# NA59 and its T&DAQ

- Why: circularly polarised photons >100GeV
- How: crystal + 180GeV e- from SPS
- Who: 29 collaborators from 12 countries
- When: 1999-2000

 

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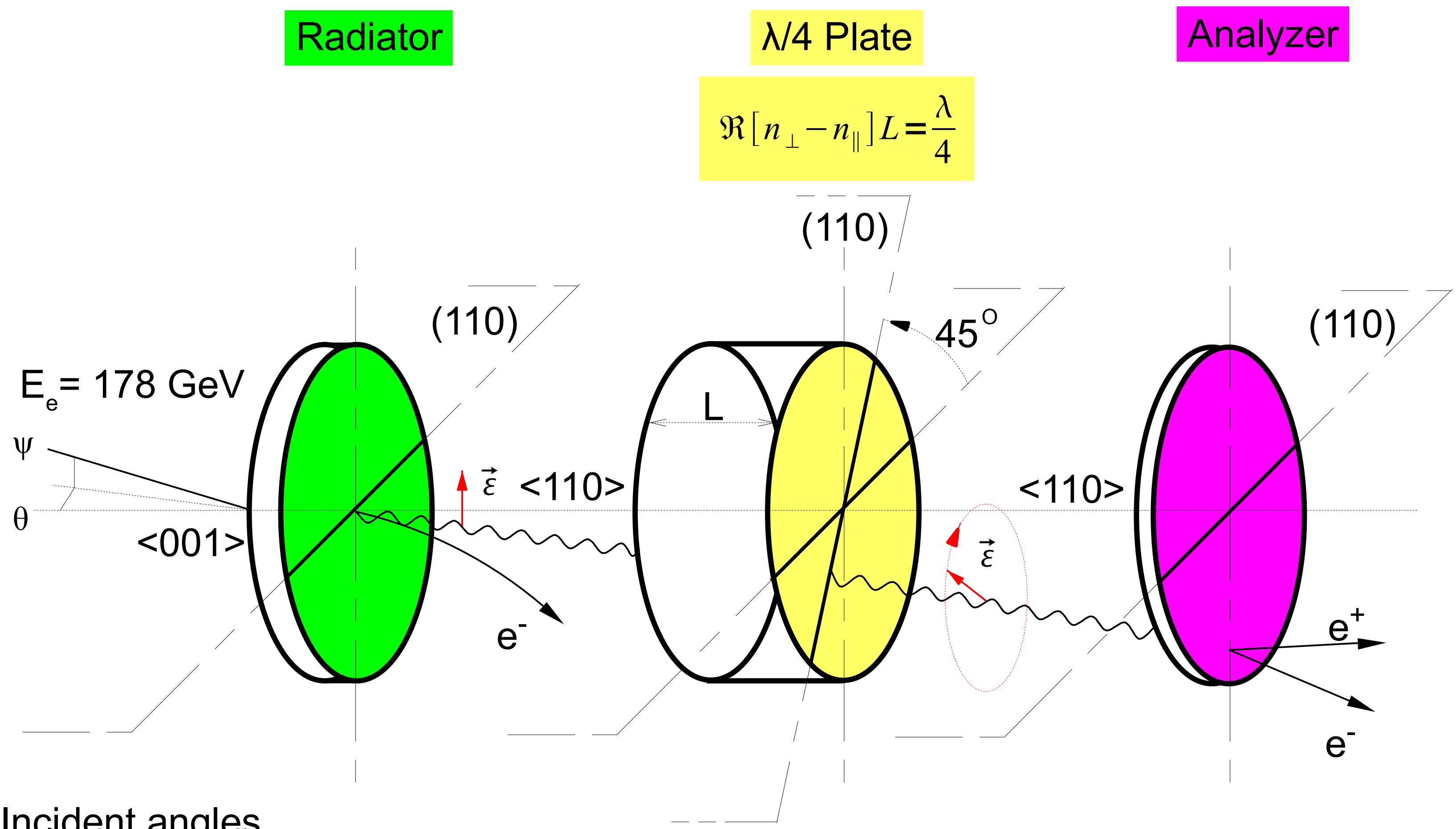
# Circularly polarised photons

- A powerful investigation tool
- Defined helicity state
  → known J of "bound state"
- Nucleon "spin crisis"
  - SMC had confirmed 30% only of proton spin in quarks
- $\gamma\gamma \rightarrow H^0$ production at <200GeV
  - Instead of waiting for ILC or CLIC ;-)

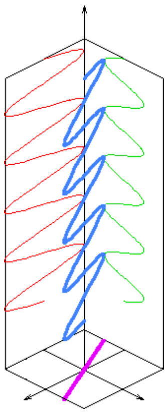
# 3 Processes:



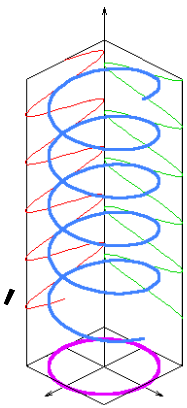

Incident angles

| | Radiator | λ/4 Plate | Analyzer |
|---|---|---|---|
| (to the axis) | 5 mrad | 2.3 mrad | 3 mrad |
| (to the plane) | 70 μ rad | 0 | 0 |

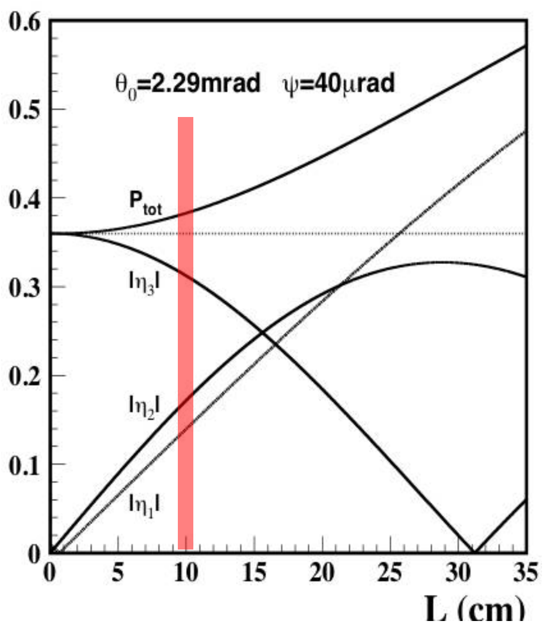
# Linear to circular polarisation



•Birefringence effect well know for visible light
•High energy equivalent postulated by Cabibbo in 1962, never tested before



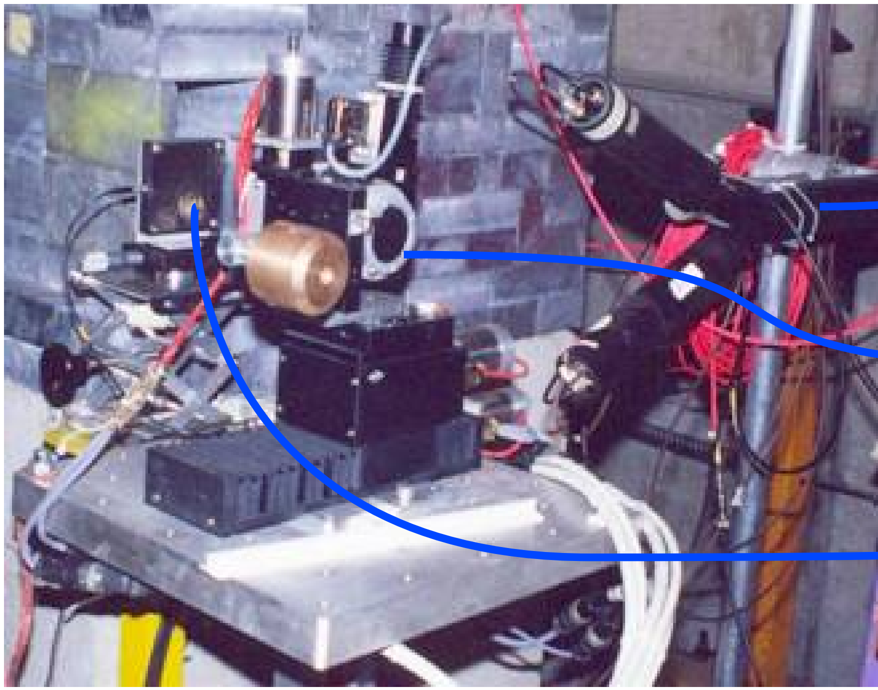
•The crystal anisotropy means absorption coefficients are different for different polarisations
•Not just for different photons: for the "components" of a single photon!
•A fully wave-like behaviour of GeV photons over a macroscopic distance




Polarization Conversion: $$\begin{bmatrix} \epsilon_1(L) \\ \epsilon_2(L) \end{bmatrix} = \begin{pmatrix} e^{in^{\parallel} E_\gamma L} & 0 \\ 0 & e^{in^{\perp} E_\gamma L} \end{pmatrix} \begin{bmatrix} \epsilon_1(0) \\ \epsilon_2(0) \end{bmatrix}$$

- L=10cm is selected for Na59 photon spectrum, compromise conversion efficiency and photon loss
- Si crystal is preferred for its availability, cost

# Polarisation conversion

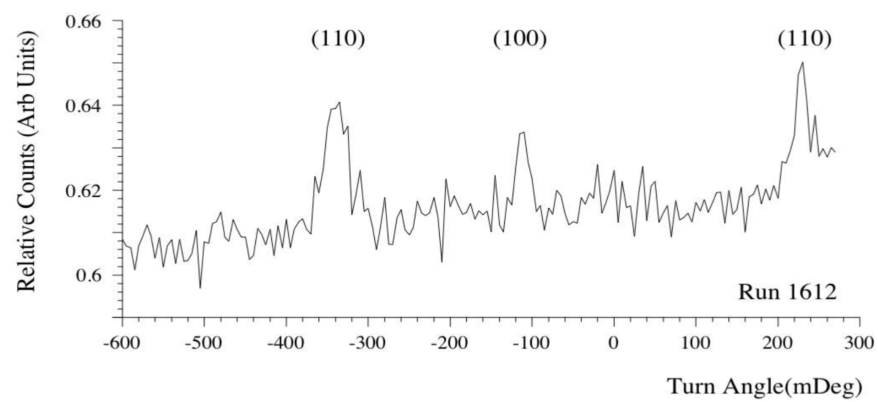


$e^-/\gamma$ tagging scintillators

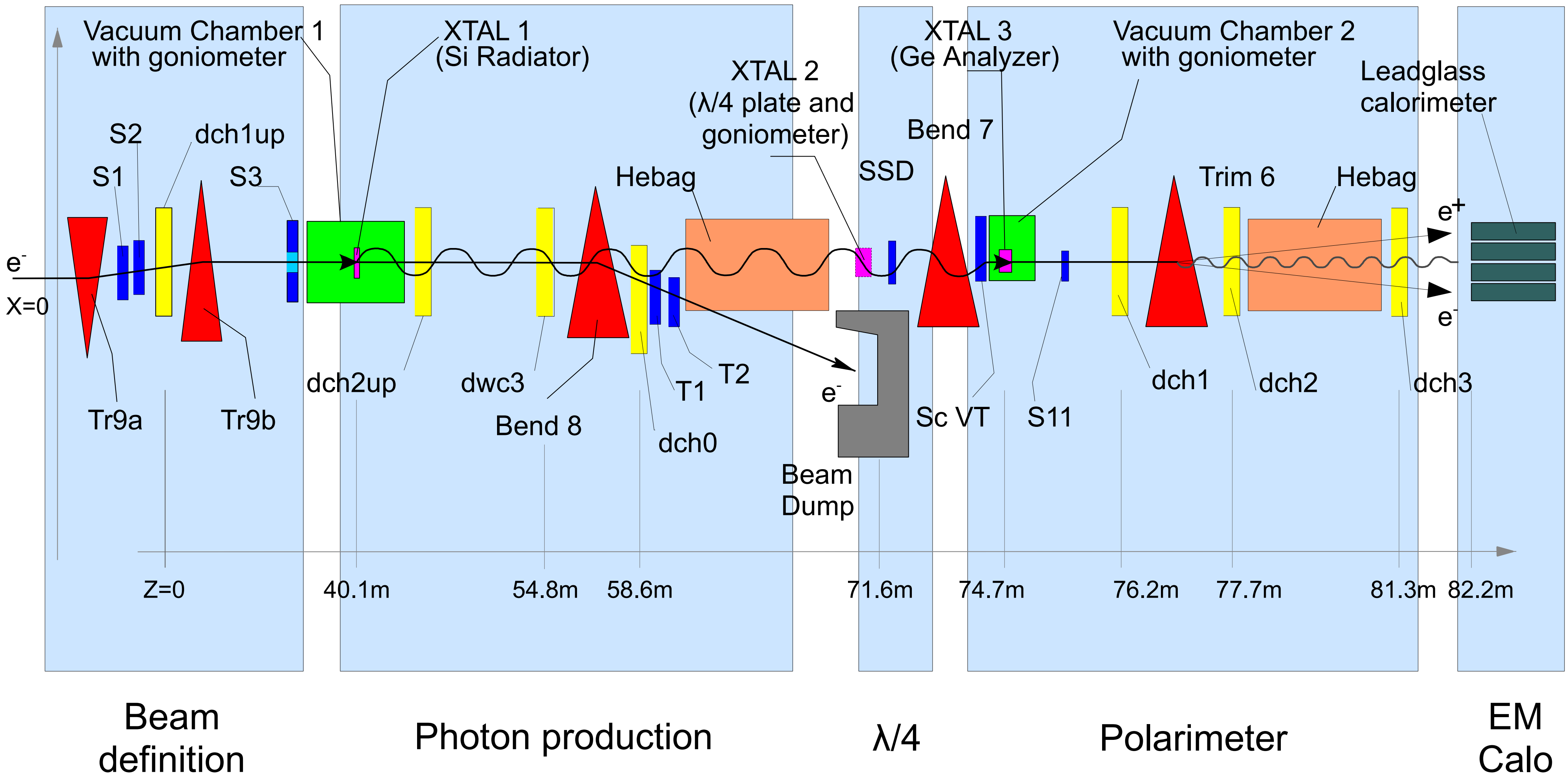
$\lambda/4$ plate: 8cm thick Ge crystal
on 3 axis goniometer (17.45μrad)
plus side displacement

Silicon detector for
charged particle multiplicity

Crystals need to be aligned w.r.t. the beam to μrad angles, checking radiation production changes, moving at every burst.
Automated and integrated in DAQ.

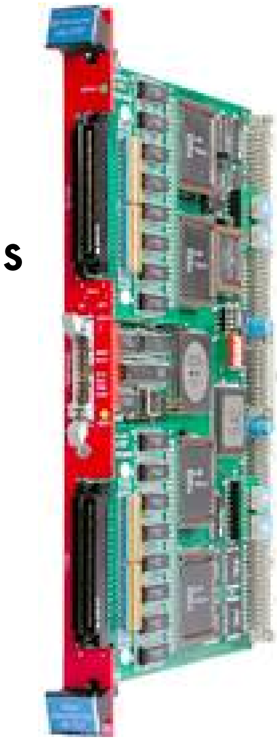


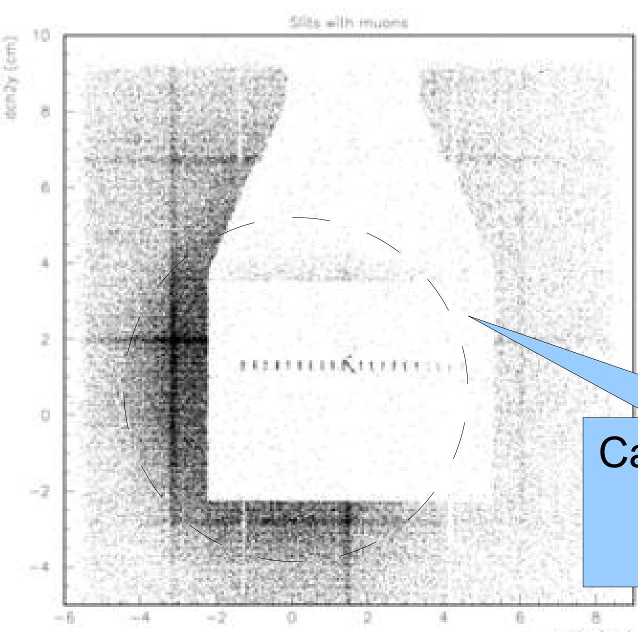
# Implementation



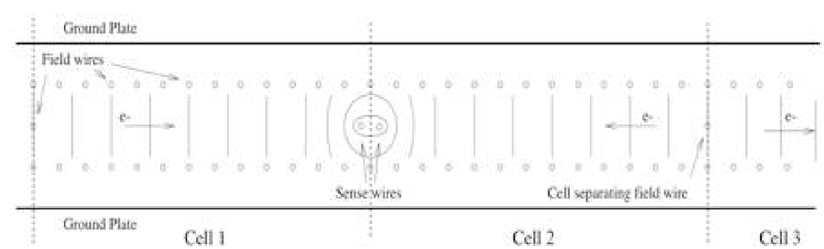
# Drift Chambers

- Charged particle tracking
- Inonisation drifts to anode, 50μm/ns
- <90μm resolution
- isobutane/argon mix 
- 6x6 cells, 15x15cm2 active area
- 12 channels, integrated preamp & discriminator
- Need multihit TDC with fast readout to handle high multiplicity: VME CAEN v767 free-clock TDC
- Physical, full-chain calibration

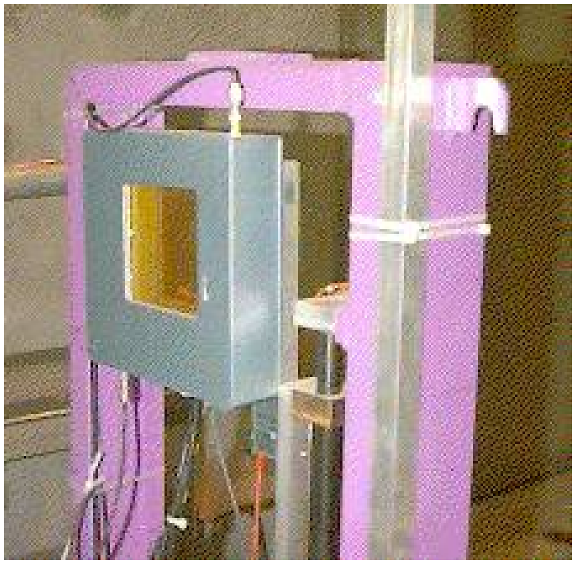


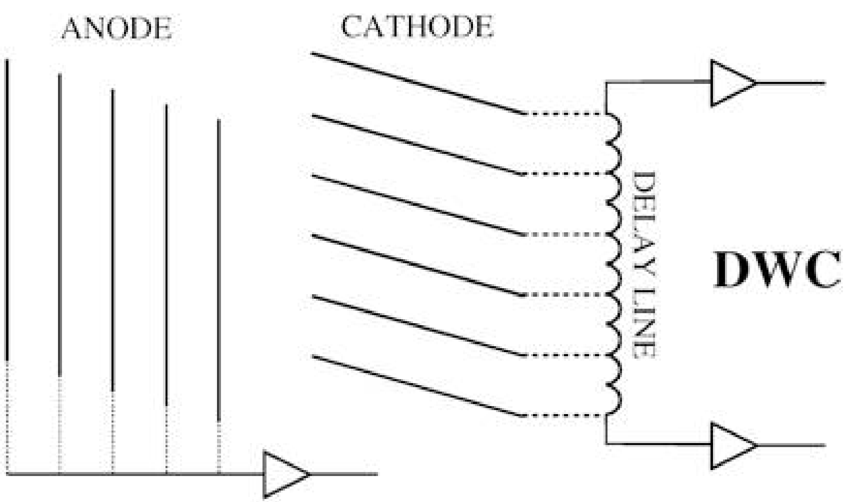



Calibration scintillator in muon beam with wide halo



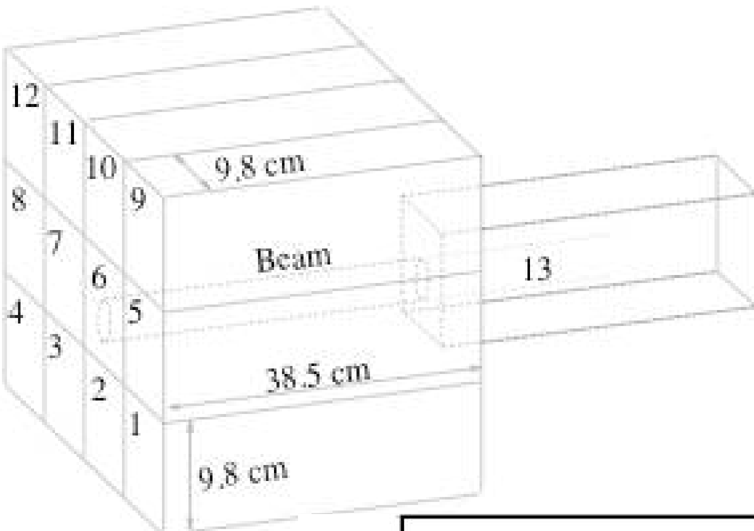
# Delay Wire Chambers

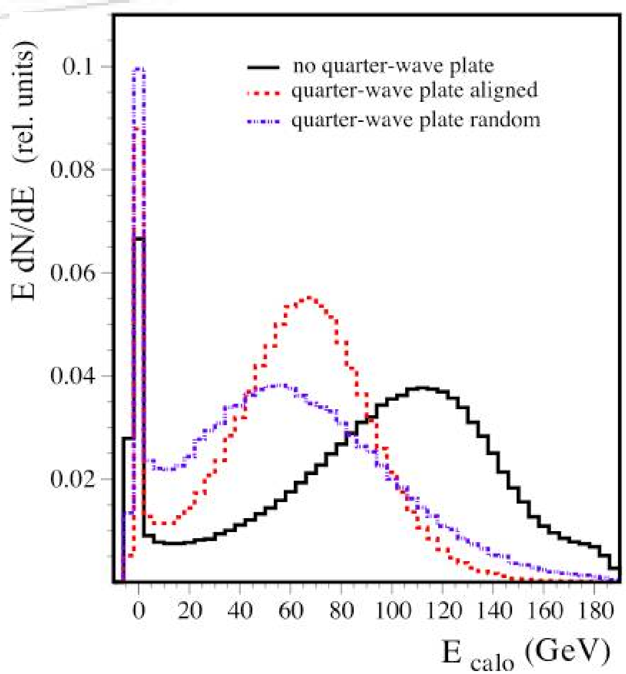





- charged particle tracking
- used as beam profile monitors
- MWPC: ionisation avalanche to anode, fast
- 200μm resolution
- non-flammable gas mix
- ~10x10cm$^2$
- cathode wire on a delay line
- 4 channels, integrated preamp & discriminators
- intrinsically single hit
- can use same v767 TDC

# Calorimeter etc

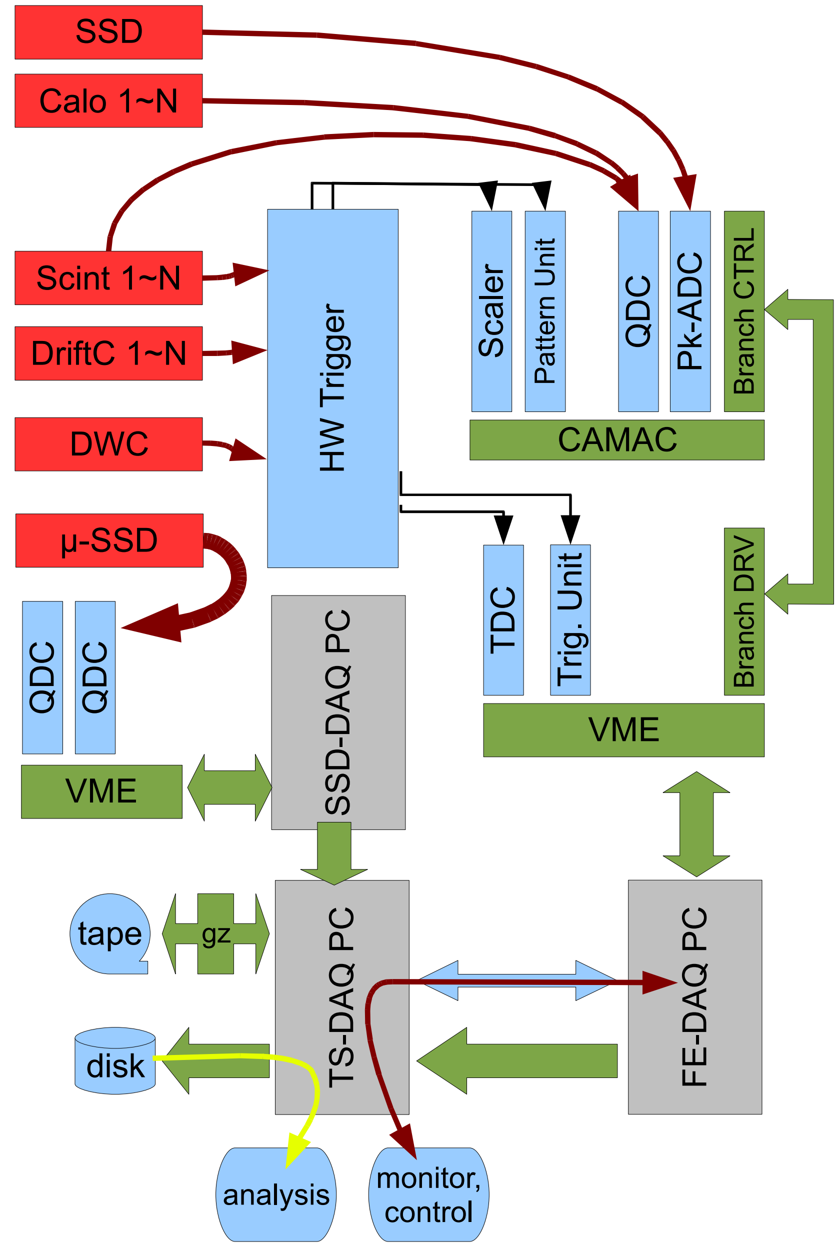



- Lead Glass as calorimeter
  - both scintillation and Cherenkov light
  - Multi-block for coverage of spectrometer acceptance
  - Readout via QDCs
- Various scintillators
  - for beam definition, photon production tagging, photon conversion in lambda/4 plate
- Single large area silicon detector for charged particle counting
  - Better efficiency and precision than scintillator
  - But more difficult – noise, electronics, readout
- μ-strip silicon tracker
  - Planned for vertex tracking
  - Original plan for polarimetry measurement based on $\rho^0$
  - Slow readout

# DAQ Overview

| Total Ch. | Type | Detector |
|---|---|---|
| 62 | TDC | Drift Chambers |
| 6 | | Delay Wire Chambers |
| 16 | | Scintillators |
| 16 | ADC | |
| 13 | | Calorimeter |
| 1 | QDC | single Silicon |
| 10 | TRIG | Trigger modules |
| 2048 | ADC | μstrip Silicon |

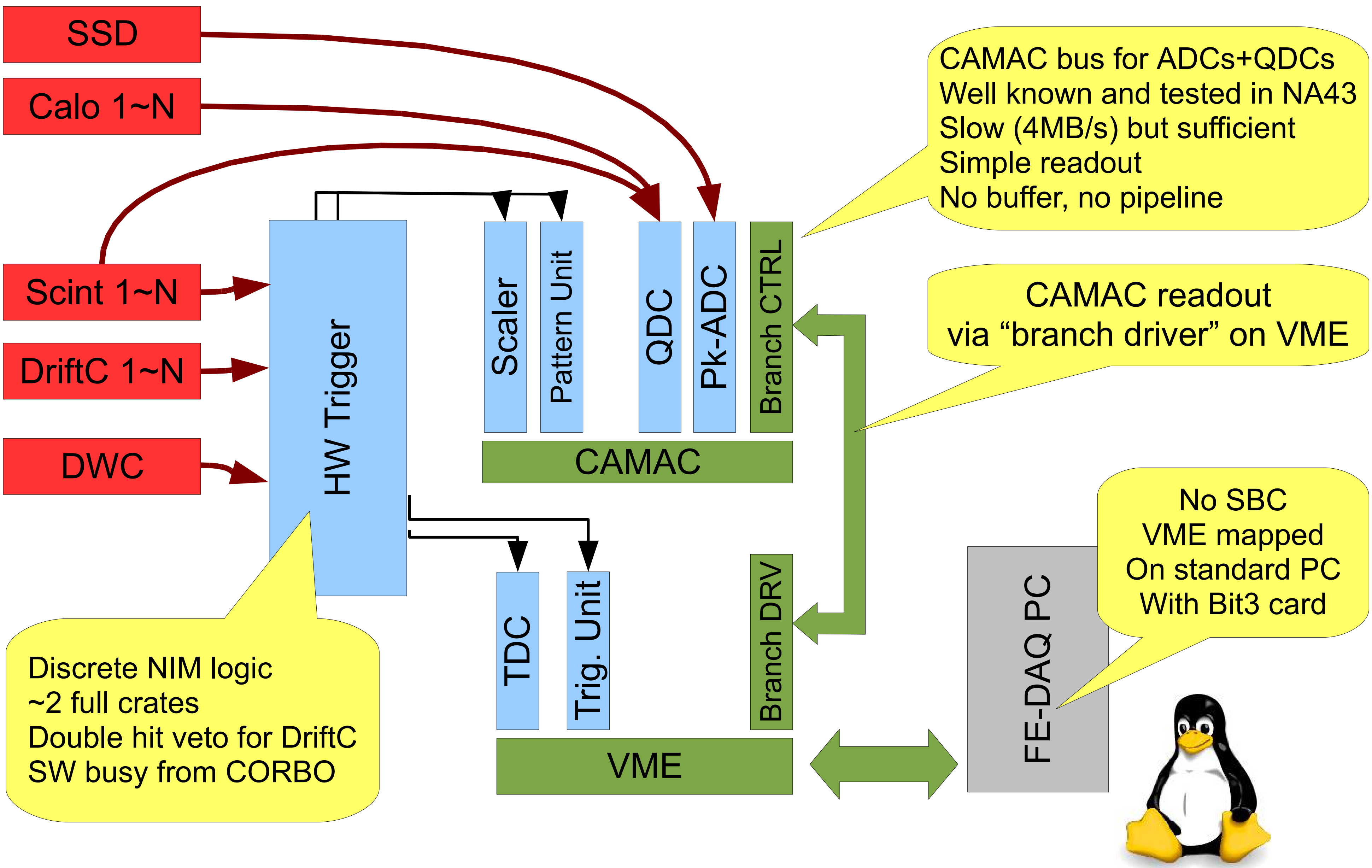



"right size":
reuse parts from NA43,
improve where needed

# DAQ Design & Performance

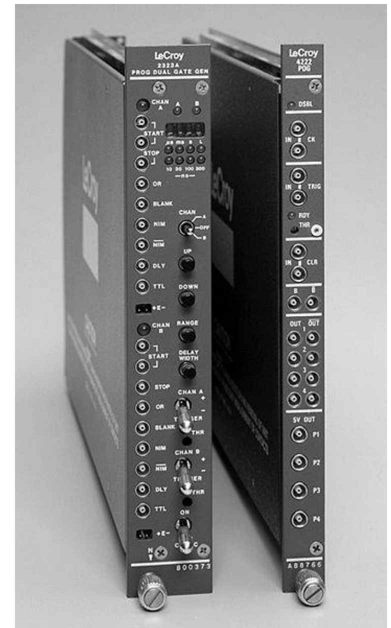
- 3.5kHz event rate over 2s burst in a 13.5s cycle
- 240 Bytes *(not kB or MB)* per event
  → 840kB/s
- No need for High Level Trigger
- Buffer all events in burst, flush after.
- Single VME, single CPU readout,
  using Linux soft real-time
- No need to manage back-pressure
- But decouple storage, monitor and control GUI

# Front end: CAMAC + VME



# CAMAC bus

- 1972 standard
- 1Mword/second
  - Sufficient for ~50ch <10kHz
- Easy, standard access
  - Crate, Number, Address, Function
  - All modules implement the same basic functions
  - VME Branch Drivers, CAMAC-PC interfaces etc
- Cheap to rent, proven (e.g. LEP)
- Mostly obsolete but still found in labs





# Linux *Soft* RealTime

- Can use standard user-space libs and in-kernel drivers
- Separate priority queue
- Non-RT processes only run when RT yields
  - Some libc calls may/will cause yields
    eg printf or any other I/O, some time functions
- In-kernel threads still can preempt RT
  - Network, disk, VM swapping, other I/O incl. Graphics
  - Better now, but in 2000 non-RT processes could block in-kernel
- Use `mlock` to avoid swapping
- Keep system very bare to avoid contention
- Very painful to debug in a time of single core CPUs...

See http://www.drdobbs.com/cpp/184402031

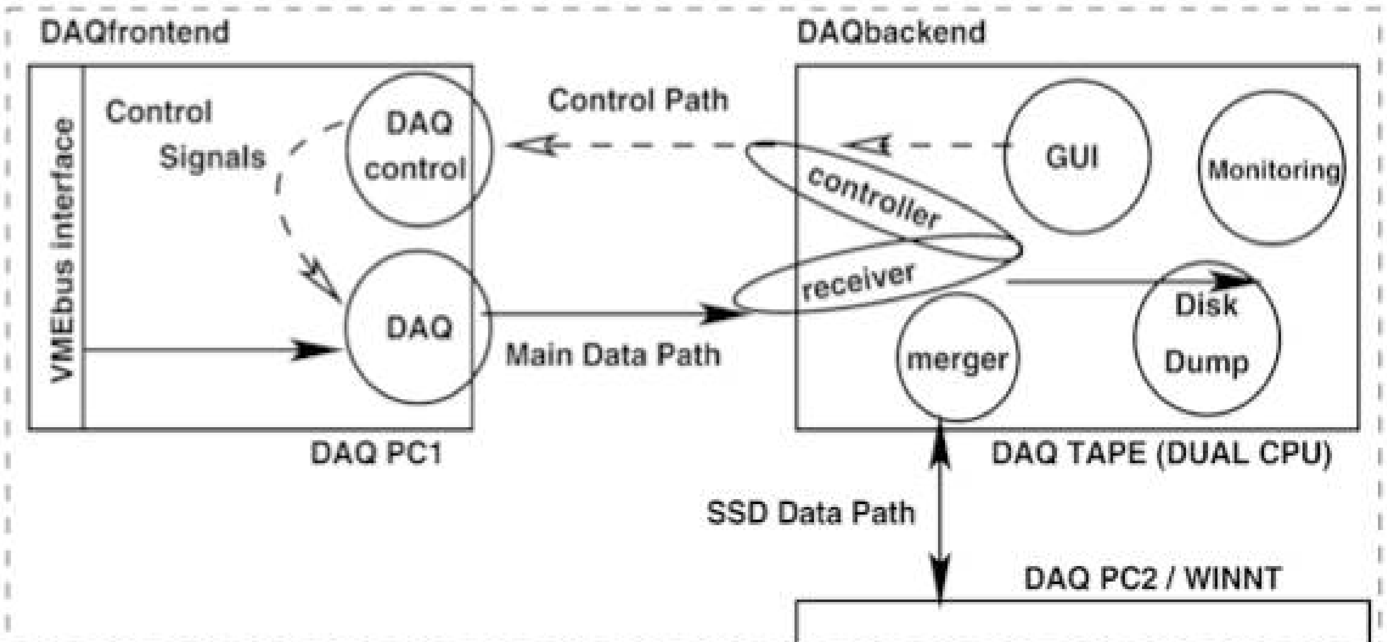
# DAQ Front-End Software

```
while (true) {
   while (state!=burst &&
          !Trigger_Read());
   if (state!=burst) break;
   Disable_Trigger();
   Event_Read();
   Clear_Busy();
   Write_Header();
}
```

- `state` is a global, controlled via a signal handler, no mutex needed
- `Trigger_Read`() checks CORBO trigger state
- `Event_Read`() does the actual job: read from T/A/QDC, store in linear buffer

- VME interface
  - SBC-Bit3 card with OpenSource drivers
  - BIG_PHYS_AREA kernel patch
- Flexibility is nice, but can be expensive in time-critical sections.
  - A way to circumvent the issue is to pre-compute as much as possible at start-up.
- Save time by writing the event header after clearing the busy

# DAQ DataFlow



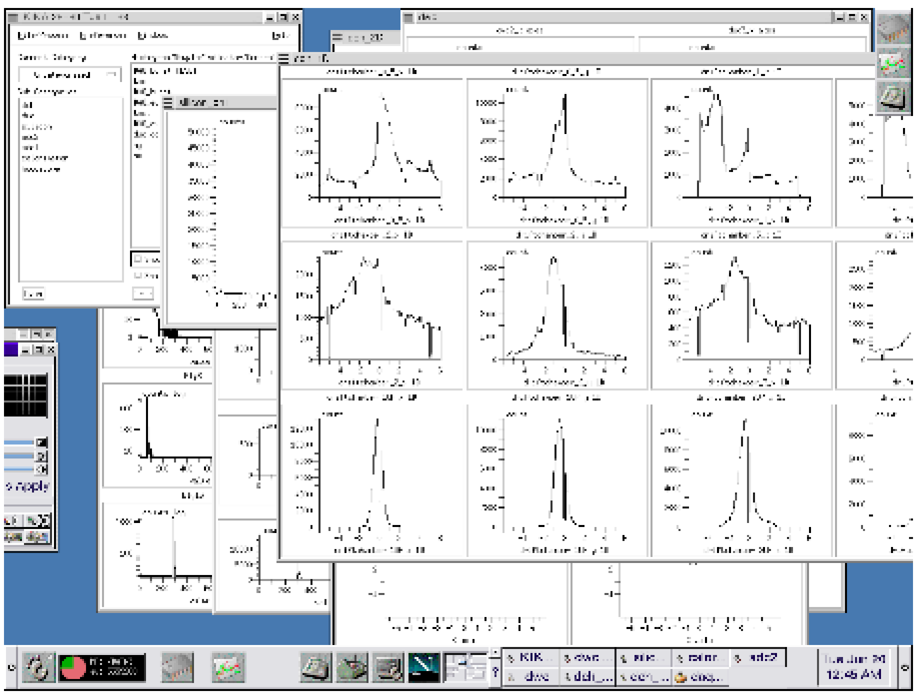

- Separate Front-End from high-latency storage
- FE stores 840kB/s in linear buffer
- Whole 2.5s burst transfer via Fast Ethernet, push from FE
- bare TCP/IP, use in-data burst/event headers

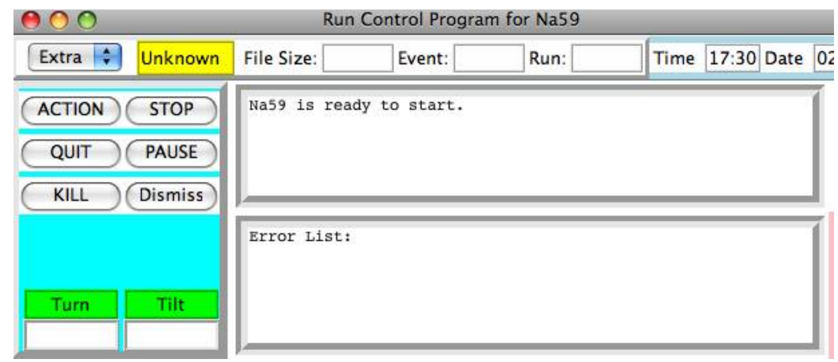
- zero (userspace) copy
- Burst-level merge of separate μstrip Si DAQ (FTP)
- Raw storage to disk
- Periodically gzip and archive to tape

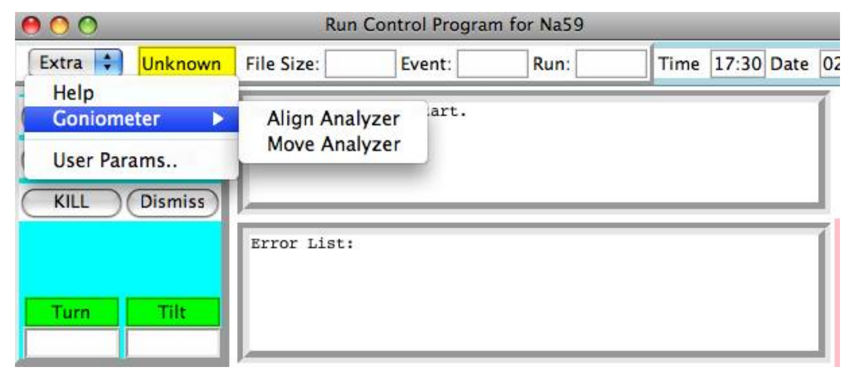
# DAQ Monitor & RunControl

- Monitoring feeds from shared memory in common with BE receiver, cannot block

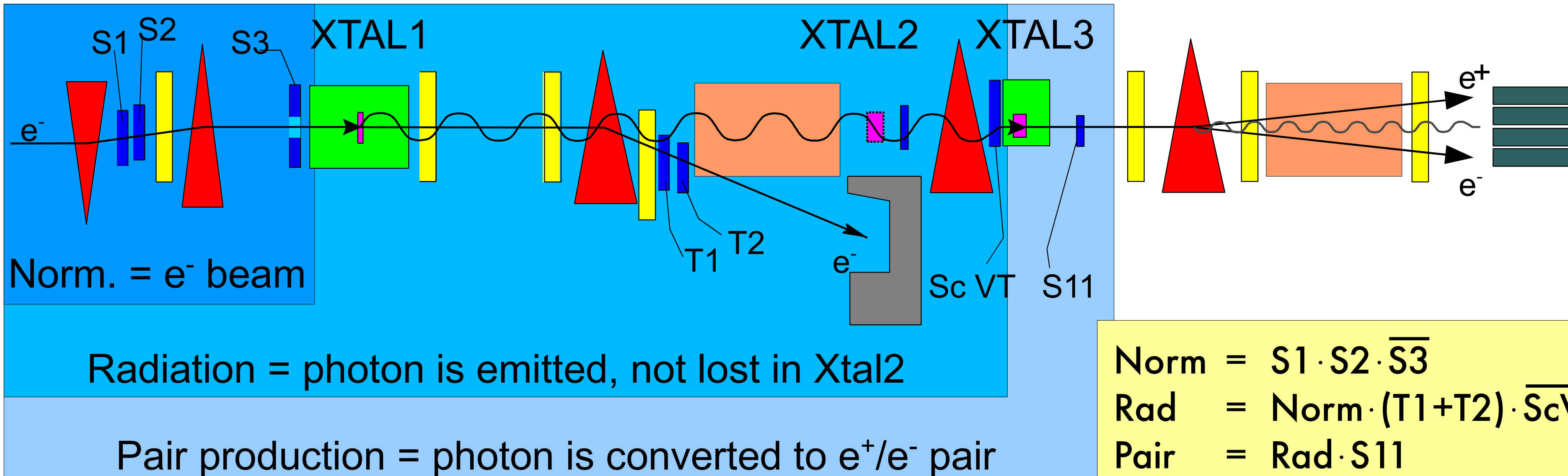
- Run Control GUI on BE talks via net with low-priority process on FE, Posix signals to DAQ
- Goniometer control is integrated





# Trigger - physical view

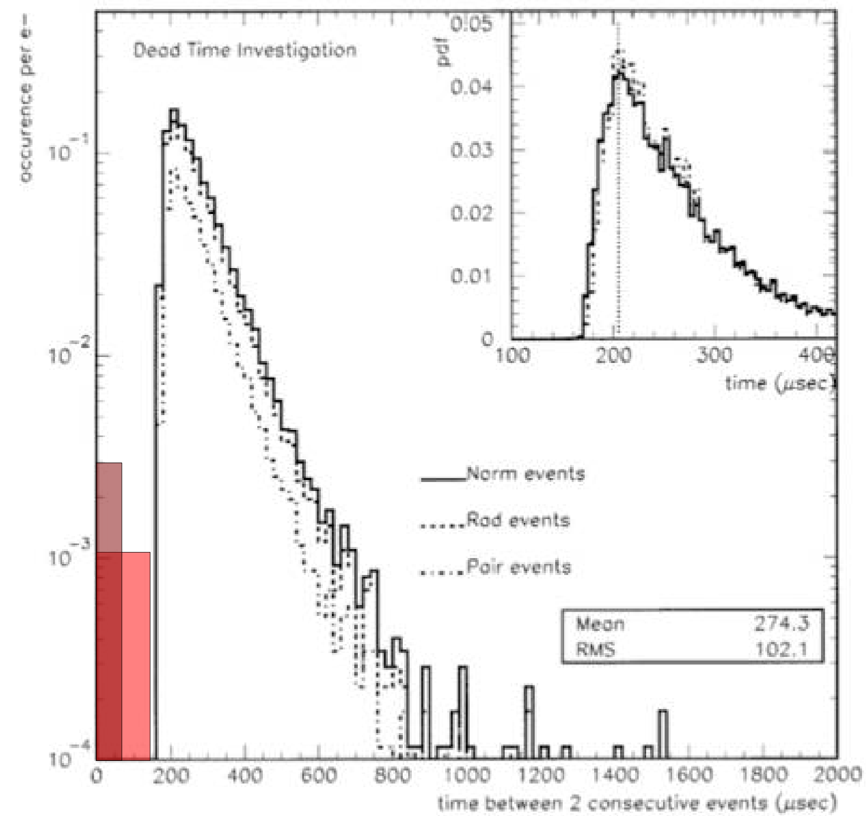



$$\begin{aligned} \text{Norm} &= S1 \cdot S2 \cdot \overline{S3} \\ \text{Rad} &= \text{Norm} \cdot (T1+T2) \cdot \overline{ScVT} \\ \text{Pair} &= \text{Rad} \cdot S11 \end{aligned}$$

- Different types of events get different prescaling before readout
  - Give more chances to interesting (Rad, Pair) events, reduce storage
- Add calibration events in the mix
- Reject event if another particle arrives within drift time of DCs
  - Would not be distinguishable – so no central drift chambers at LHC exp.
- Fully implemented in HW
  discrete NIM modules, about 2 crates

# Validate Trigger & DAQ

- Instrument your DAQ for performance
  - But careful because `gettimeofday` yields!
- Check dead time via $\Delta t_{event}$
  - Most Probable 205μs, avg 275μs
  - minimum 170μs
  - VME readout time 160μs (bus analyzer)
  - 60μs CAMAC ADC (Lecroy 2249A)
- Compare with real rates
  - Scalers with no busy veto



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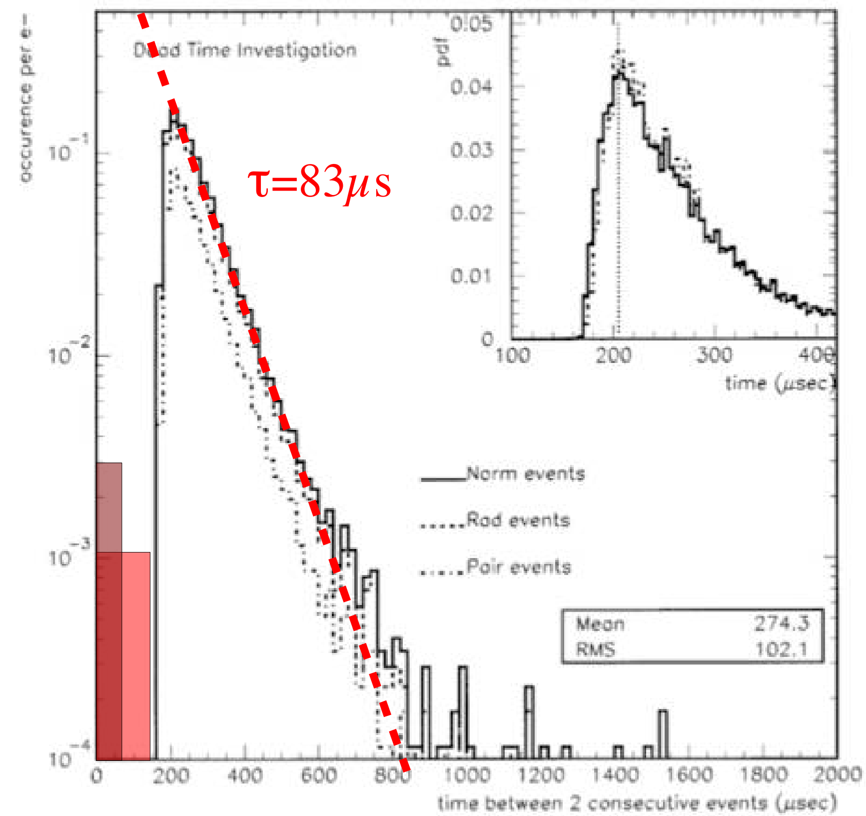
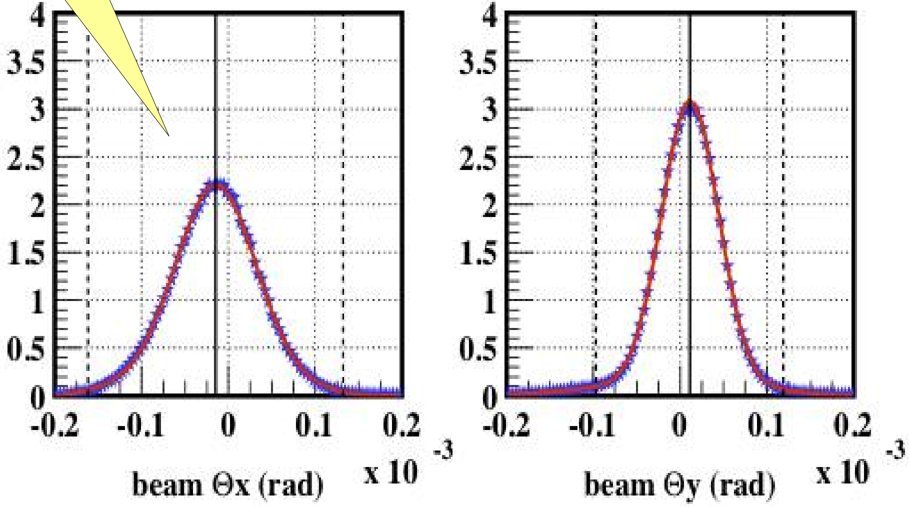


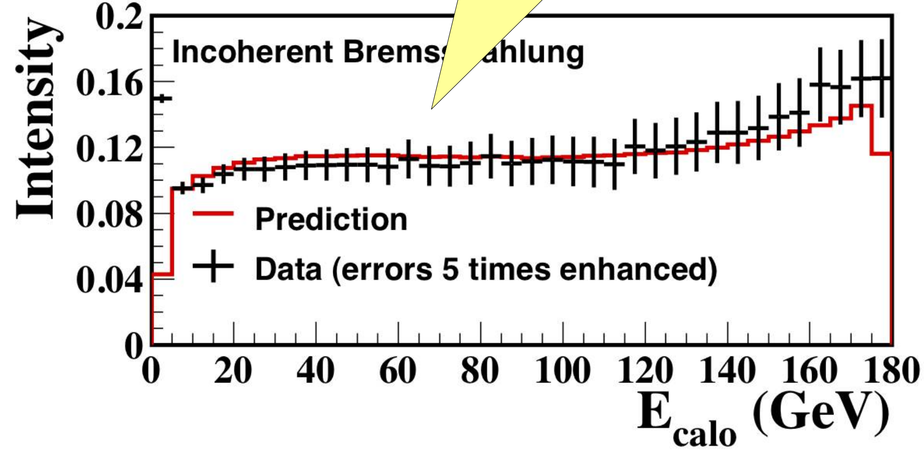

- Compare for different trigger types (*democratic trigger*)
- Analyse minimum-bias (NORM) events to check that the HW trigger cuts actually behave as expected

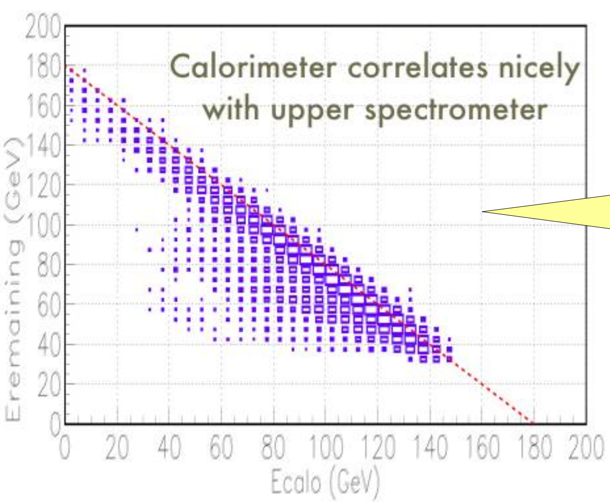
# Data Validation

Beam

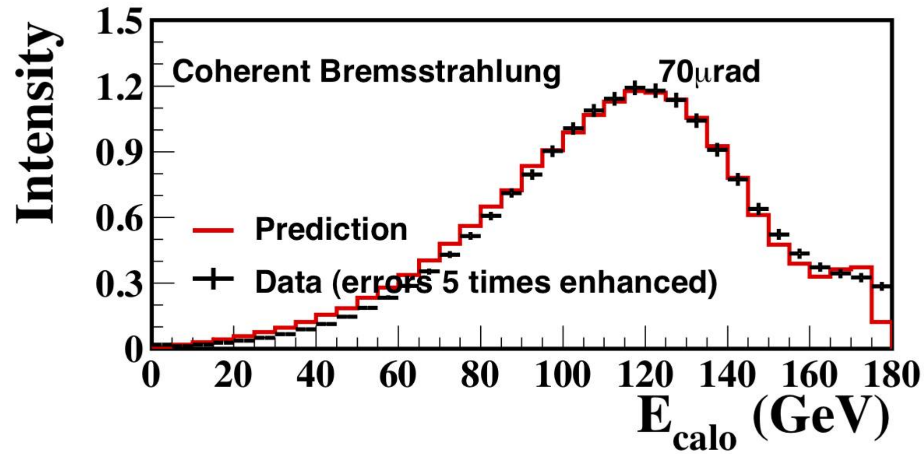



Radiator crystal orientation and calorimeter



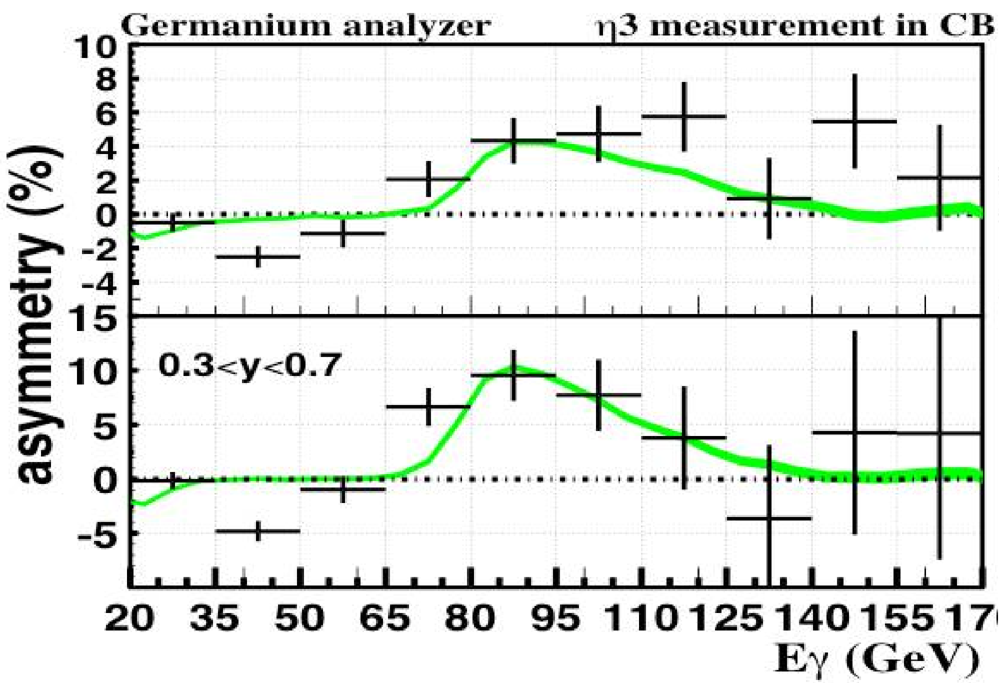

Photon tagging

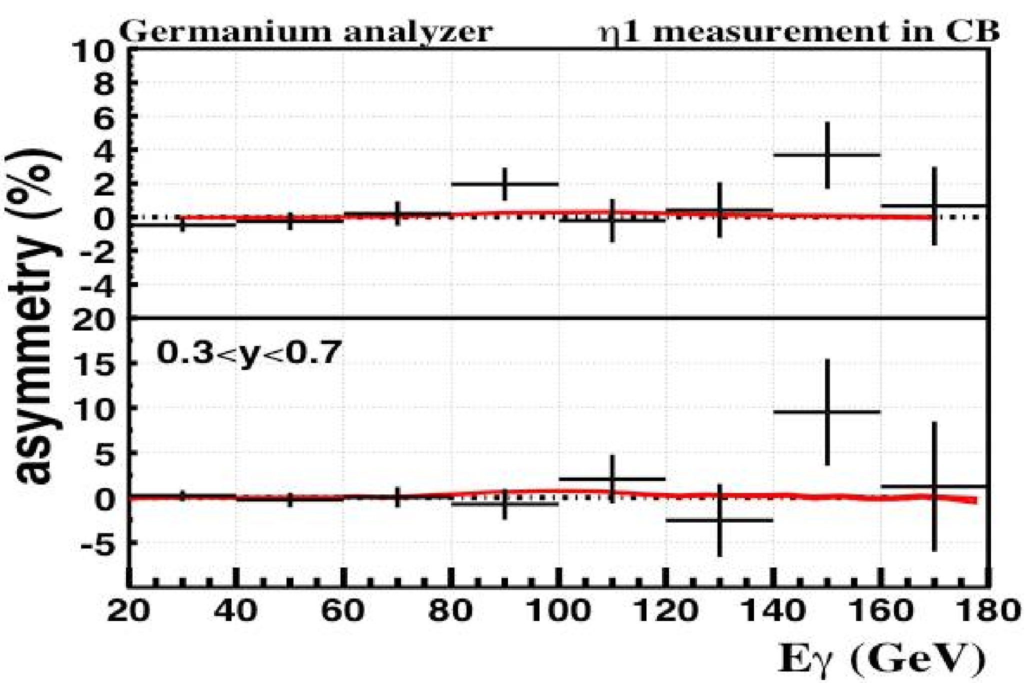


# Ge Polarimeter

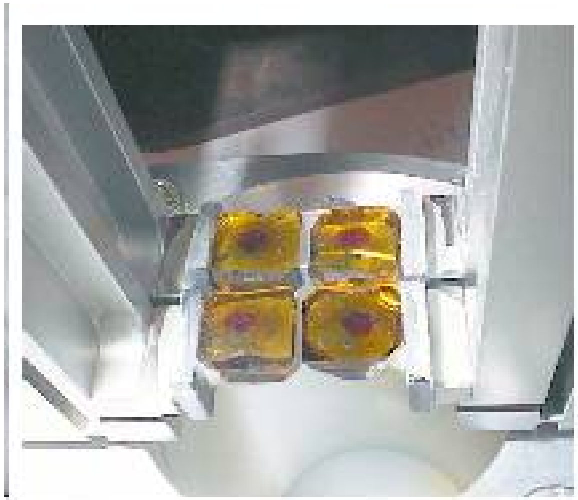
- The Ge Polarimeter was validated in the 1999 run

- In 2000 it provided confirmation of theoretical expectations for the photons from radiator

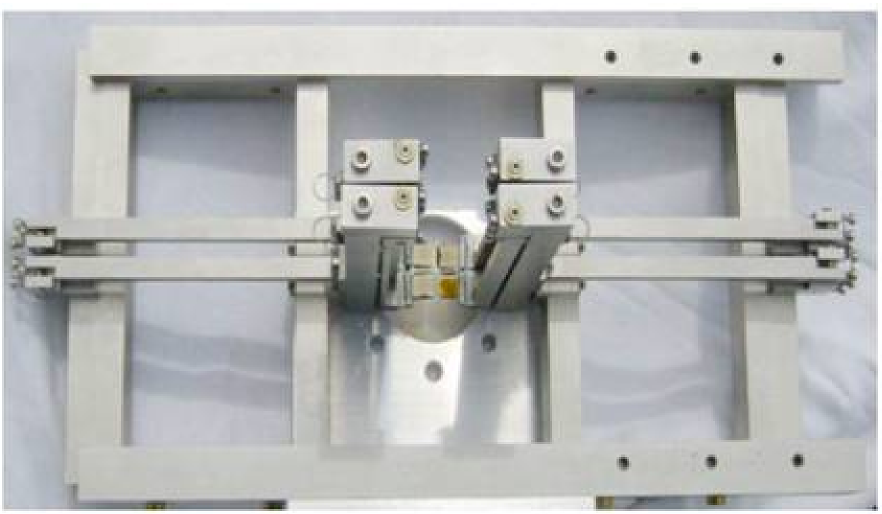


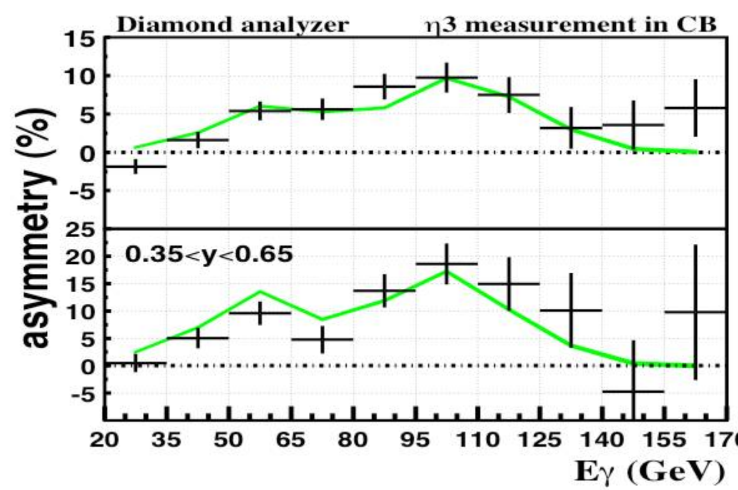



# Diamond polarimeter



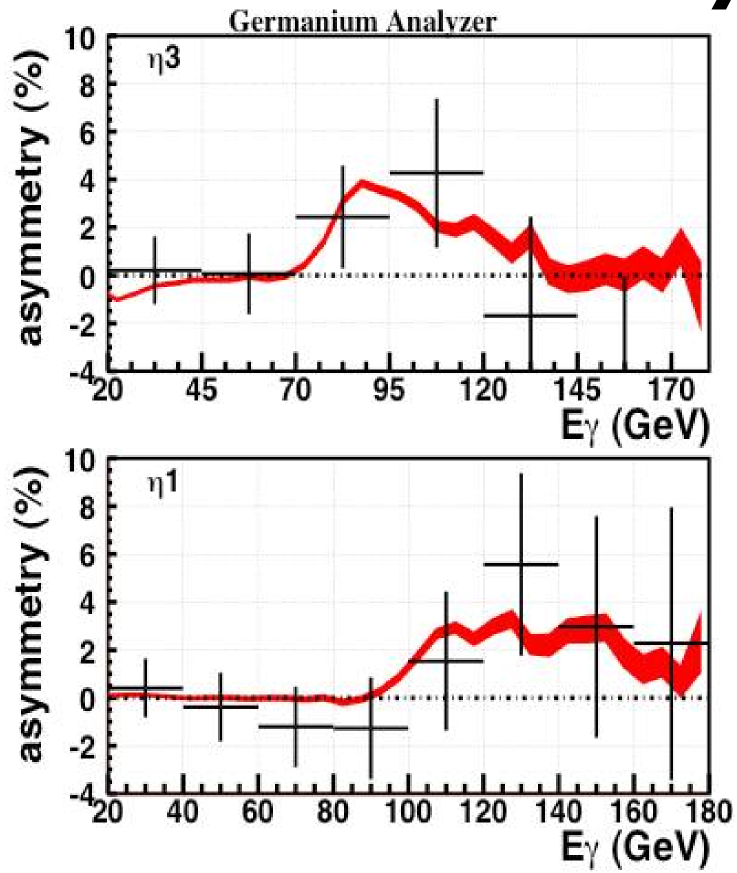
- 4 tiles of HPHT single-crystal diamond from DeBeers
- 4mm x $8x8mm^2$
- Adjustable relative alignement of tiles
- Pre-aligned at ESRF, Grenoble

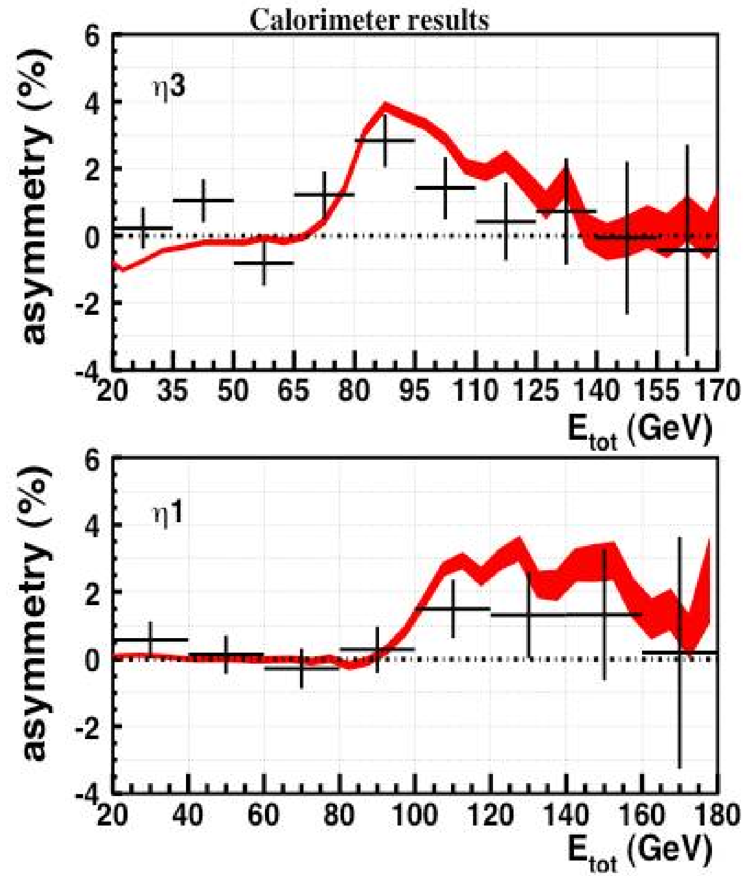





**More sensitive than the Ge analyser**

# Physics results




spectrometer results

too few clean pairs

η3: decreased from 44% down to 28 ± 7%
η1: increased from 0% up to 1.4 ± 0.7%

η2: created 21 ± 11% expected 16%

calorimeter results

diluted by photons

# Conclusions

- A right-sized DAQ
- Conservative where possible
- Advanced where needed
- Two-person effort for few months

- Good polarimetry for photon beams
- Nice macroscopic QM effect
- Possible use in future beamlines ?
  - Competing techniques have advanced since we ran NA59

# Conclusions

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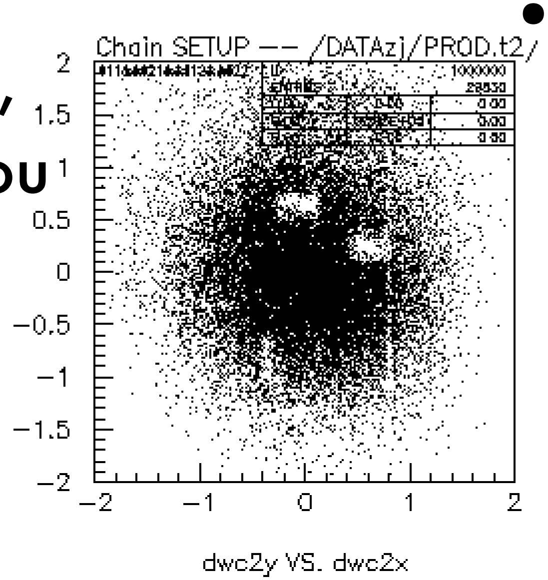
- Conservative where possible
- Advanced where needed
- Two-person effort for few months
- Don't panic, even when you find ghosts in the beam!

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# References

- http://na59.cern.ch
- Physics results
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  - IEEE Trans.Nucl.Sci.51:1482-1487,2004
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