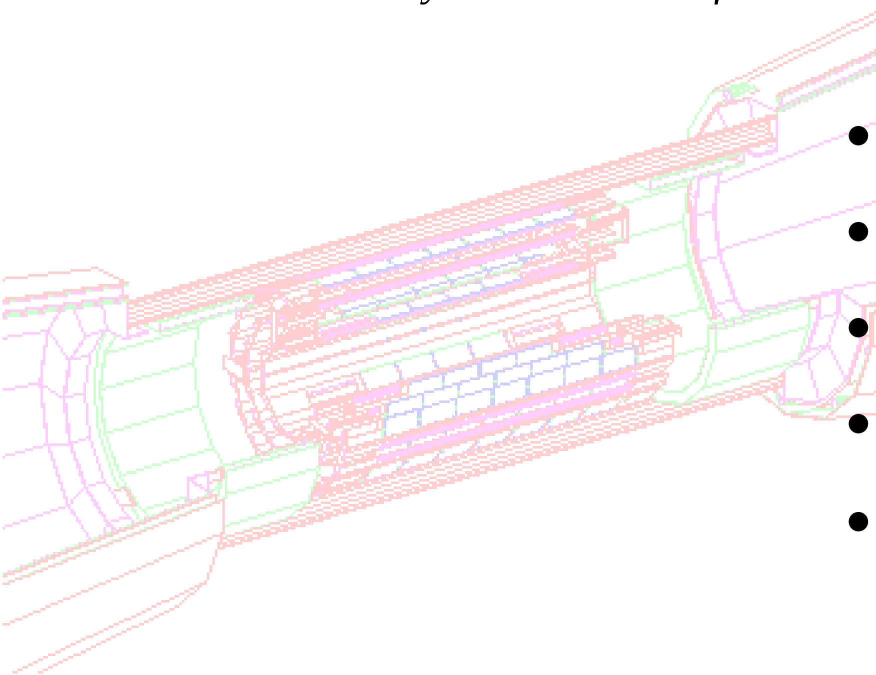
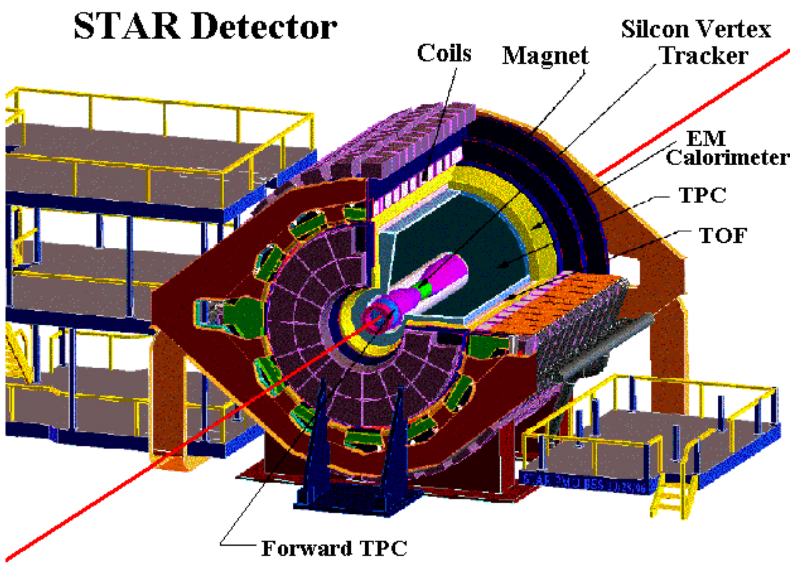
Silicon Drift Detectors
as
Tracking Devices

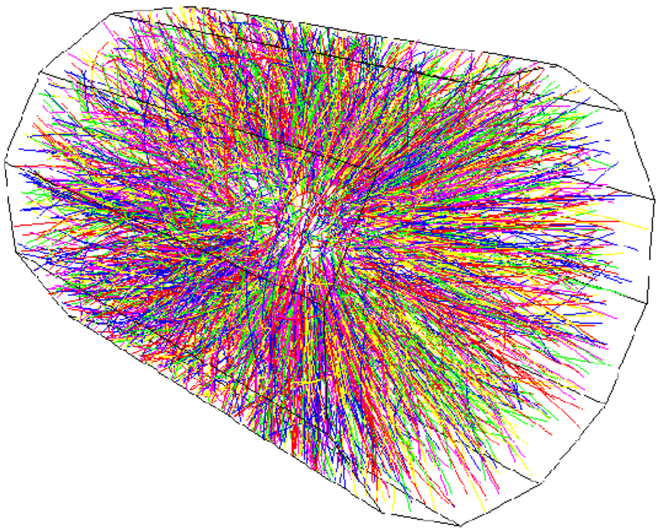
by Jun Takahashi for the STAR/SVT Collaboration



- **The STAR-Silicon Vertex Tracker**
- **Silicon Drift Detectors**
- **Performance of SDD**
- **Recent application in E896**
- **SVT present status**

The inner tracking detector of the STAR experiment



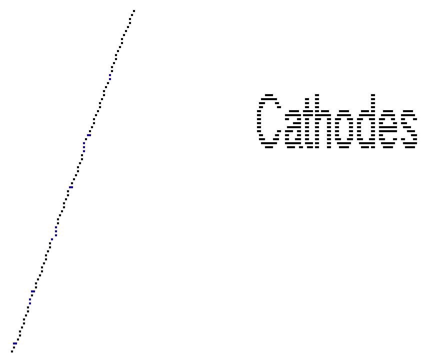


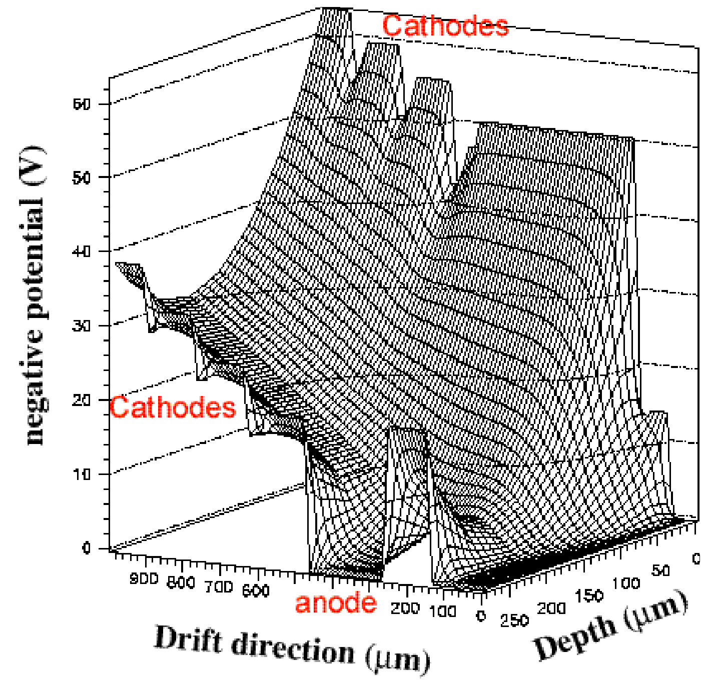
- Improve primary vertex reconstruction.
- Enhance momentum resolution.
- Increase acceptance for low momentum particles.
  TPC alone p_t>150 MeV/c
- Increase reconstruction efficiency for weakly decaying particles.

Requirements for inner tracking detector

SVT requirement	Technology requirement
High occupancy (2500 charged particles/event).	High position resolution.
Good momentum resolution.	
High tracking efficiency.	Maximum active area.
Maximum coverage.	Large area detector with reduced number of readout channels.
Low cost.	
Particle identification through dE/dx	Good energy resolution.

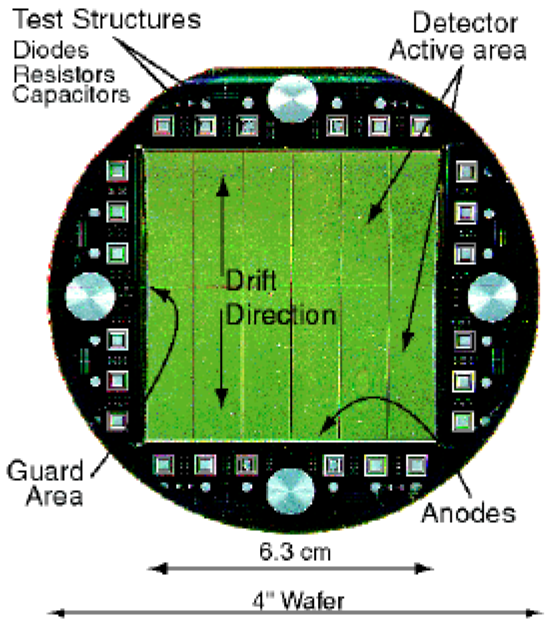
Silicon Drift Detectors

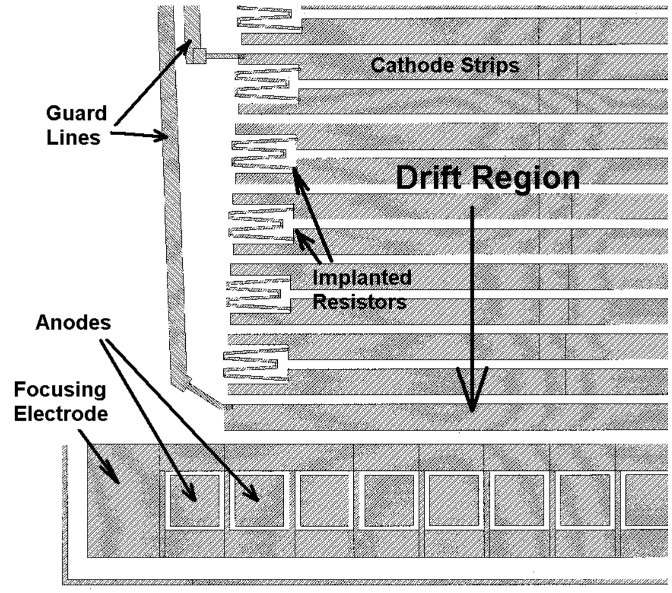




- Proposed by E.Gatti and P. Rehak.
- Unambiguous 2 dimensional position measuring devices with one dimension readout. (Anode position & drift time).
- Low capacitance anodes (low noise, ~500e$^-$ for SVT).
- Low number of read-out channels.

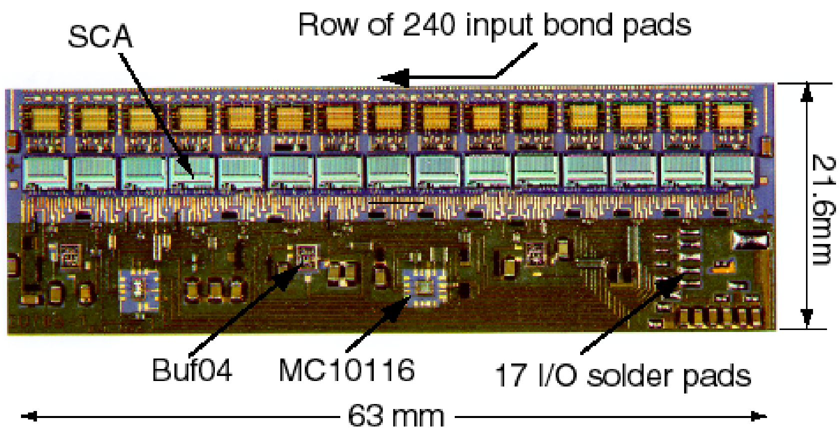
STAR/SVT Silicon Drift Detectors

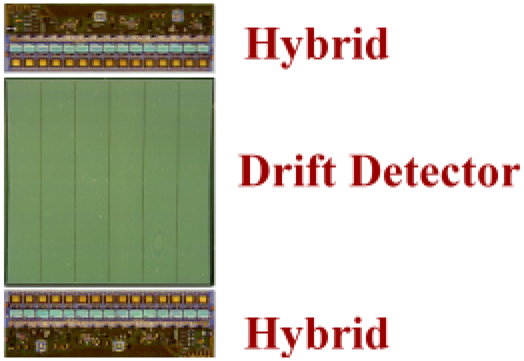




- 6 ´ $6\ cm^2$ active area.
- 4" NTD type silicon wafer with a resistivity of 3 kΩ cm.
- 300 μm thick, MIP~25,000 e^-
- 2×240 anodes, (spacing of 250 μm).

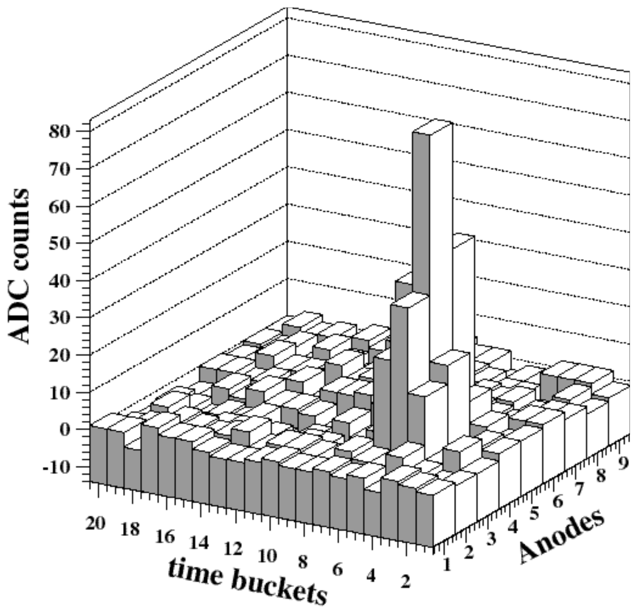
Front End electronics

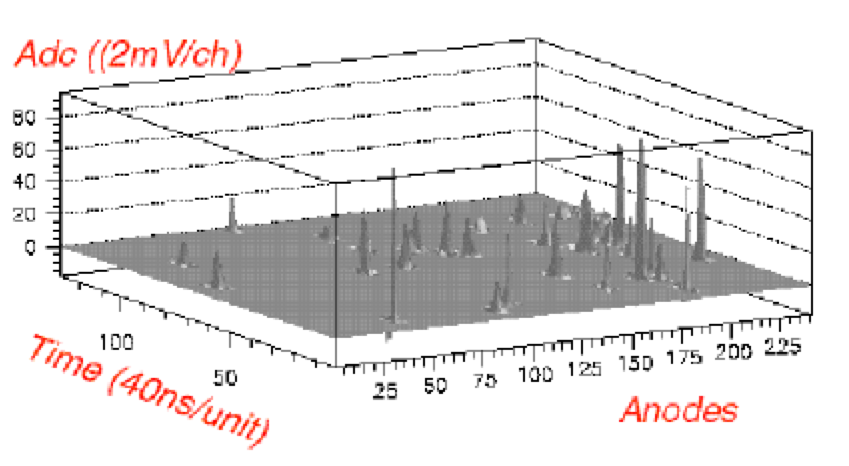




- **Beryllia substrate multi-chip hybrid carrier.**
- **15 PASA chips:**
  Pre-amplifier/Shaper integrated circuit based on bipolar technology
  16 input/output channels with gain factor of 7μV/electron
- **15 SCA chips:**
  Switched capacitor array based on CMOS technology
  Circular buffer with 128 capacitors with clocking frequency of 25 MHz
- **Readout time:** 4 μs drift time, and 5 ms readout of all SVT wafers.

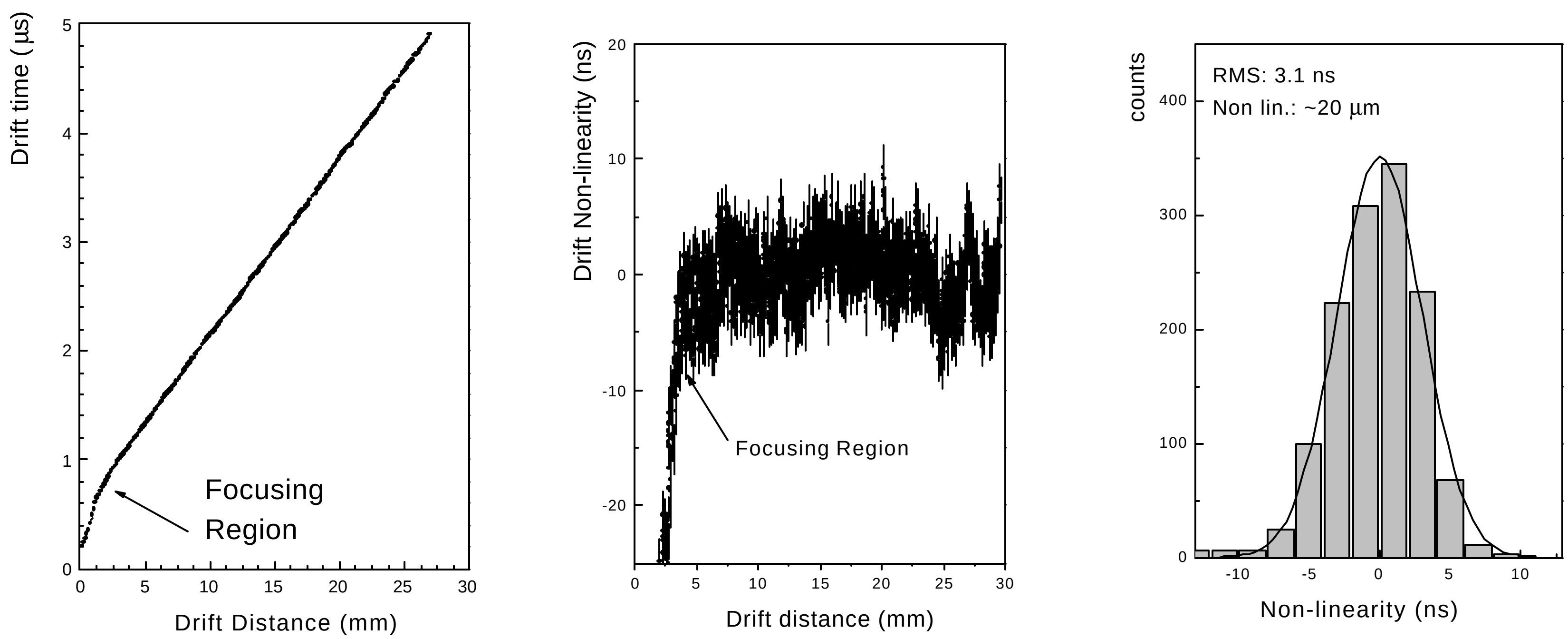
Hits in the SDD





- 240 anodes with a spacing of 250 μm.
  128 time buckets of 40 ns, ~250 μm.
- MIP-Hit cluster size: 4 anodes × 6 timebuckets = 24 pixels.
- Charge sharing between pixels allows better position resolution.

Drift Linearity and position resolution

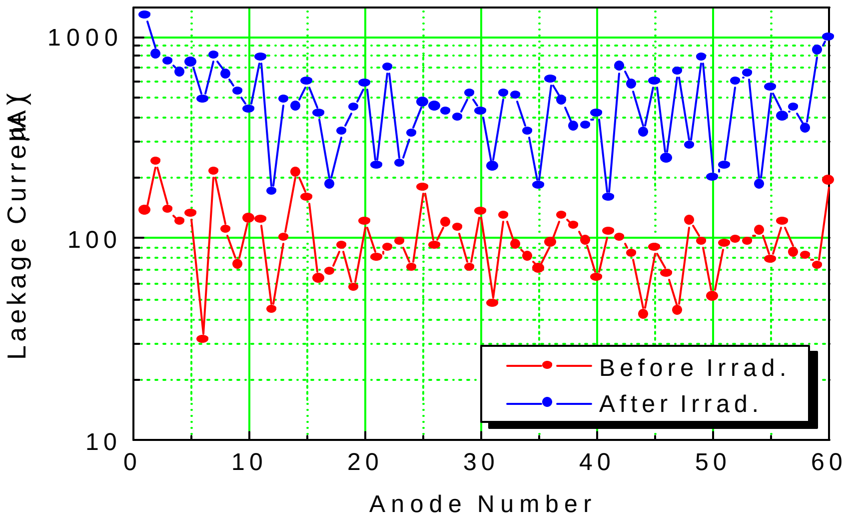


- Drift non-linearity: ~20 µm.
- Position resolution in anode direction: ~10 µm.

Radiation Hardness of the STAR-SDD

- RHIC expected luminosity: 2×10^{26} /cm^2-s
  Ionizing radiation load on the first layer of the SVT: **1Krad per year**
  Total fast neutron flux per year: **5×10^9 n/cm^2**

- Detector and front-end electronics irradiated up to:

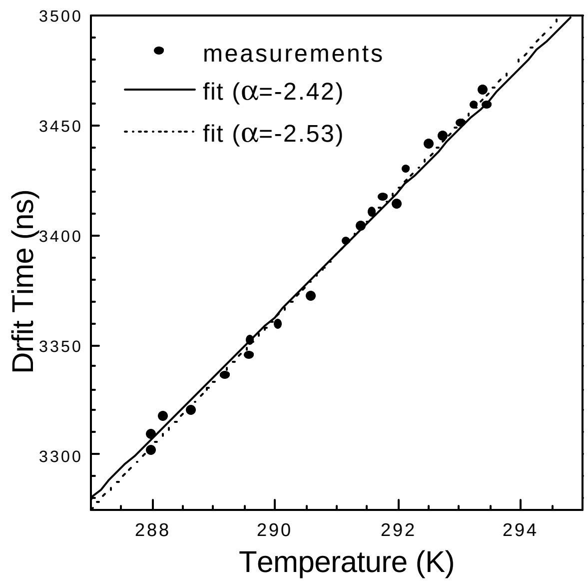


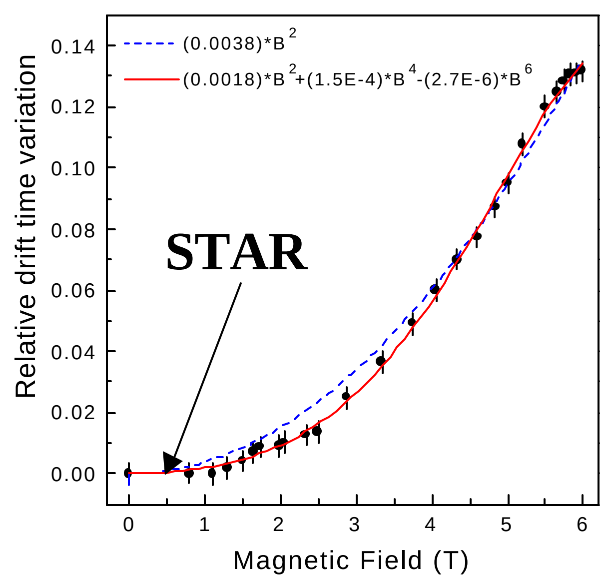
neutron-radiation: 10^{12} n/cm^2
g-radiation: 23 Krads

Effects:
- Increase of leakage current ~200 nA
- Noise increase 20%.
- Position resolution degradation

- For the radiation levels of RHIC, SDD and associated FEE is sufficiently radiation hard to withstand 10 years operation!!!

Temperature and Magnetic field dependence





- **Temperature**

  Detectors run in room temperature, tested up to 60°C.

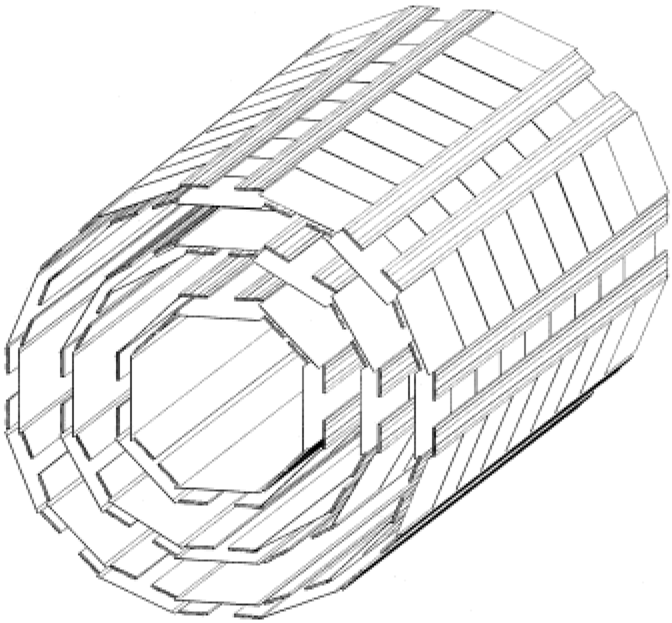
  1°C variation in temp. ≈ 1% in drift velocity.

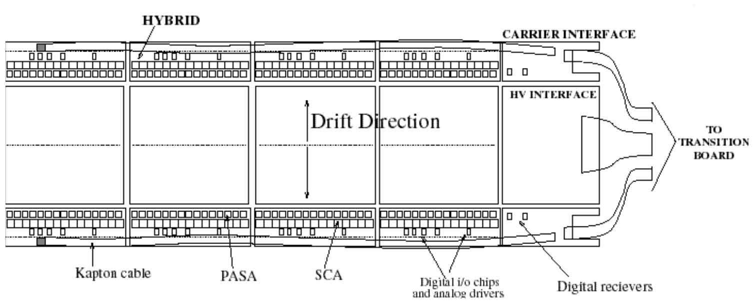
  Charge injection lines calibrate drift velocity.

- **Magnetic field**

  Detector works well in high magnetic field environment , tested up to 6.4T.

The STAR Silicon Vertex Tracker





- 216 Silicon Drift Detector.
- 3 concentric barrels, at radius of 6.6 cm, 10.6 cm and 14.5 cm.
- Pseudo-rapidity coverage of $\eta=\pm1$.
- Radiation length 1.4% per layer
- Occupancy:
  - 78 hits/wafer (inner barrel), 35 hits/wafer (middle), 23 hits/wafer (outer).
  - peak occupancy $(78 \times 24 \text{ pixels})/(480 \times 128) = 3\%$
- Double track resolution of 500 μm.
- ~13 mi. pixels, multiplexed into 1.3K read-out channels.

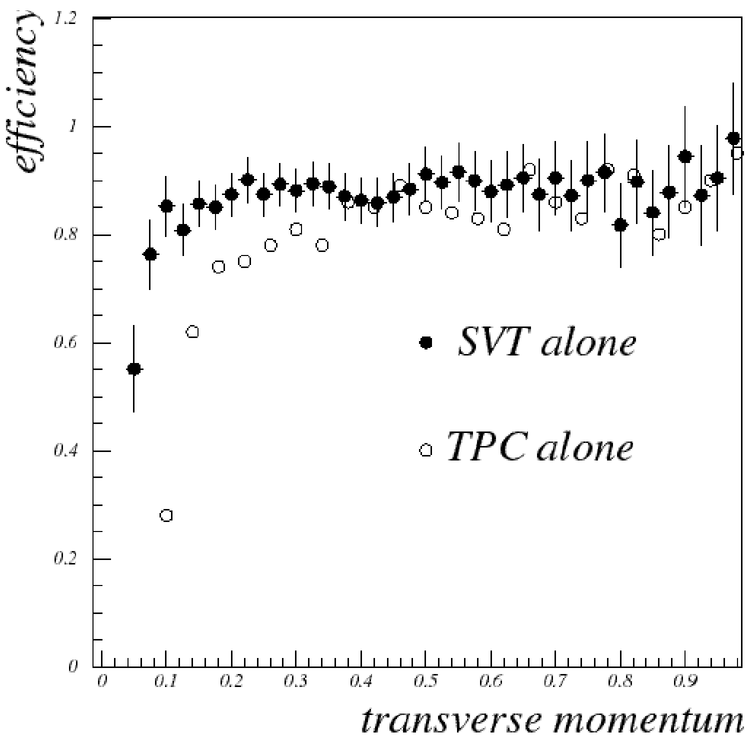
Tracking with the SVT in STAR

Primary Track reconstruction

- Improve primary vertex position resolution:
  Primary particle momentum resolution, especially for high p_t tracks.

  Secondary particle identification.

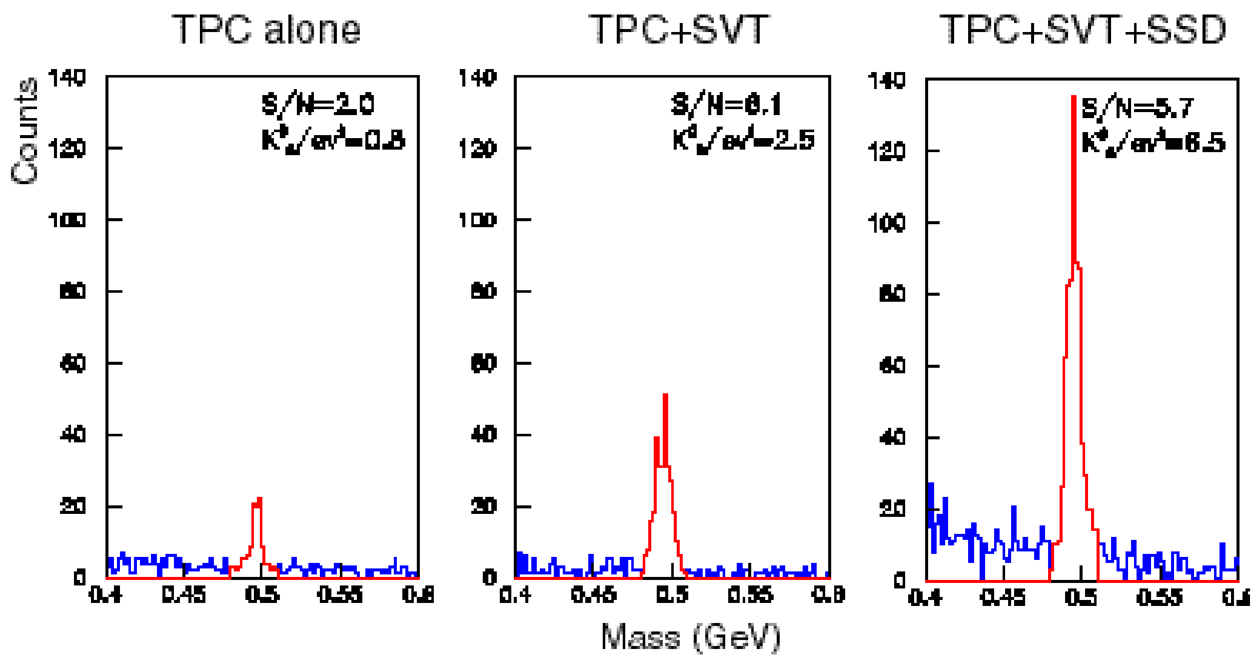
- Extends the range of particle reconstruction in STAR for low momenta.



Tracking with the SVT in STAR (cont.)

Secondary Track reconstruction:

- Measurement of decay vertices to reduce combinatorial background of short-lived particles such as ϕ, K^0_s, and Λ.



K^0_s reconstruction ~100 Au+Au Hijing events

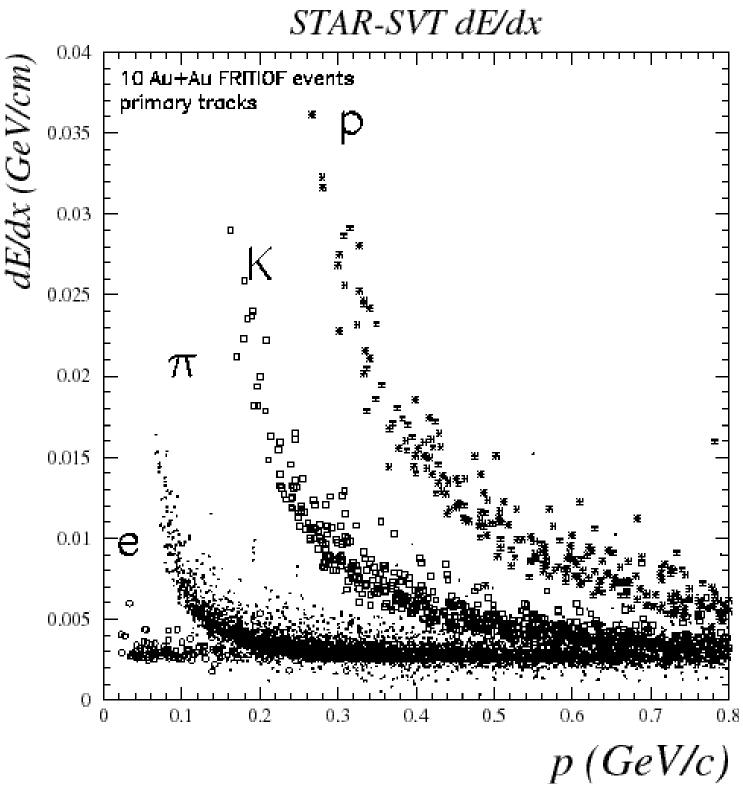
Tracking with the SVT in STAR (cont.)

Particle Identification with dE/dx

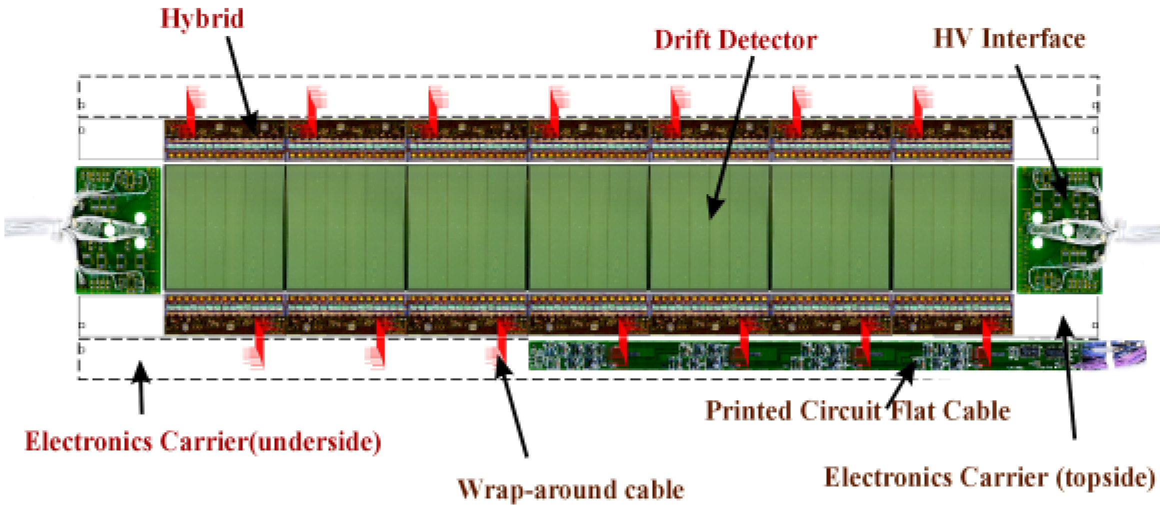
- Extend the upper limit for:
  K-π separation to about 600 MeV/c
  p-π to about 800 MeV/c.

Two-track resolution for event by event HBT

- Efficient secondary vertex reconstruction, for K^0_s interferometry.
- Enhance pion pair reconstruction by increasing the momentum range.



Status of the SVT

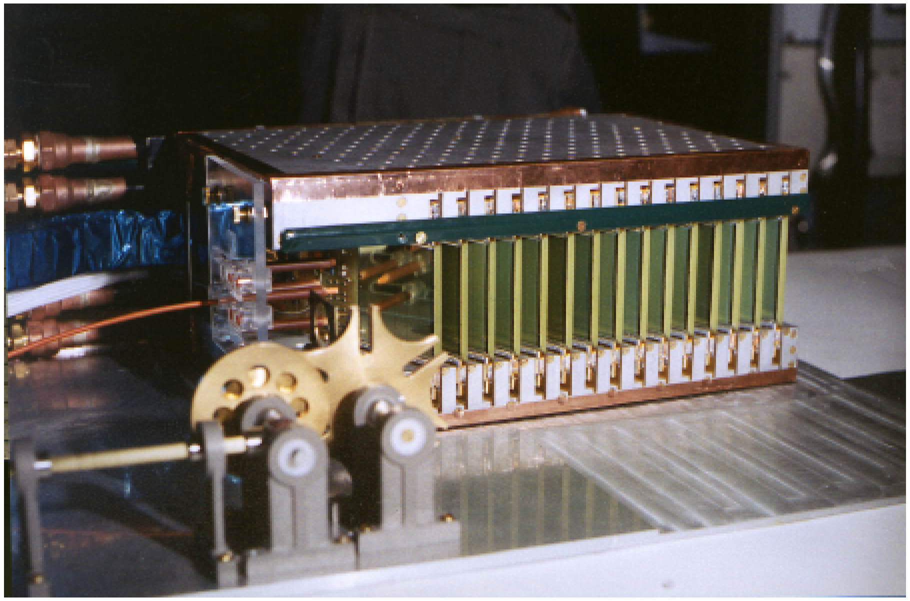


- **SDD Wafers**
  - Production nearly complete with 250 wafers (yield of ~70%).
  - Passive probe testing for selection criteria and quality control.
- **Front End Electronics**
  - PASA & SCA production complete, yield of ~85%.
  - Hybrids in assembly at present moment.
- **SVT ladders**
  - Few complete ladders assembled, production rate ~1 per week.
  - 1 ladder installed in STAR!

Recent Application of the STAR SDD

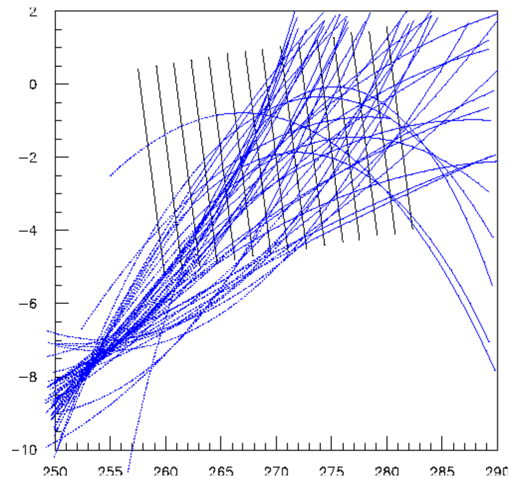
BNL-AGS experiment 896

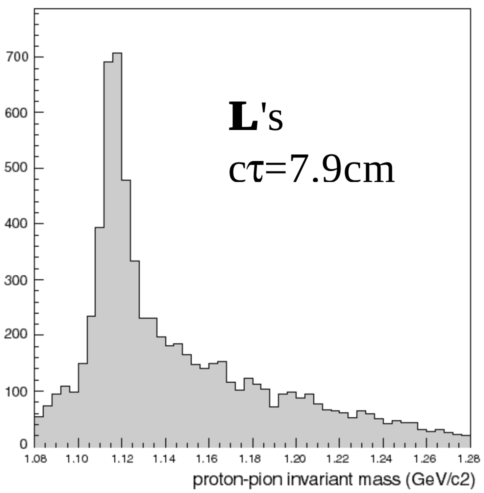
- Fixed target experiment
- 11.6 GeV/n Au+Au
- April 1998

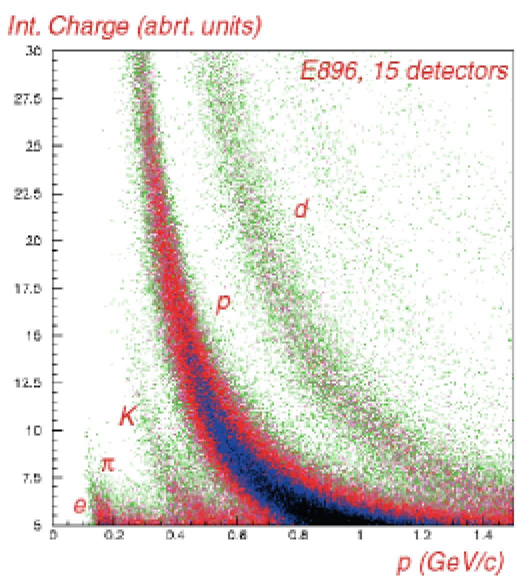


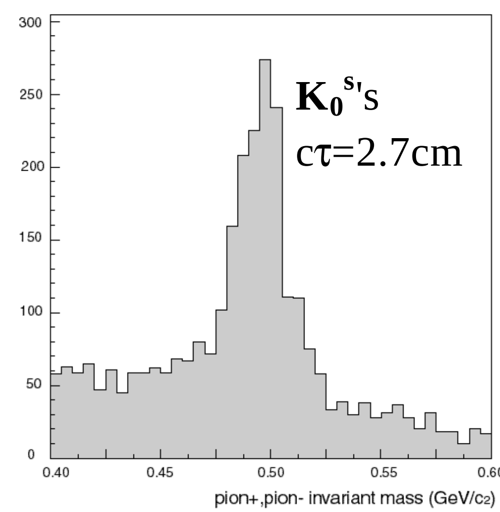
- First tracking device based on Silicon Drift Detectors (B=6.4T).
- 15 SDD detectors with associated FEE.
- Prototype of SVT-DAQ used.

Performance of SDD in experiment BNL-AGS896









Conclusions

- **Mature technology.**
  - High production yields.
  - Detector performance well characterized.
- **Operates in high tracking density environment.**
  - Provides unambiguous X-Y measurement.
  - Position resolution of 20 μm.
  - Low interaction length.
  - Maximized active area.
- **Ideal for large area detectors**
  - Good signal to noise ratio (low anode capacitance).
  - Low cost per area due to reduced number of readout channels.
- **STAR/SVT in construction now, installation in fall of 2000!**