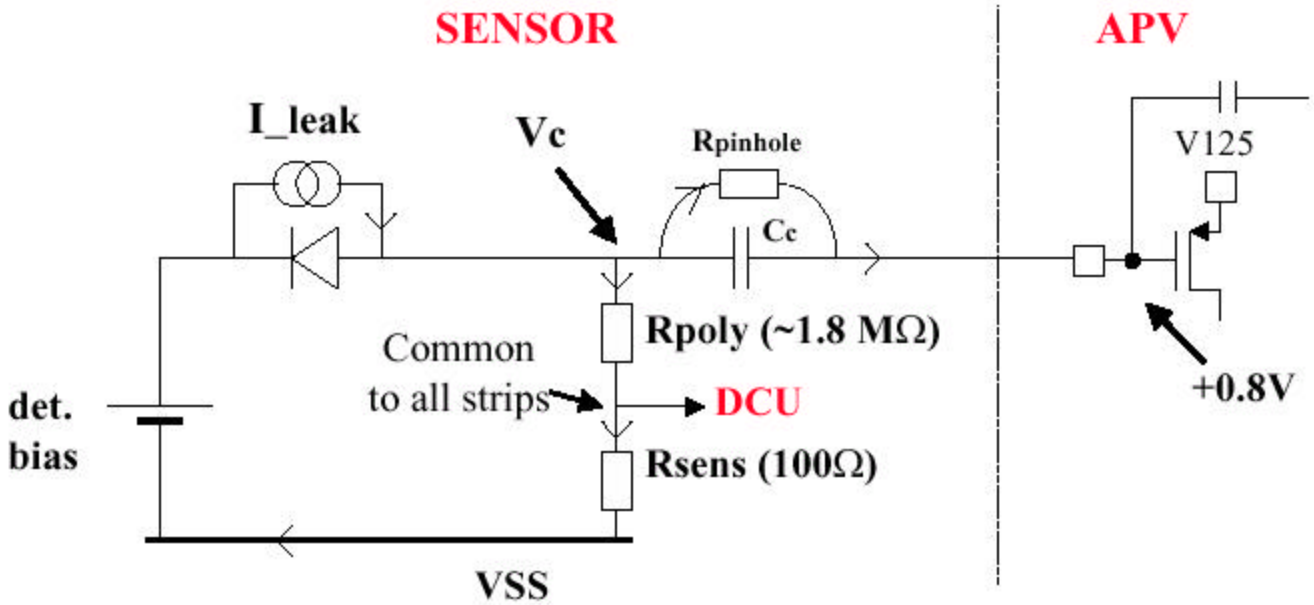


- **Big signal from silicon (holes) gives -ve pulse at V_{IN} :**
  - Inverter FET switches hard on, which steals current from 127 other inverters. (APV disabled until capacitor discharges.)
  - N.B. If R_{INV} were reduced, total current available to inverters would increase.

- **Leakage current via pinhole into APV :**
  - Same again, but permanent.

- **Leakage current via pinhole out of APV :**
  - Inverter FET switches hard off. Takes no current, so other 127 channels still work.

Bias Circuit

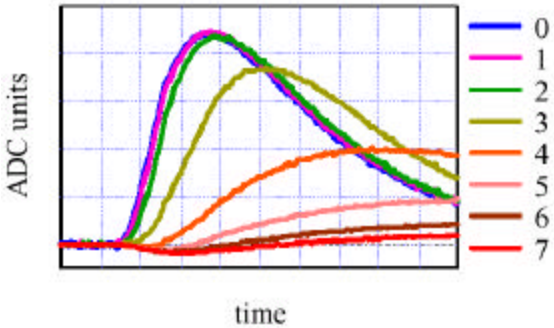


If Vc > 0.8 Volts, current flows into APV via pinhole (BAD).
If Vc < 0.8 Volts, current flows out of APV via pinhole (OK).

V_c will exceed 0.8 V in old (irradiated) detectors with large leakage current.

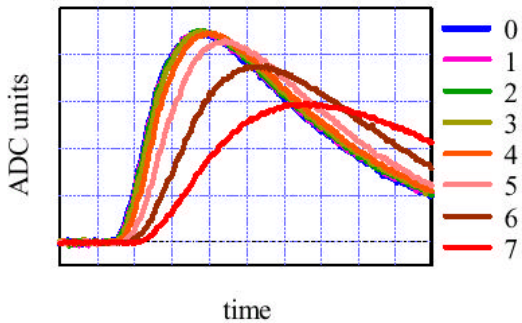
Number of Pinholes

Inject 1 μA of (pinhole leakage) current into 1-7 APV channels.
Then inject a 1 MIP charge into 1 other channel and see what it looks like:



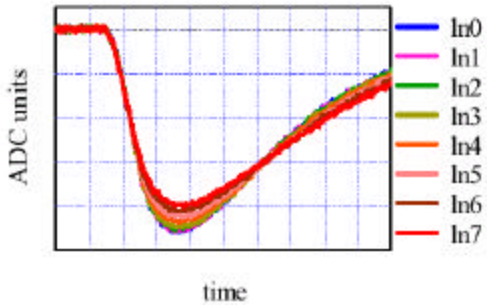
Rinv 100 Ω

Signal suffers if more than 2 pinholes



Rinv 50 Ω

Signal suffers if more than 4 pinholes



APV inverter off

Signal OK for more than 7 pinholes (but reduced dynamic range)

APV Concerns in Perspective

- Both HIP events and pinholes (after installation) are very rare.
  - CDF and D0 Run IIa: “A few pinholes”.
- Both problems can be mitigated by changing R_{inv} from 100 to 50 ohms.
- In cases where there are more than 4 pinholes per APV the inverter can be turned off (with loss of dynamic range).
- It may be possible to avoid the pinhole effect by applying a small voltage to the bias ‘ground’.
- The test beam activity at PSI in 15-21 May 02 confirms the understanding of the HIP effect.

FE hybrid status

- Industrial hybrid (V0 – unpackaged chips on thick film ceramics) production started with two producers. Over 160 hybrids delivered by one vendor (yield 65%).
  - A lot of little problems in manufacturing or final assembly ("the feature size" is too small for mass production; difficult cable attachment).
- The 2nd producer had problems with shorts – a handful delivered.
- (V1) Design of this version of the hybrid (packaged chips on ceramic) is done. Order will go to 1st producer after delivery of the 160(x0.65) hybrids
- (V2) 40 hybrids of this type (packaged chips on FR4) were received in Strasbourg. 10 have been populated and they look okay.
  - Robust media but needs to be evaluated –e.g. thermal issues

Hybrid- New Technology Decision

- New Candidate Technology: monolithic FR4 (kapton cable is part of the hybrid)

- At the next CMS Week in June ’02 the technology will be chosen

- Issues to be addressed by June are:
  - Mounting scheme: should hybrid be glued on a rigid substrate (CF or graphite) before adding pitch adapter;
  - Radiation hardness;
  - Electrical performance;
  - Thermal performances;
  - Price;

Hybrid- Delivery Schedule

- Decision expected in June'02
- 10-20 FR4 prototypes being done
- It takes 6 months from the decision 'till deliveries of first production FR4 hybrids (bidding, order placement, fabrication, etc.)
- First hybrid from production order expected in Jan'03
- A short order (~1000) will be placed after positive decision resulting in hybrids delivered in October '02.

Status of Component Orders

- Sensors: Contracts signed
- Frames: Tender finished
- Pitch Adapters: Market Survey (MS) done, Small orders done/prepared
- APV25 Chips: small fraction available
- Other ASICS (PLL, MUX, DCU): being packaged
- FE Hybrids: Technology decision imminent….
- Optoelectronics: Tenders (4) finished and LOI sent for some contracts

Module Testing at SiDet

ARCS (2/7)

CMS DAQ (3/4)

Two PC-based test systems are now in operation at SiDet. The DAQ system represents a pre-prototype version of the final system.

Rod Testing

- Plan is to perform module burn-in once rods are assembled
  - We are studying use of commercial chest freezers and commercial chillers for the burn-in facility
  - We're in discussion with CERN physicists and engineers to specify the thermal-cycling tests to be done during burn-in.
  - This will drive the design of the cooling and controls.
- We hope to prototype much of the system this summer/fall.

Conclusions

- The U.S. CMS Si-Tracker effort is part of a larger effort to build the CMS Tracker system.
- Our project relies on timely deliveries of quality components from European collaborators and assemble these into modules and rods.
- Viability of the final APV25 + hybrid designs are being finalized.
- The first news from the Test Beam look promising.
- The current schedule has us starting production in early 2003.