Diamond based detectors for timing applications in HADES

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for the HADES Collaboration

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Acknowledgements

For the preparation of the detectors, metallization and bonding of the diamonds we highly appreciate the support of E. Berdemann, M. Träger et al., GSI Detector Laboratory and A. Hübner et al., GSI Target Laboratory.

Outlook

Heavy ion program Au +Au @ 1.25 AGeV

Planned experiment in 2012: reaction Au +Au @ 1.25 AGeV, 4-5 weeks.

Start detector issues: Radiation hardness, time resolution and efficiency.

Test in Nov 2010 (20 hours of beam) – reported during 2nd CARAT Workshop

Test in Aug 2011 (5 days of beam) – this presentation

Proton and pion induced reactions – short summary

Why do we need the Start detector:

Beam position monitoring.

Start signal for Time-of-Flight measurement.

Fast trigger signal for Data Acquisition System.

→ Position sensitive, fast detector, directly in front of the target.

→ Included in the LVL1 trigger. Selecting beam particles which hit the target.

→ Time resolution: below 50 ps.

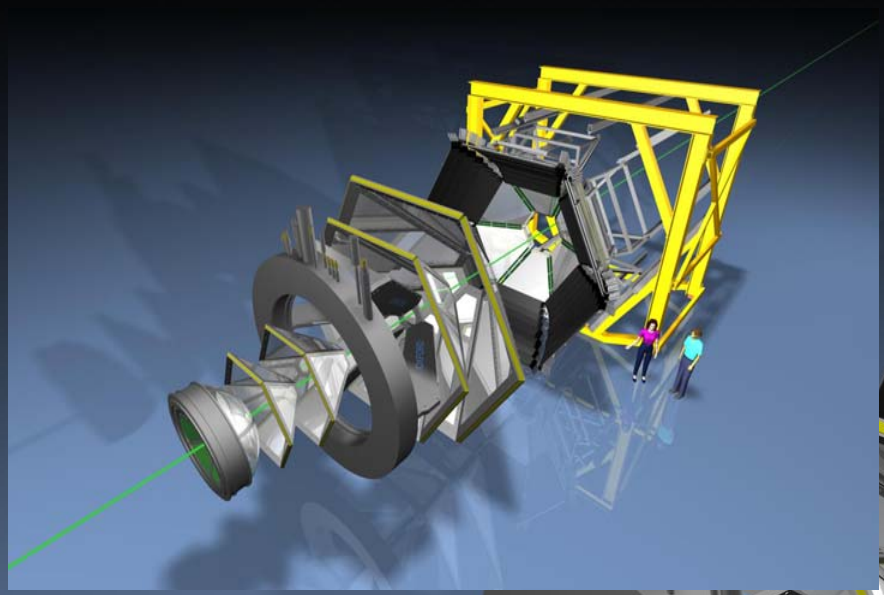
→ Efficiency: close to 100 %.

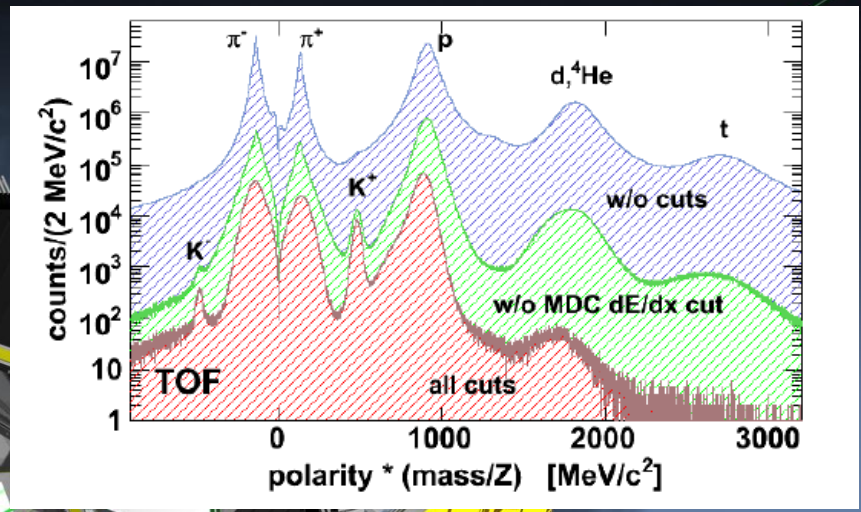
→ Fast readout electronics

The HADES detector at GSI

HADES

http://www-hades.gsi.de





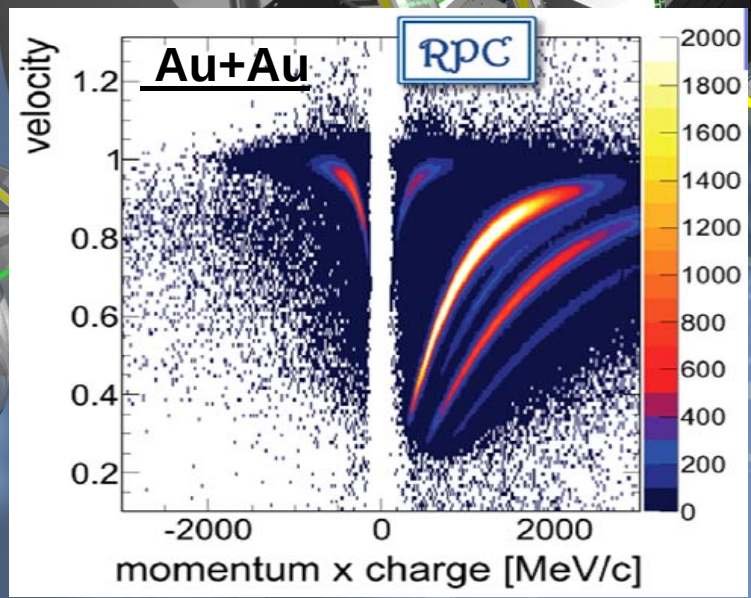
ToF measurement

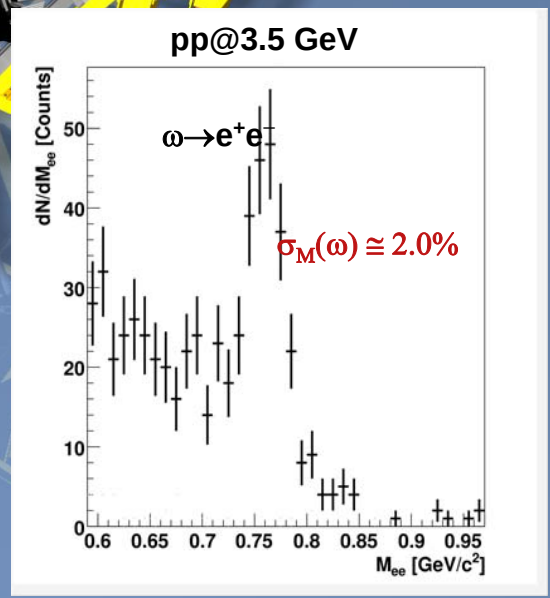
essential part of

particle identification

(T0 determination)

→diamond detector



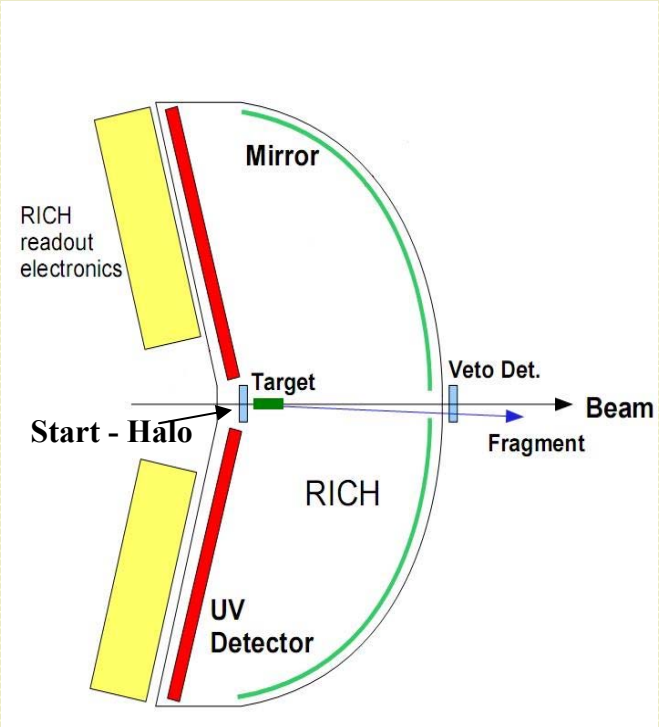


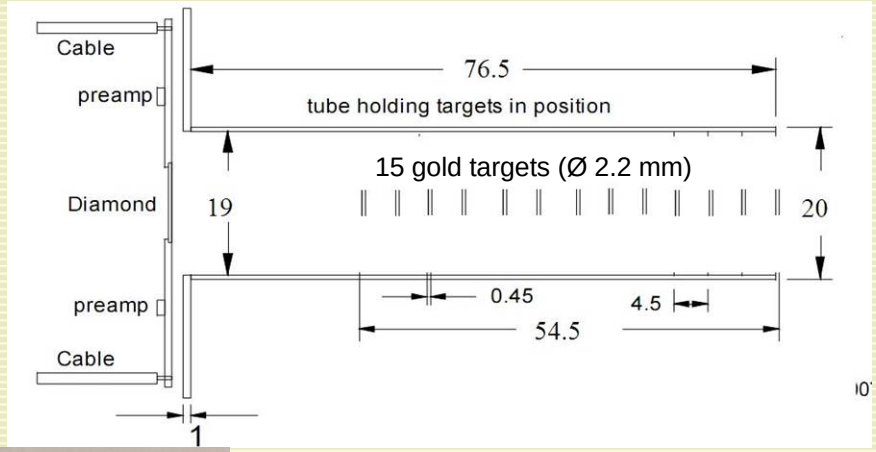
HADES Start-Veto system (Au+Au)

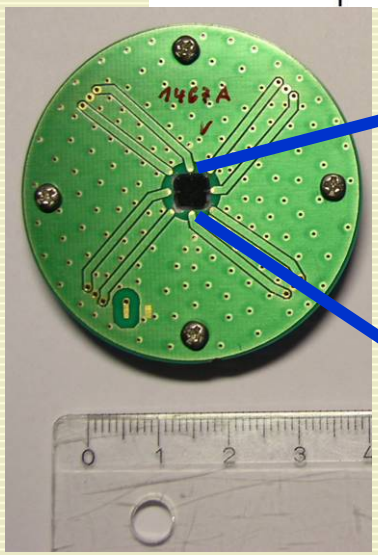
Detector properties:

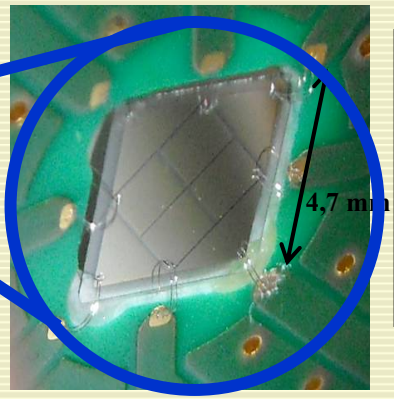
- ✓ Low material budget (low interaction probability), good time resolution (below 50 ps)
- ✓ In vacuum operation, located directly in front of the target in order to reduce load on the RICH

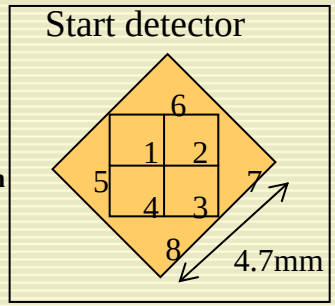
→ Start det.: monocrystalline diamond, 50 μm thickness, 4.7mm x 4.7mm
→Veto det.: polycrystalline diamond, 100 μm thickness, behind the RICH Detector.











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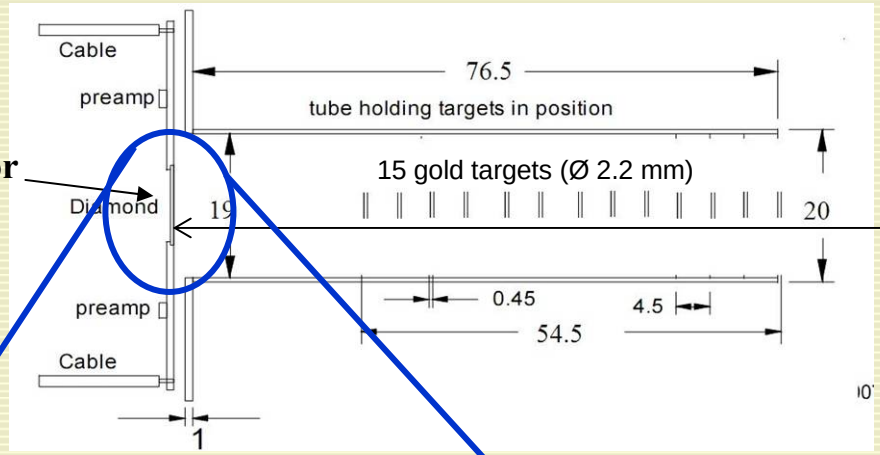
HADES Start-Veto system (Au+Au)

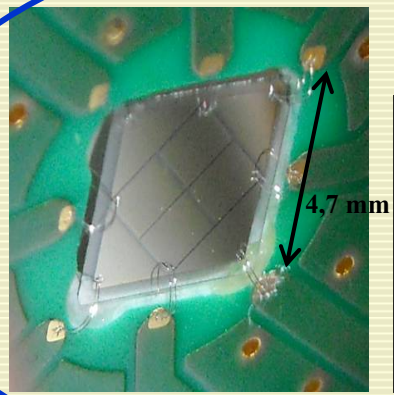
→ Start det.: monocrystalline diamond, 50 μm thickness, 4.7mm x 4.7mm
→Veto det.: polycrystalline diamond, 100 μm thickness, behind the RICH Detector.

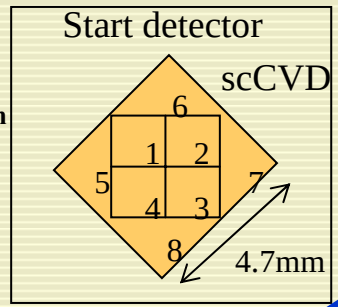


Start detector

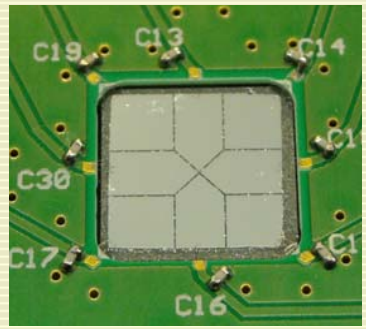
45 cm

Veto detector





Veto detector, pcCVD reference detector



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Start-Veto system readout electronics

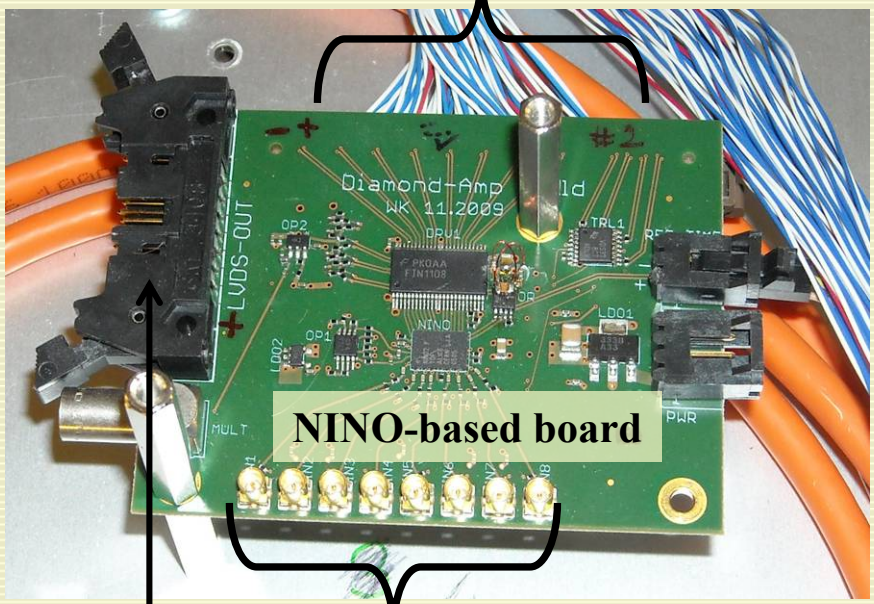
Issues:

- ✓ High rate, up to 10^7/s per channel.
- ✓ Fast signals, analog signal from diamond – 200 ps rise time, base width < 1ns.

Our approach:

- ✓ Dedicated NINO based discriminator board with trigger functionality.
- ✓ Time measurement performed by HADES TRB board – based on HPTDC.

8 x LVDS timing output signals



8 x input signals

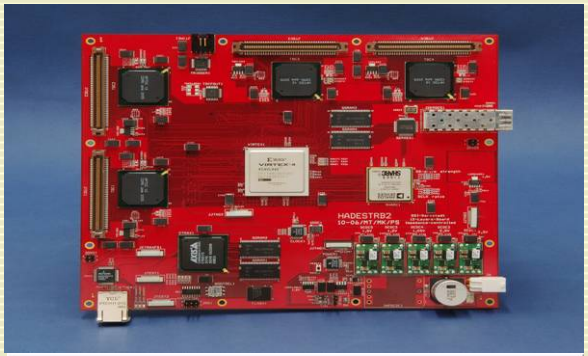
8 x scaler/trigger output signals

NINO chip: Developed for Time-of-flight measurements in the ALICE experiment

Key features:

- ✓ Adjustable discriminator thresholds.
- ✓ Front end time jitter <10ps.
- ✓ Sustains very high rate (>>10MHz)
- ✓ Peaking time: 1ns.
- ✓ Input signal range: 30fC - 2pC.
- ✓ Noise: <2500 e-.
- ✓ Discriminator threshold: 10fC - 100fC.
- ✓ Timing precision: <10ps jitter.
- ✓ Output: LVDS.

The Multipurpose Trigger Readout Board TRB



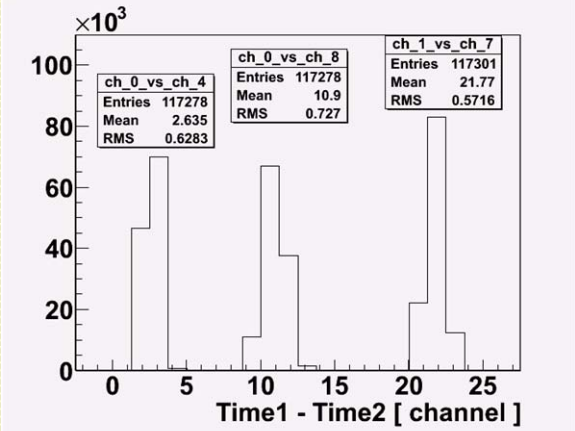
TRB Board:

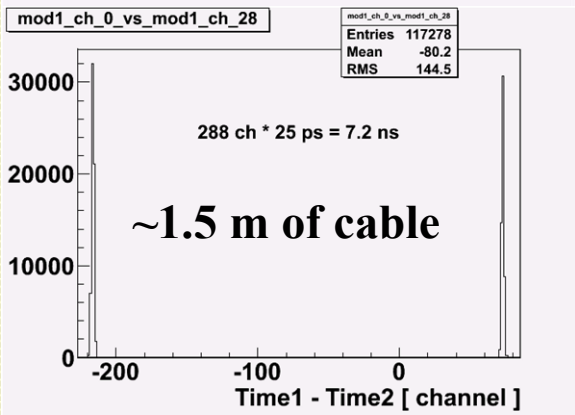
4 TDC – 128 channels (HPTDC), 4x512Mb SDRAM, FPGA – Virtex4LX40, ETRAX, FS – 4 processors, 100Mb/s,TCP/IP, 2,5 Gb/s optical link, DSP TigerSharc, DC/DC converters, AddOn connector

→ Time, ToT, 96ps/bin - 128 channels

→ **Time, ToT, 25ps/bin - 32 channels**

→ **Rate capability: up to 3 MHz per channel**

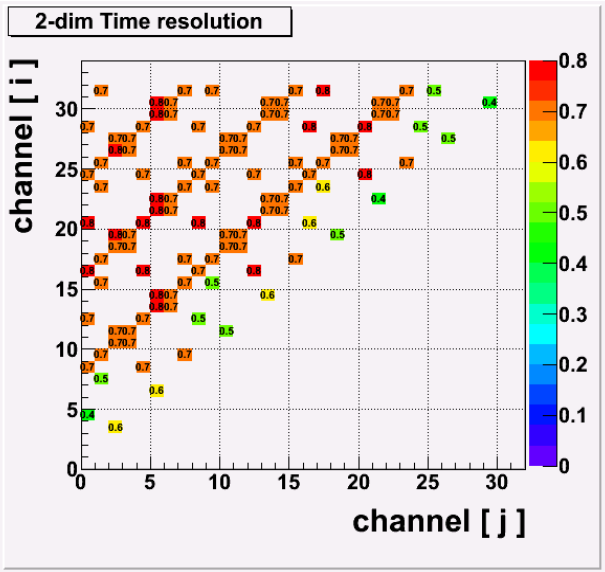


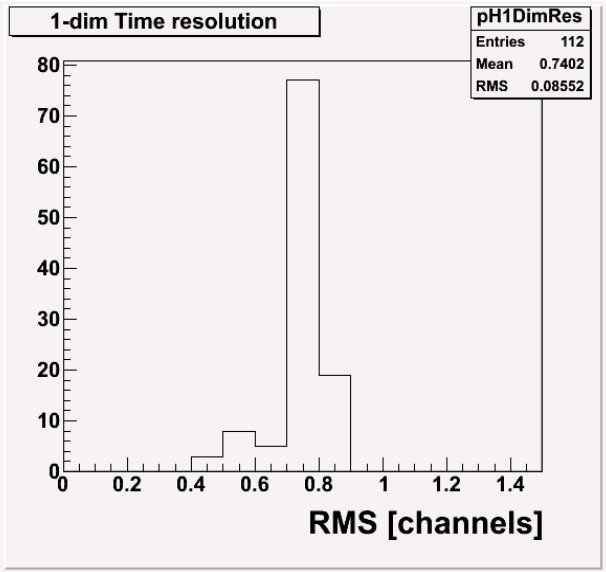


Pulser test signal sent to 8 channels.

✓ Individual INL corrections for each channel

→ **All 32 channels show RMS below 25ps/1.4 = 17.8 ps**

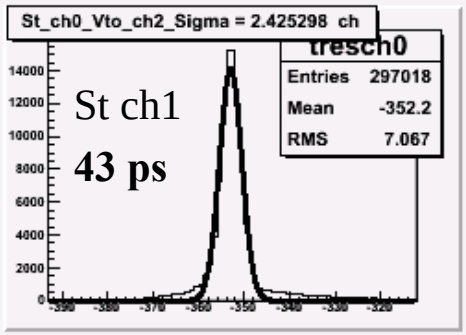


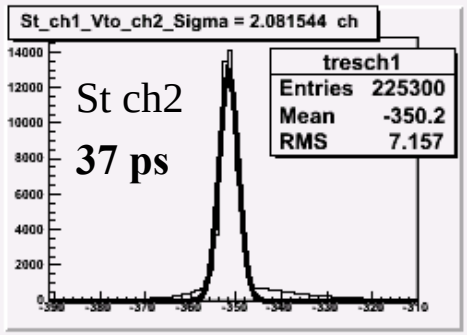


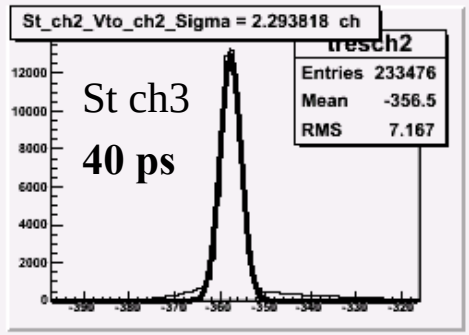
Start-Veto system – test with Au beam (Nov 2010)

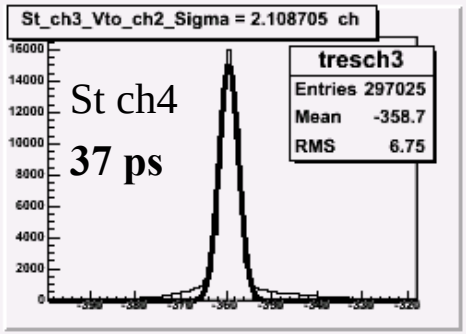
Setup and conditions:

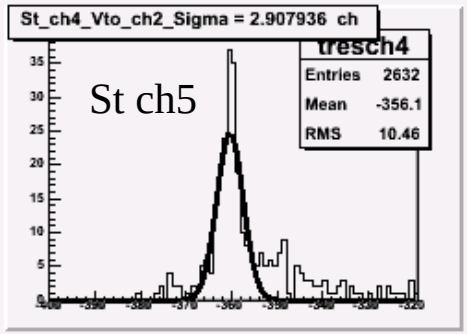
- ✓ Start det.: monocrystalline diamond, 50 μm thickness, **HV set to 200 V**
- ✓ Veto det.: polycrystalline diamond, 100 μm thickness, **HV set to 200 V.**
- ✓ Beam particles intensity: **10^6/s per channel.**

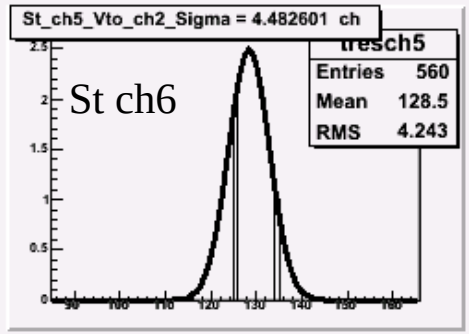


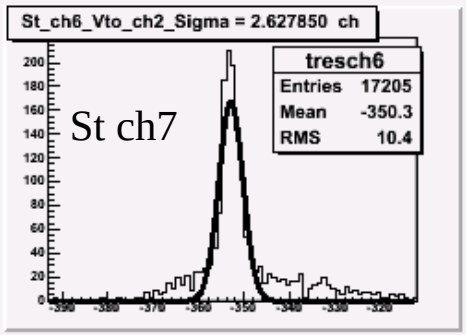


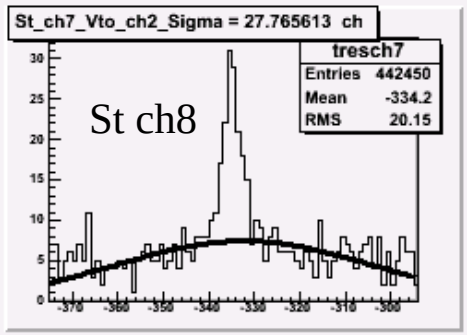


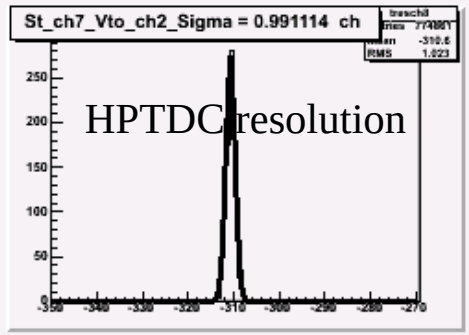


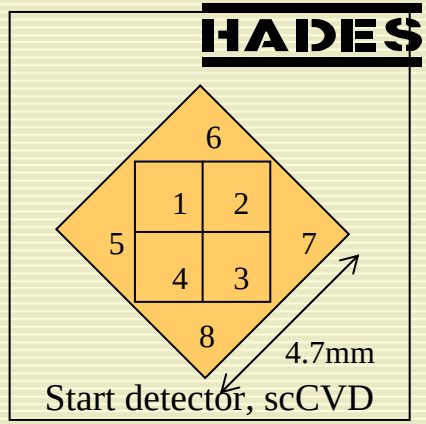


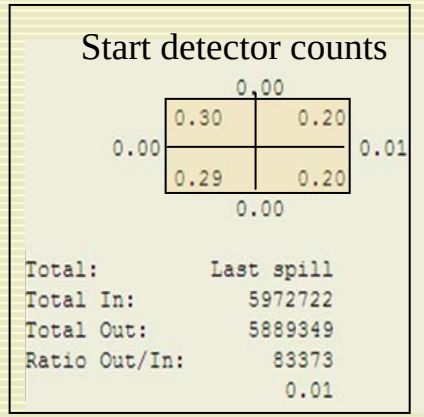


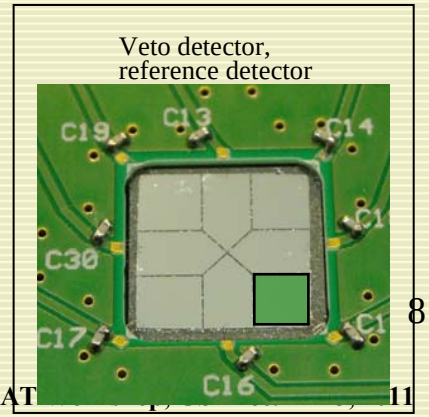










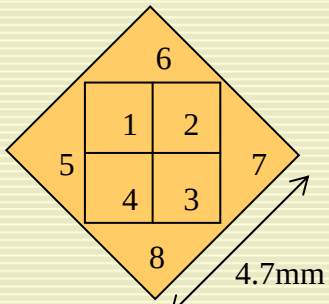


Start-Veto system test with Au beam (Nov 2010)

HADES

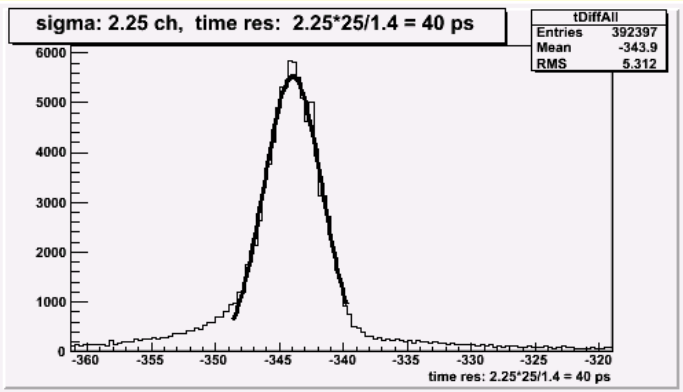
Setup and conditions:

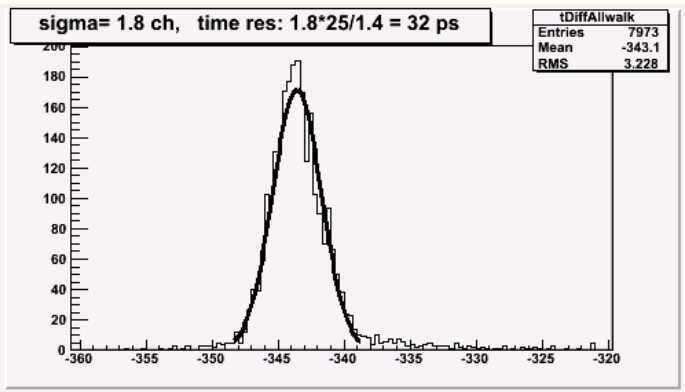
- ✓ Start det.: monocrystalline diamond, 50 μm thickness, **HV set to 200 V**
- ✓ Veto det.: polycrystalline diamond, 100 μm thickness, **HV set to 200 V.**
- ✓ Beam particles intensity: 10^6/s per channel.

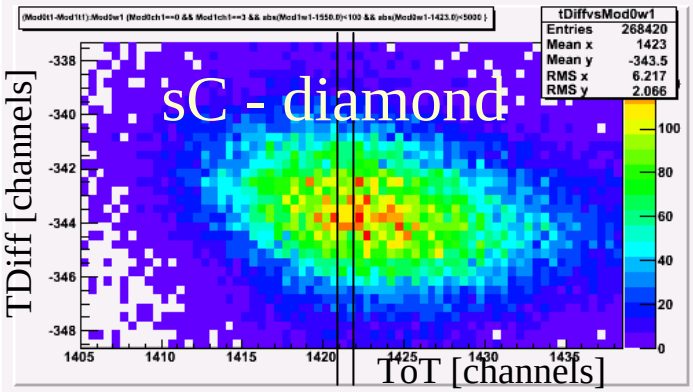


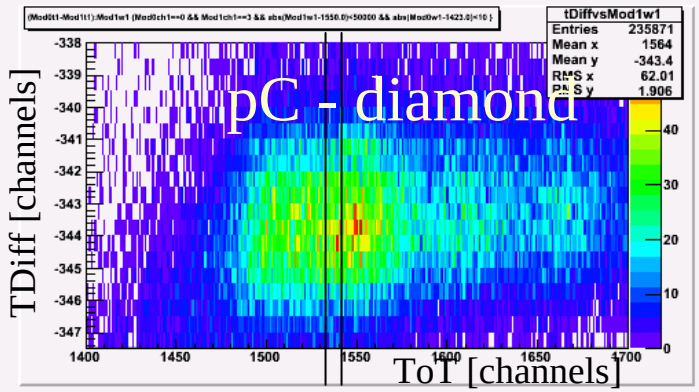
Start detector

One channel with "walk" correction – 32 ps

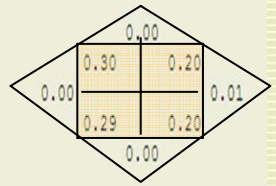






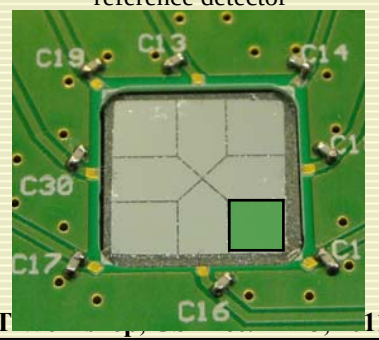


Start detector counts



Total:	Last spill
Total In:	5972722
Total Out:	5889349
Ratio Out/In:	83373
	0.01

Veto detector, reference detector



Start-Veto system test with Au beam (Nov 2010)

stability problem !

Setup and conditions:

- ✓ Start det.: monocrystalline diamond, 50 μm thickness, **HV set to 200 V.**
- ✓ Veto det.: polycrystalline diamond, 100 μm thickness, **HV set to 200 V.**
- ✓ Beam particles intensity: 10^6/s per channel.

Long term stability problem - raising current

- ✓ Effect clearly visible after 2-3 hours of continuous Au beam with intensity 10^6/s
- ✓ Visible for Start and Veto (mono and poli-crystalline material)

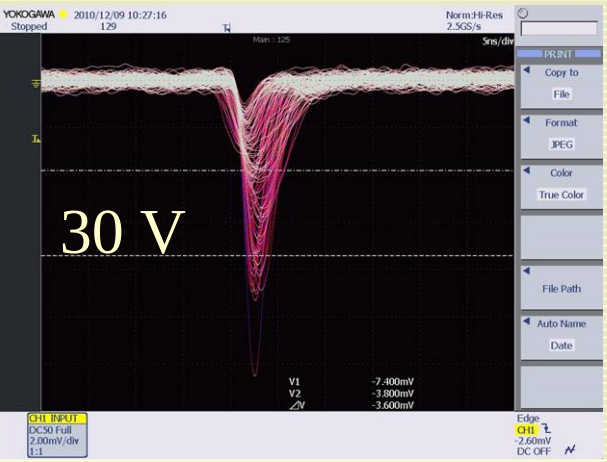
Time	Start current in spill	Start current off spill	Veto current in spill	Veto current off spill
10:00	2.5 μA	0.00 μA	2.6 μA	0.00 μA
11:39	2.5 μA	0.09 μA	2.6 μA	0.04 μA
12:01	1.4 μA	0.88 μA	1.8 μA	0.20 μA
12:41	2.2 μA	0.88 μA	2.4 μA	0.40 μA
. . .				

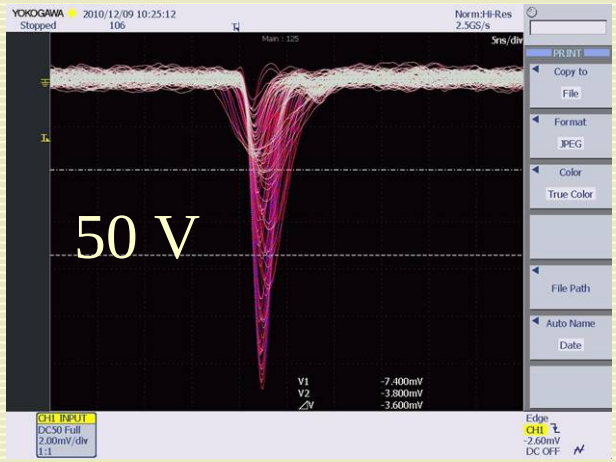
→ strong dependence on the HV observed: example: 200 V – 0.25 μA

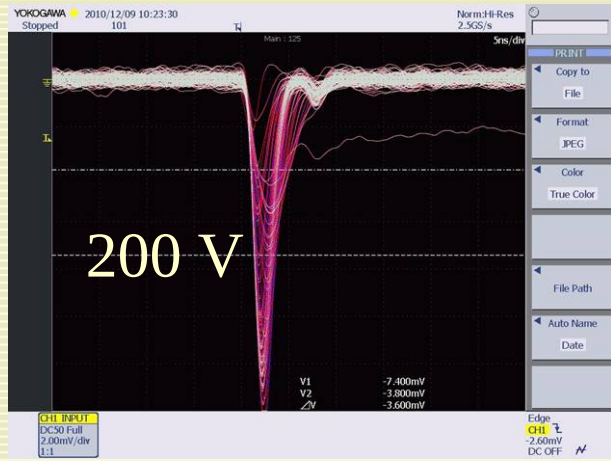
150 V – 0.08 μA

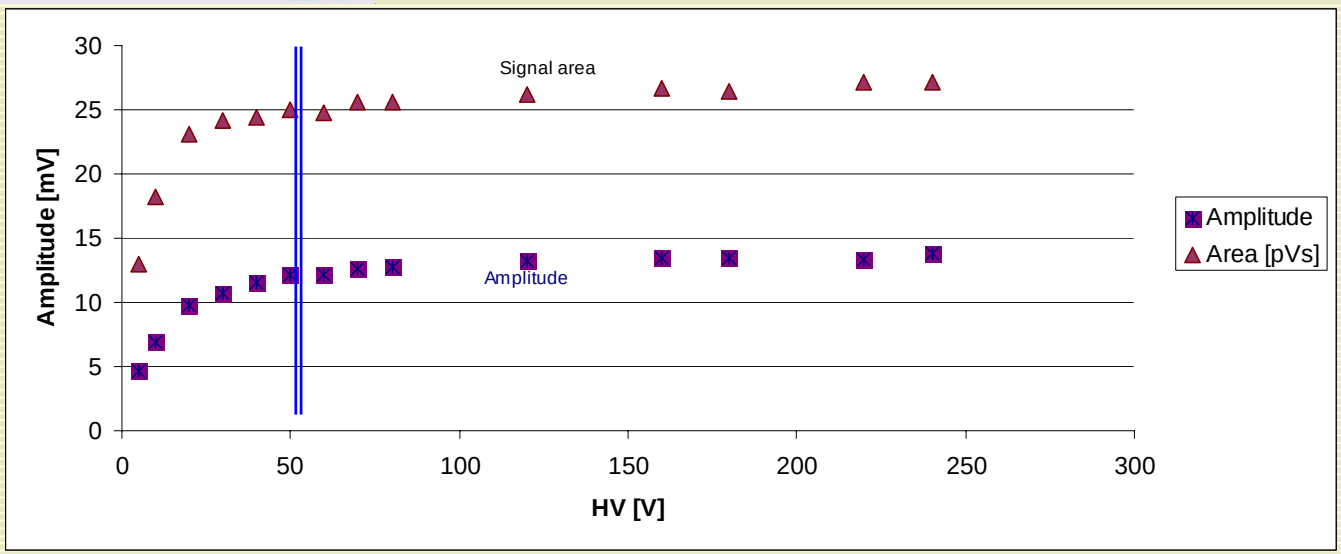
4-5 weeks of Au+Au production run in HADES !!!!

Start-Veto system – test with Au beam, working point determination with Alpha source

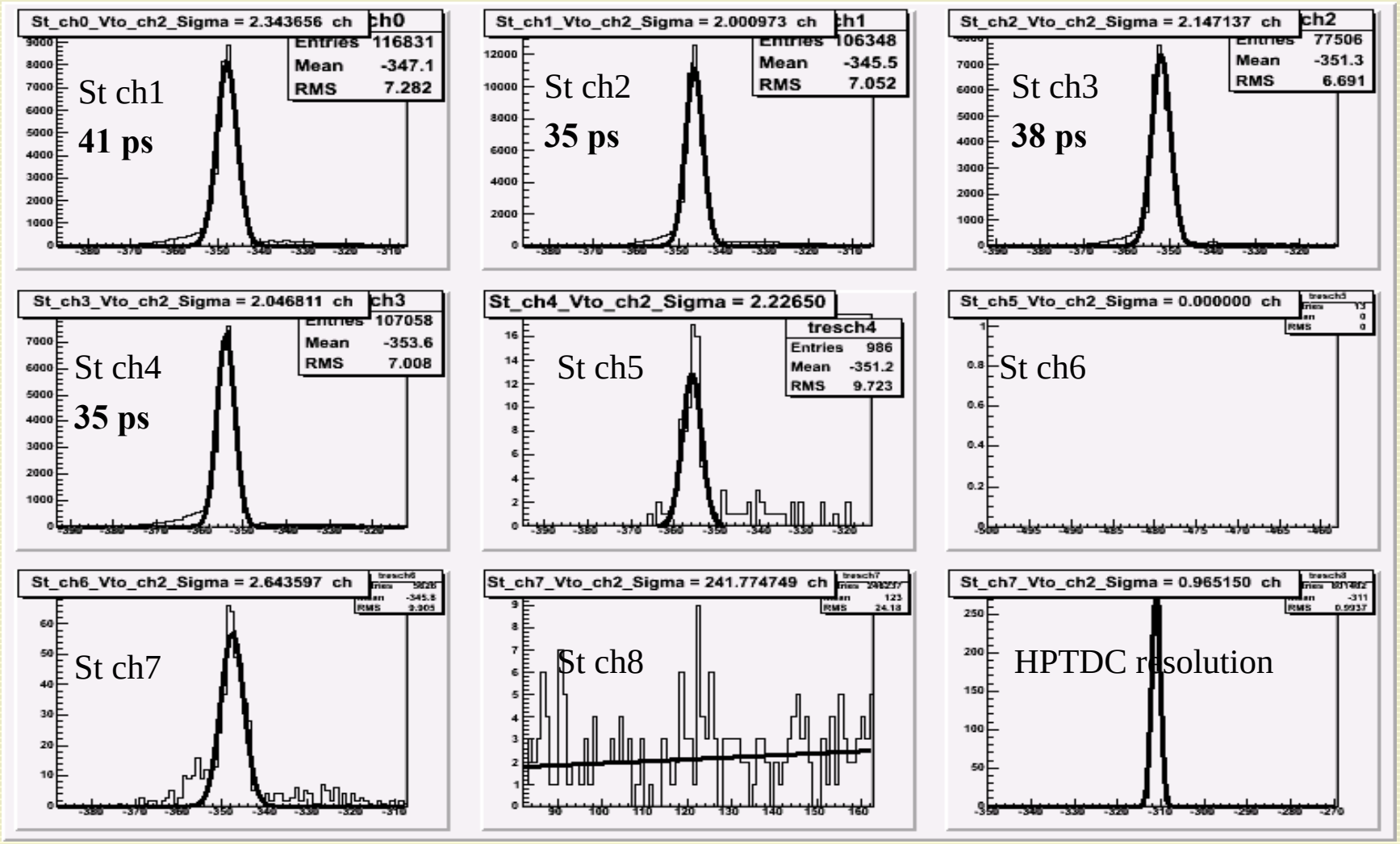








Start-Veto system – test with Au beam, time resolution at 1V/ μm (HV = 50 V)



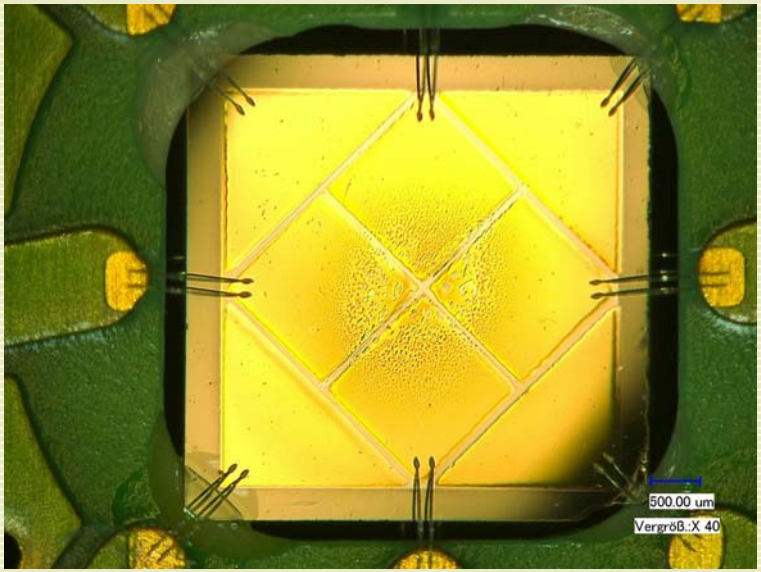
HV reduced by a factor of 4 (200 V → 50 V) - the time resolution below 50 ps

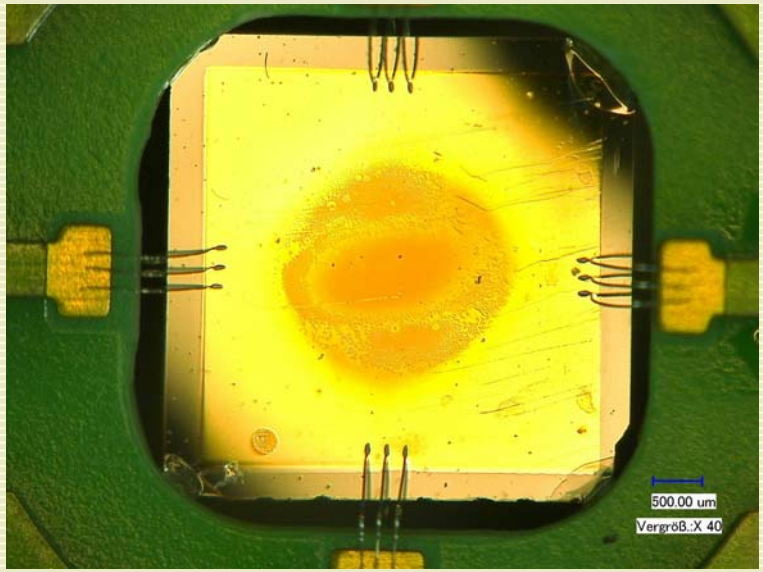
→ expected stable long term operation during high intensity HI run !

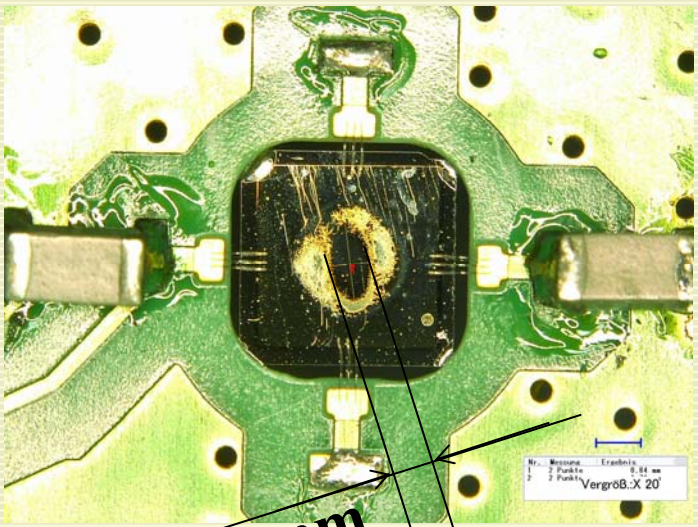
... but five days with Au beam (Au 2011) and ...

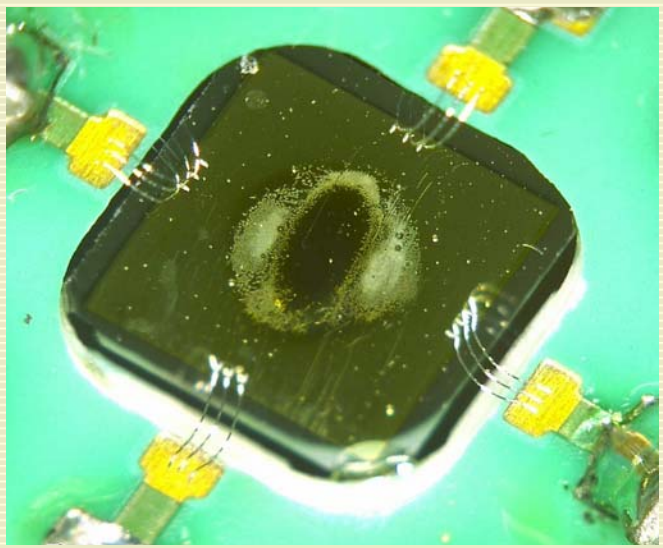
Dismounted Start detector:

M. Träger, GSI Det.Lab









Beam spot

0.8x1.6 mm^2

→ **1.28 mm^2**

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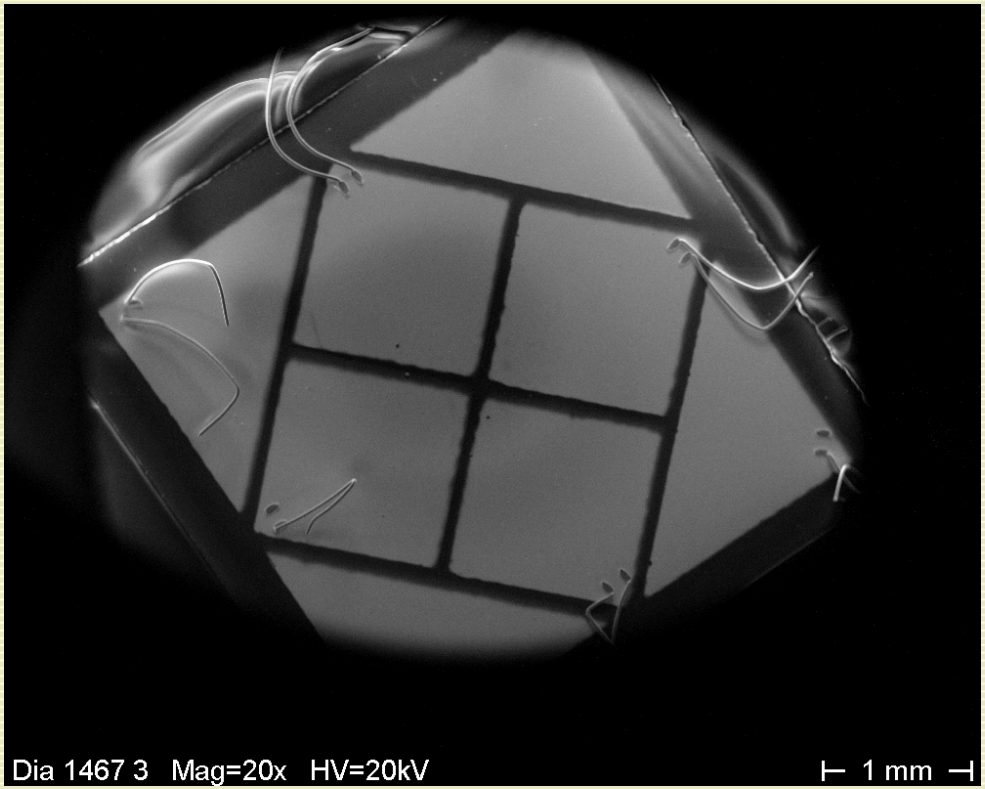
Surface (metallization) damage ?

Electron microscope



GSI Target.Lab

Beam spot
0.8x1.6 mm^2
→ **1.28 mm^2**

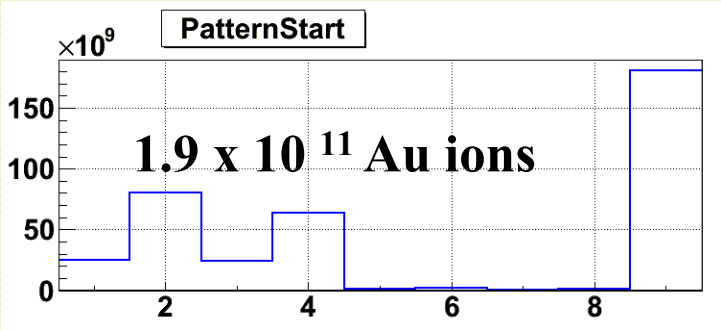
X-ray Microanalysis (EDX)

No damage to the Au metalization surface visible !!!

... but five days with Au beam (Au 2011) and ...

HADES

Total dose during 5 days measured in the Start detector



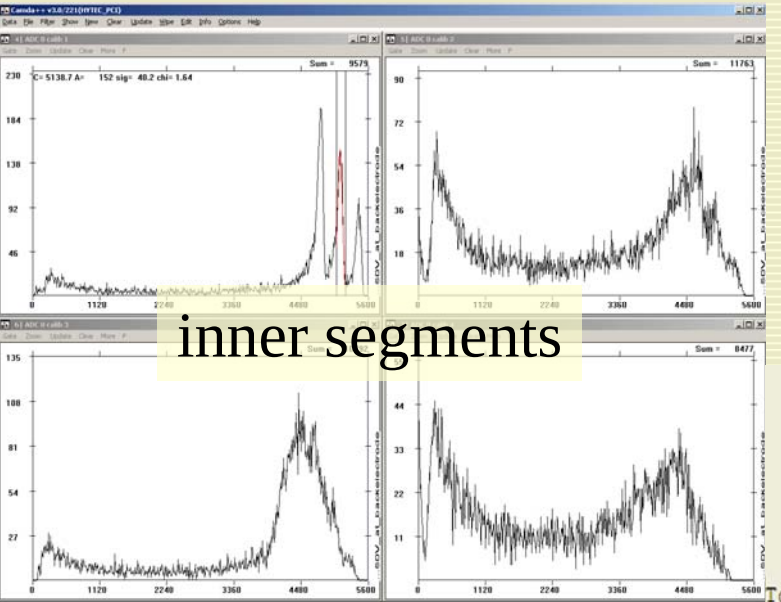
+ 30 % DAQ off + 30 % beam times in 2010

→ 3.04 x 10^{11} Au ions / 1.28 mm^2

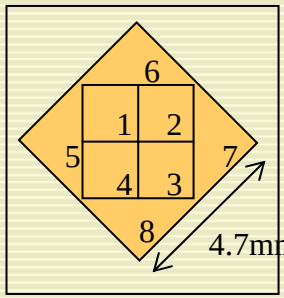
→ 2.37 x 10^{11} Au ions / mm^2

ADC spectra: Pu239 - Am241 - Cm244 in vacuum

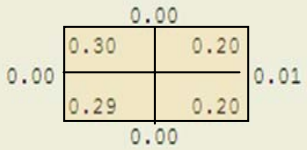
(5.157 MeV, 5.486 MeV, 5.804 MeV)



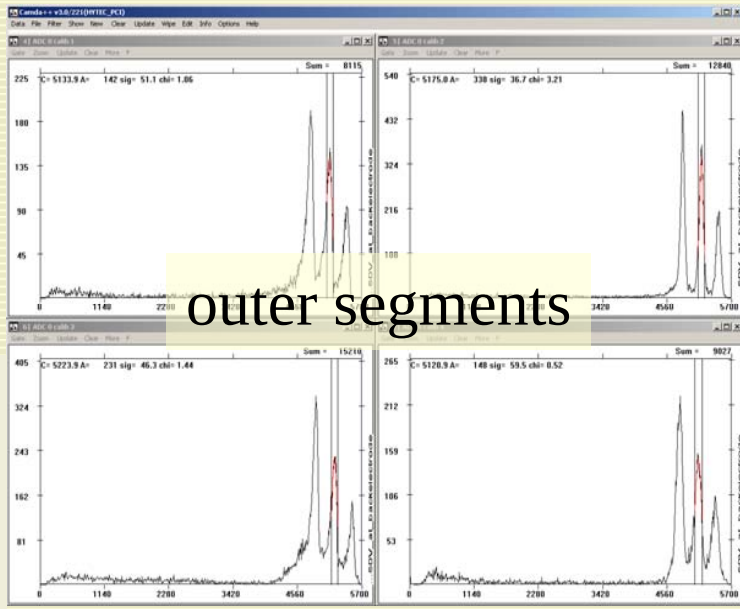
inner segments



Start detector counts



Total:	Last spill
Total In:	5972722
Total Out:	5889349
Ratio Out/In:	83373
	0.01



outer segments

GOETHE UNIVERSITÄT FRANKFURT AM MAIN

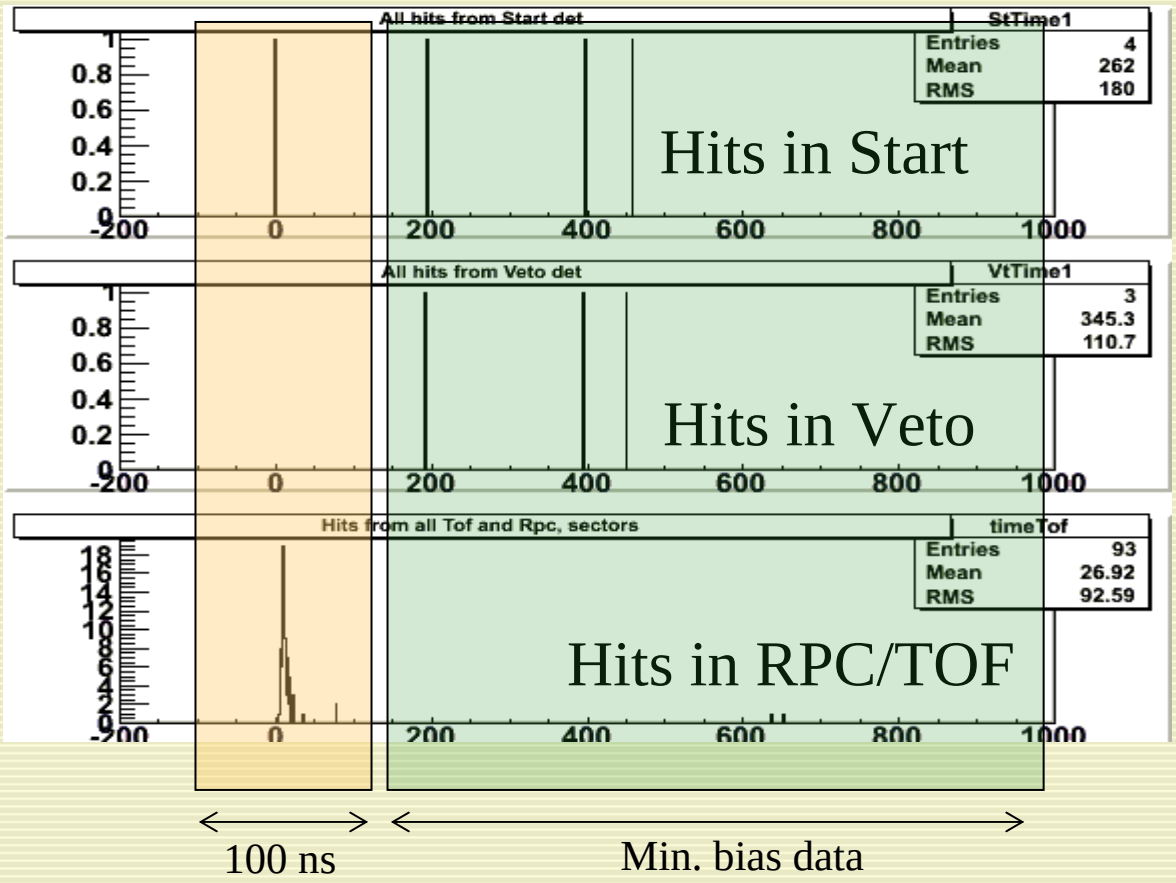
M. Träger, GSI Det.Lab

Start detector efficiency determination

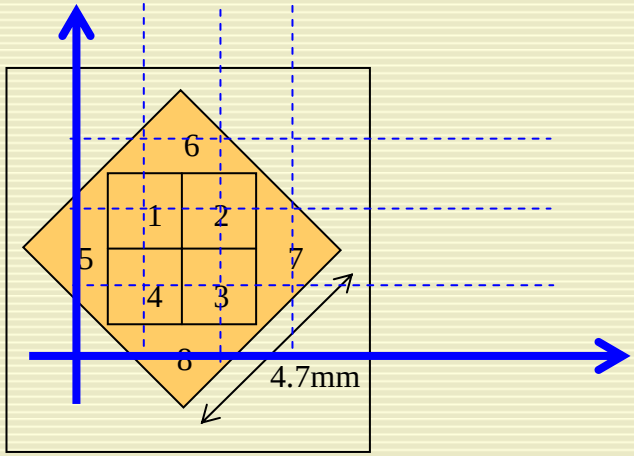
- ✓ Start detector included in 1st Level Trigger !!! – can not be used for efficiency estimation
- ✓ 8 channels of Start and 8 channels of Veto detector,
- ✓ TDC with multi-hit capability

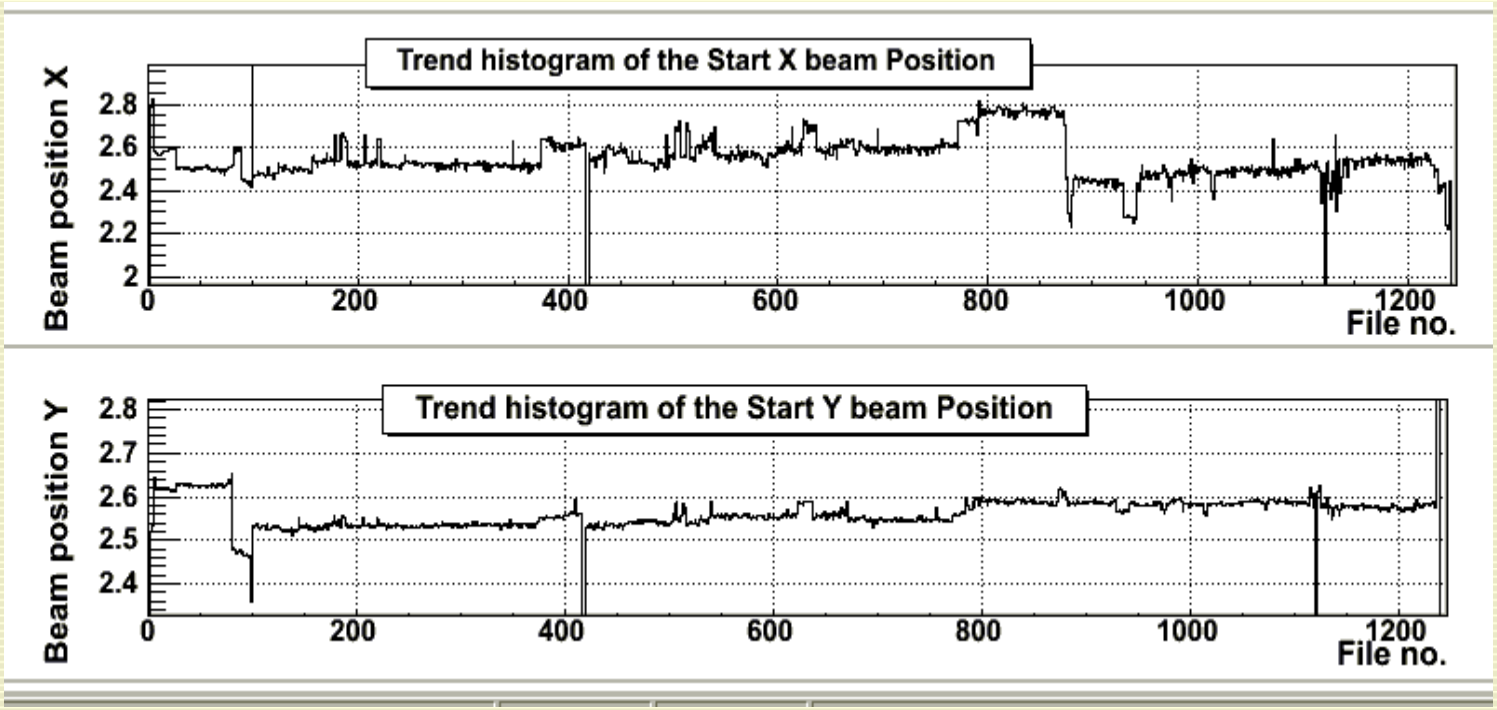
  → minimum bias trigger T>50ns

Single event, hits in Start, Veto, RPC and Tof



Beam position monitoring



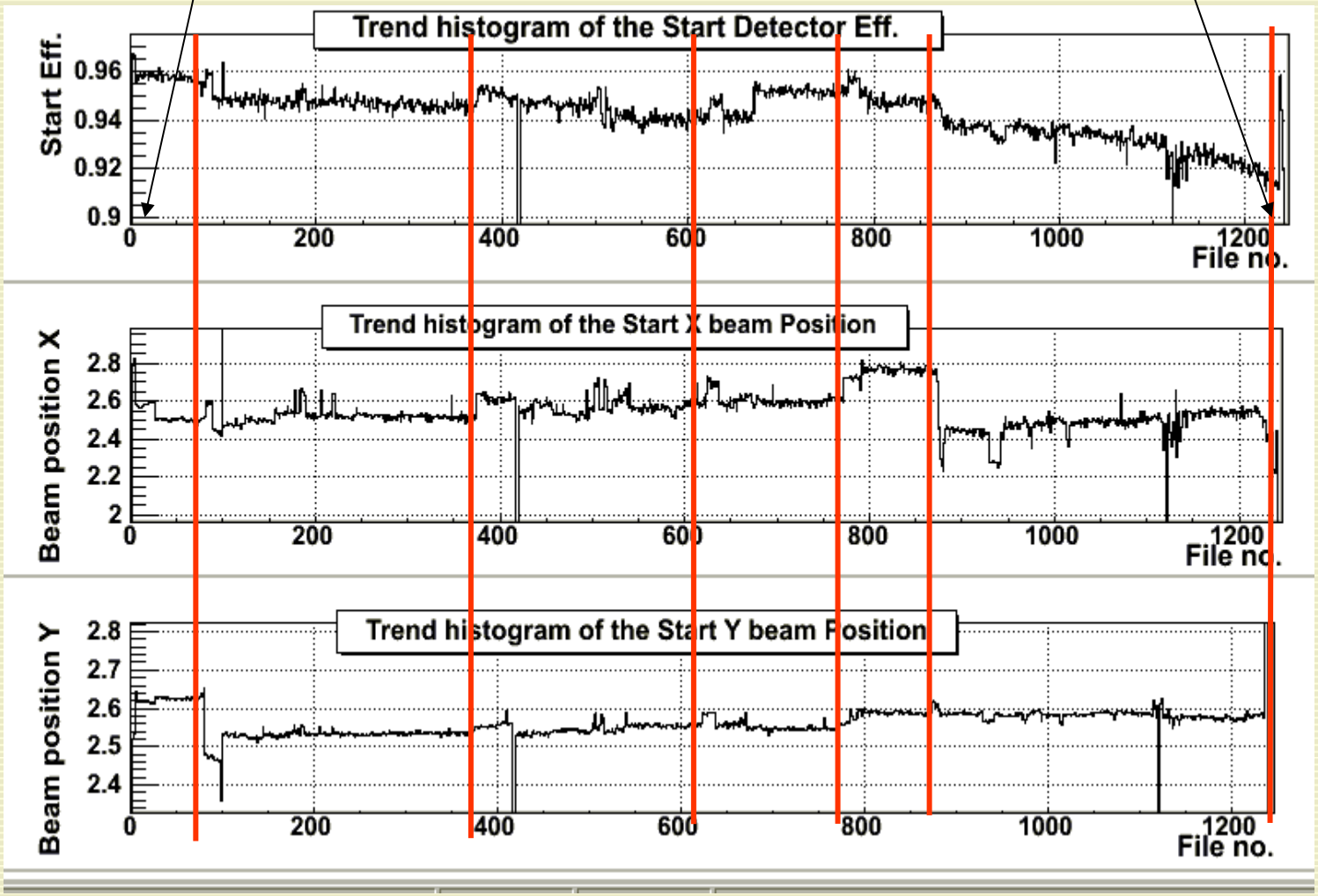


→Precise position information

Start detector efficiency determination

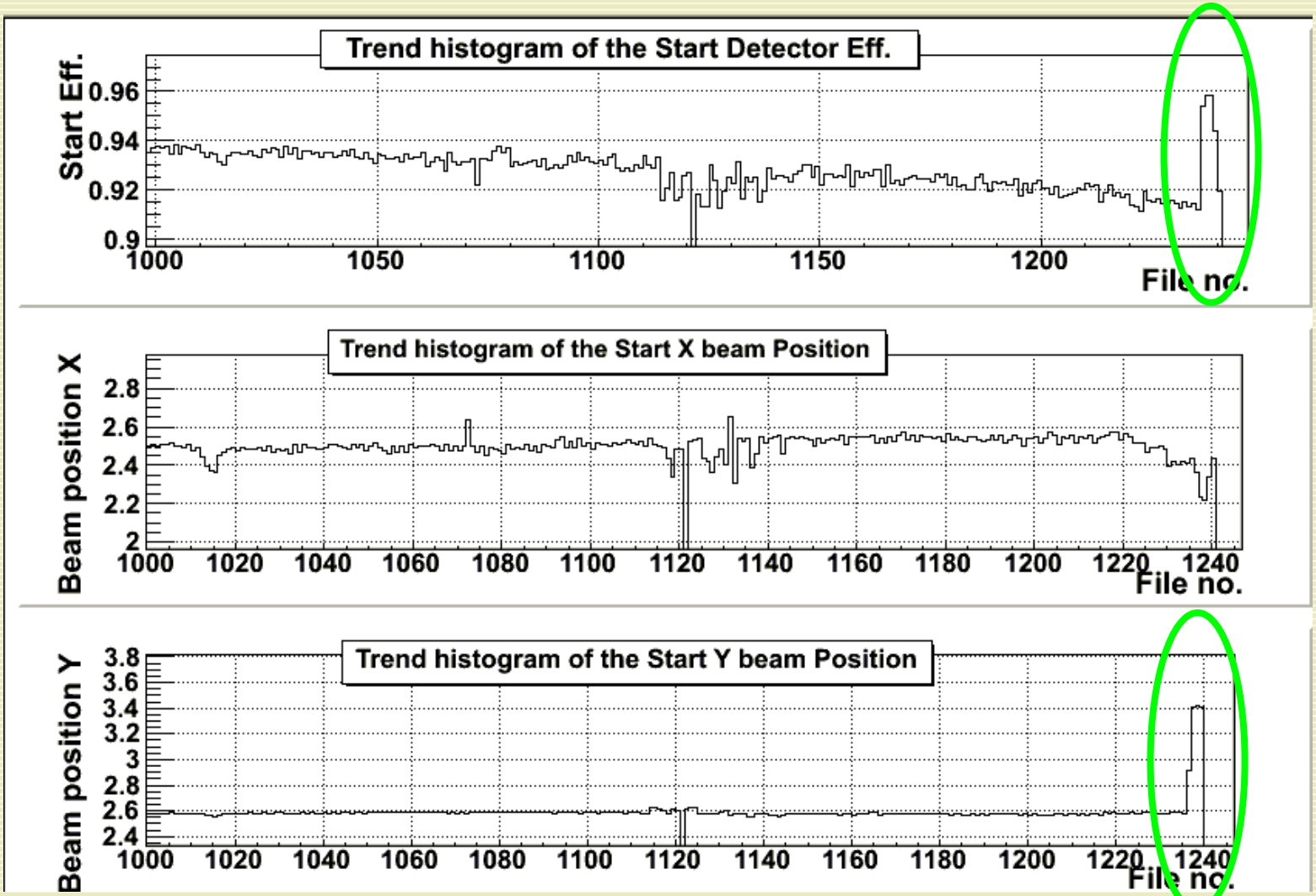
0.70 x 10^{11} Au ions / mm^2

2.37 x 10^{11} Au ions / mm^2



→Strong eff. changes correlated with shifts in beam position !!

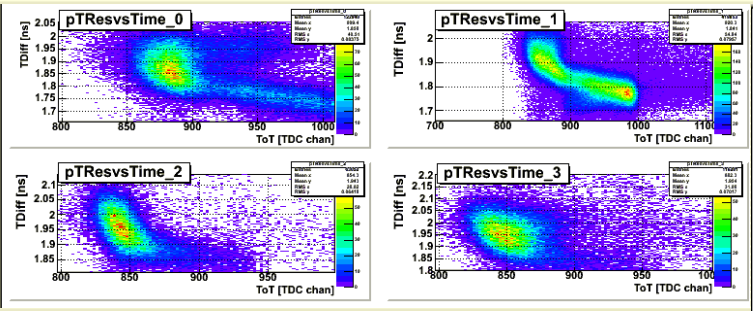
Start detector efficiency determination

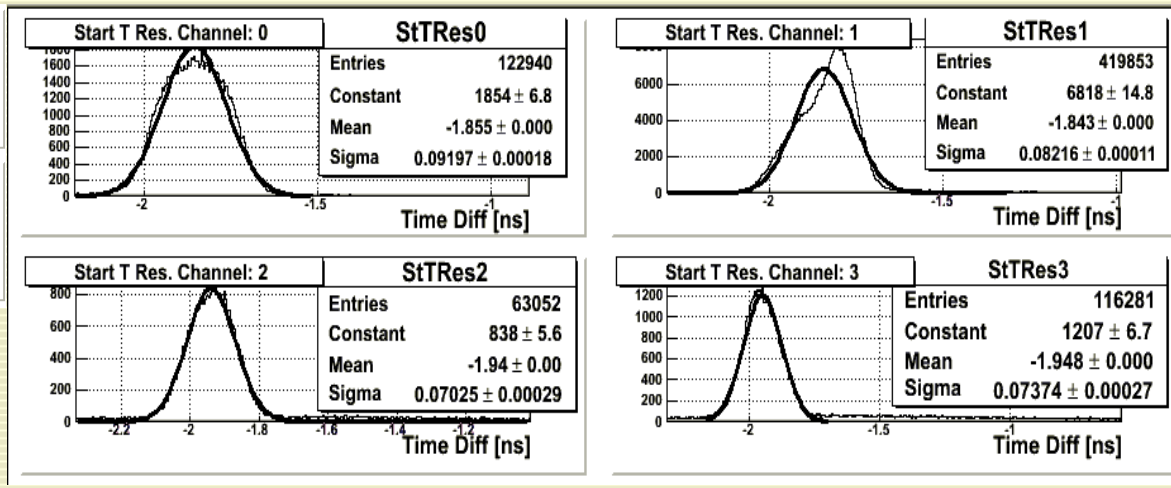


→Strong eff. changes correlated with shifts in beam position !!

Start detector time resolution

(after 0.70 x 10^{11} Au ions / mm^2)





- ✓ Strange ToT distributions
- ✓ improved time res. after walk corr.

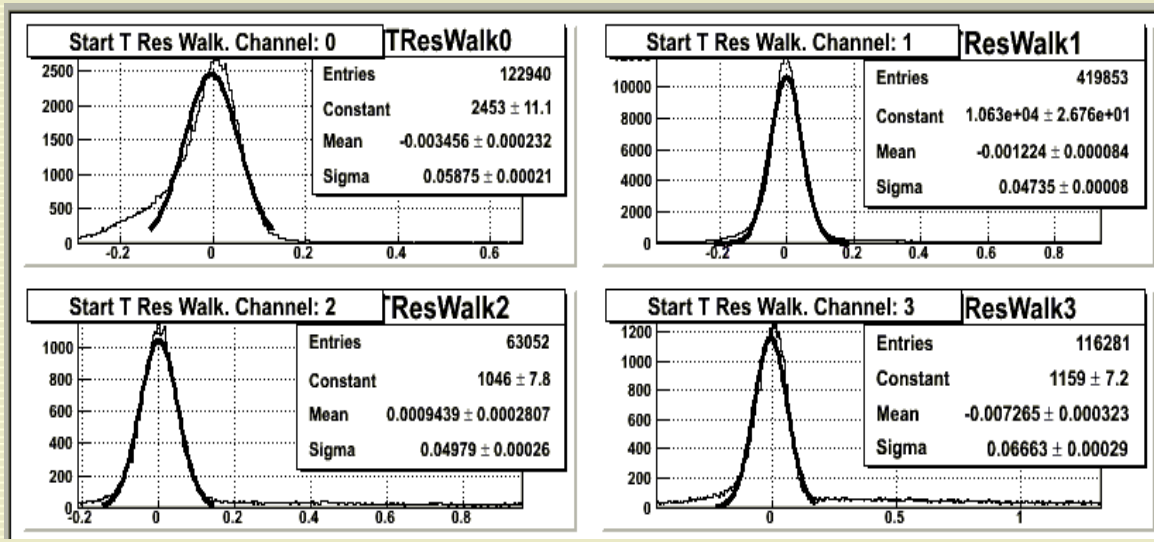
91 (65ps) → 58 (41ps)

82 (58ps) → 47 (33ps)

70 (50ps) → 49 (35ps)

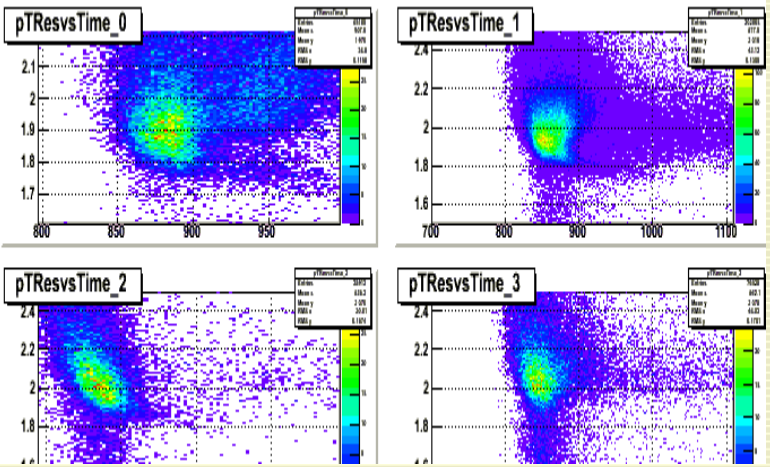
73 (52ps) → 66 (47ps)

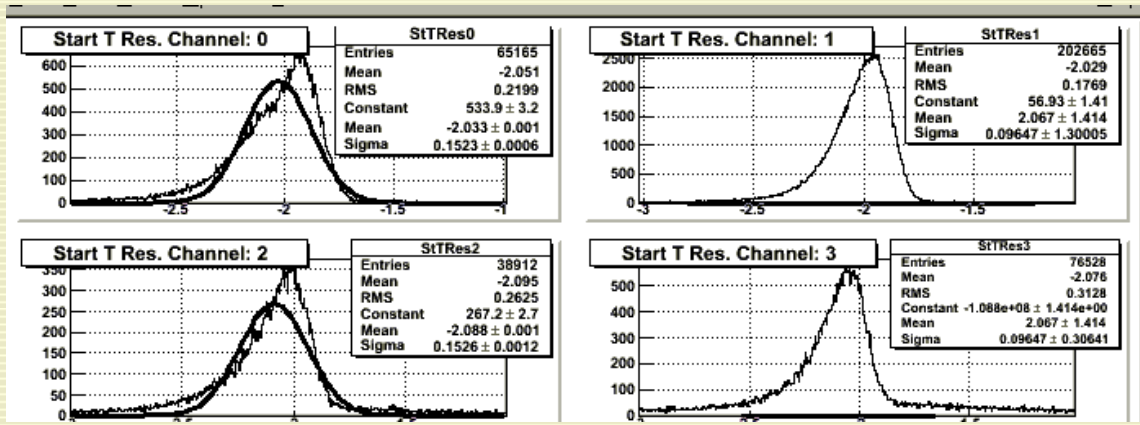
Time resolution with walk correction

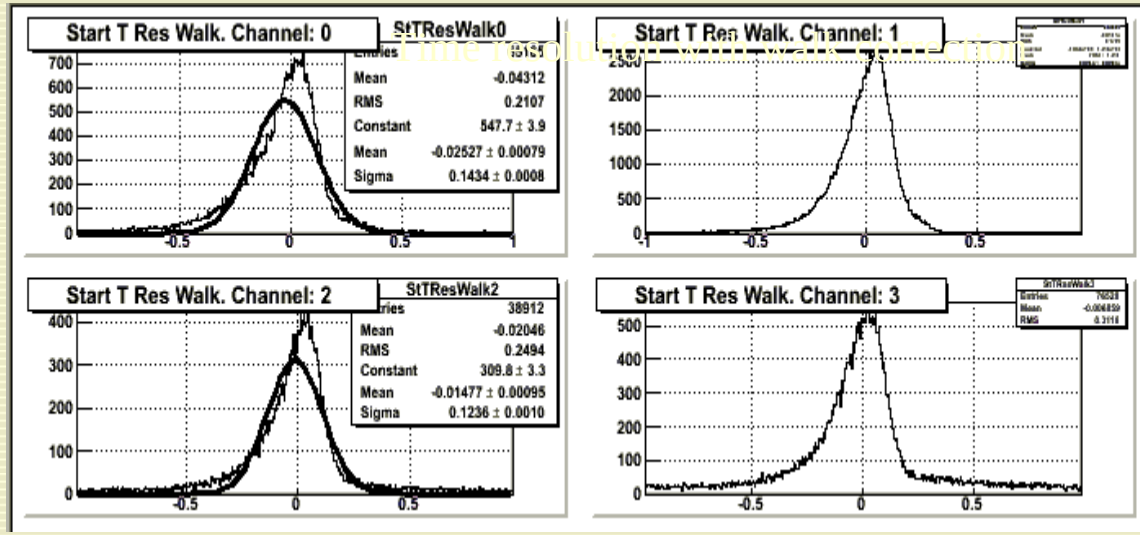


Start detector time resolution

(after 2.37 x 10^{11} Au ions / mm^2)







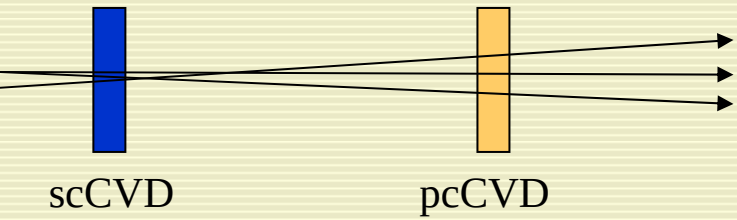
✓ Strange ToT distributions

152 (107ps) → 143 (102ps)

112 (80ps) → 108 (77ps)

152 (107ps) → 123 (87ps)

142 (101ps) → 139 (99ps)



→ poor time res. after walk correction.

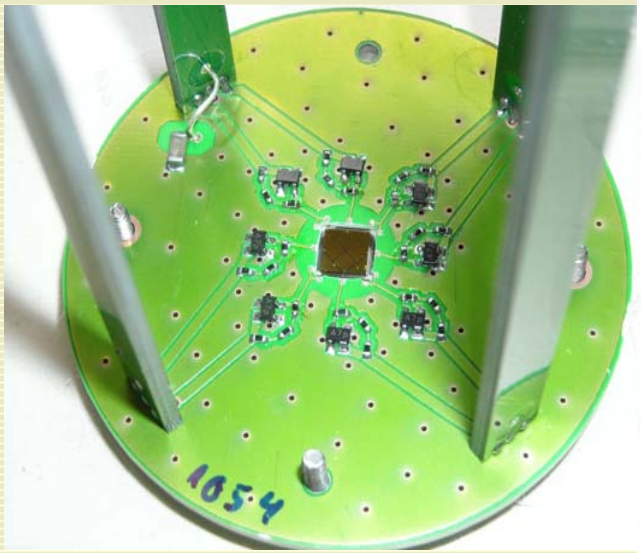
contribution from Veto Detector (pcCVD) ? To be checked

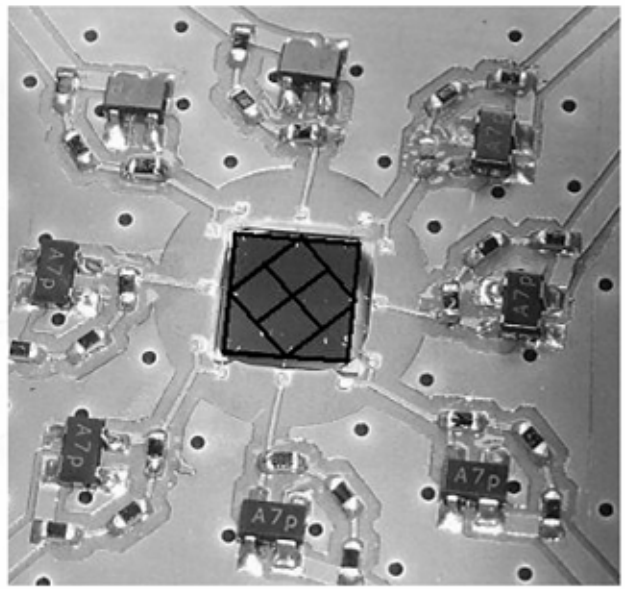
Start-Veto system for HADES pion/proton experiment (MIPs)

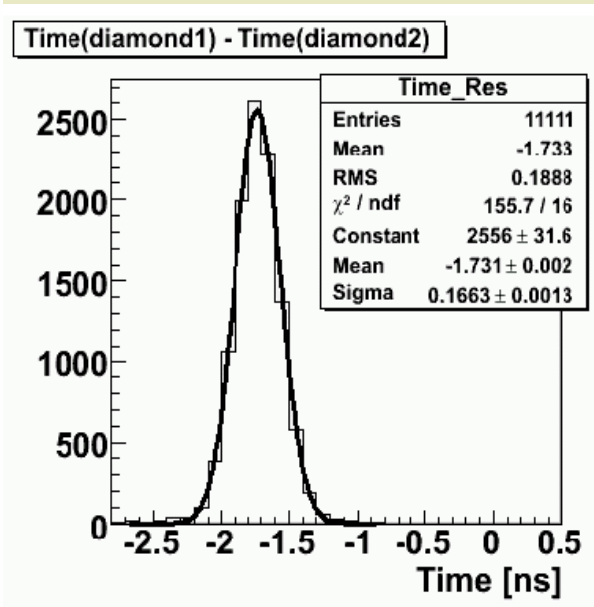
Experimental conditions and requirements for HADES pion experiment:

- ✓ **Secondary pion beam, mom.=1GeV/c (MIPs) → scCVD**
- ✓ Demanding beam particles intensity $>10^6$ pions/sec
- ✓ **Secondary beam. Beam spot diameter 1-2 cm → Large area moncrystaline diamond**
- ✓ **Timing signal for Tof measurement and for trigger - 50 ps time resolution**

Prototype: 4.7 mm x 4.7 mm, monocrystalline: used for proton induced reactions







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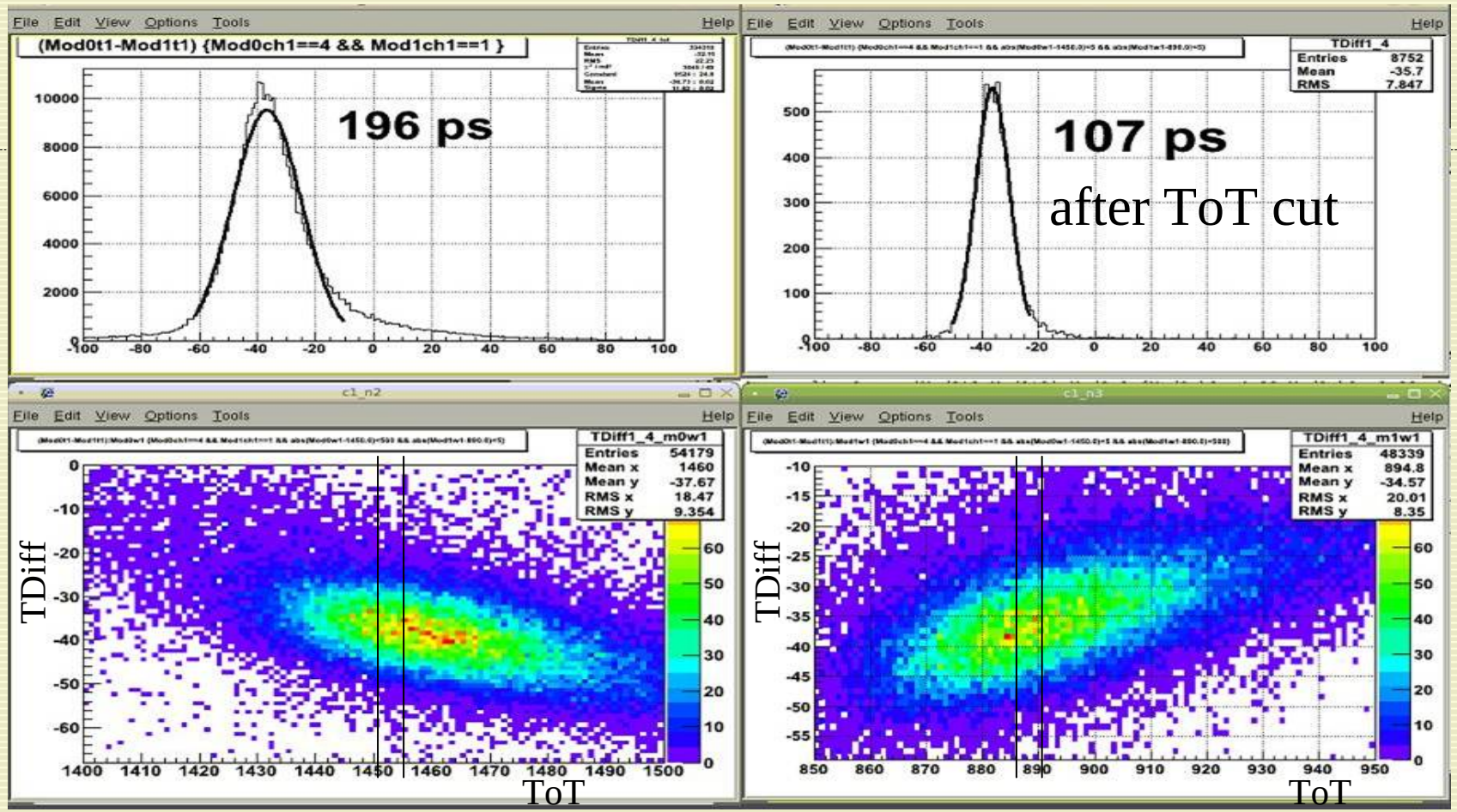
Start-detector for MIPs – test with p beam

Juelich proton beam, 2.95 GeV:

- ✓ Two Start det.: monocrystalline diamond, 500 μm thickness, 4.7mm x 4.7mm, with halo functionality, 50nm Cr/150nm Au metallization.
- ✓ Stable operation at intensities > 10^6 protons/ s/channel, BEST TIME RES = 100 ps, expected 50ps



Summary and outlook

- ✓ Segmented diamond based sensors for HI and MIPs beam tested.
- ✓ Single particle detection at beam intensities above 10^6/mm^2/s with time resolution < 50ps (HI)
- ✓ Stable operation for MIPs at intensities > 10^6 protons/ s/channel, time res. 100 ps,

But:

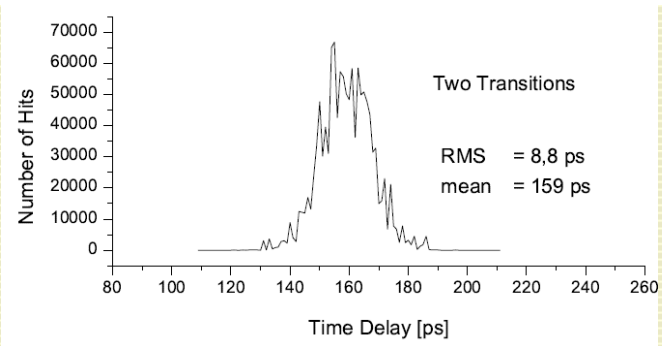
☹ Significant radiation damage at Au beam above 10^{11} Au ions/mm^2, under investigation.

In preparation:

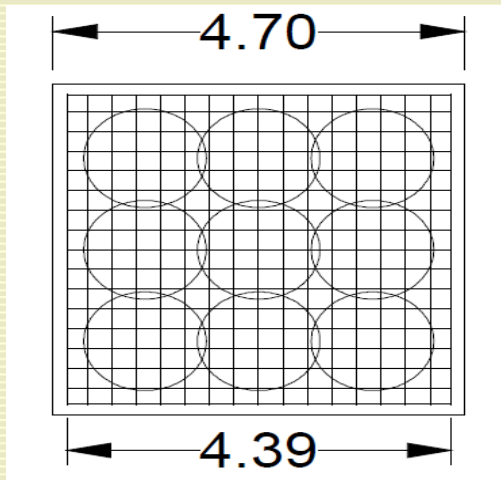
- ✓ ~~New metalization ready, test with Am source ....~~
- ✓ Double-sided multi-strip diamond based sensor for HI (16 channels on each side)
- ✓ Precise charge measurement of fast signals → see W.Koenig's talk
- ✓ New generation of TDC will be available soon (TDC in FPGA)

A High-Resolution (< 10 ps RMS) Multi-Channel Time-to-Digital Converter (TDC) Implemented in a Field Programmable Gate Array (FPGA)

Eugen Bayer and Michael Traxler

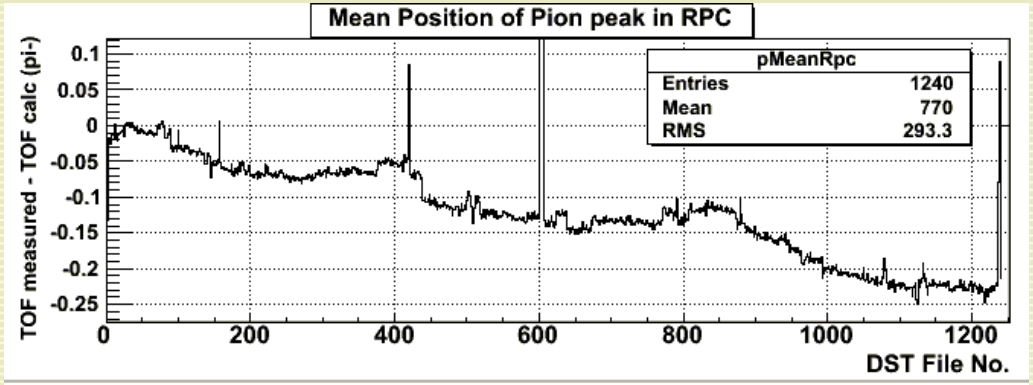


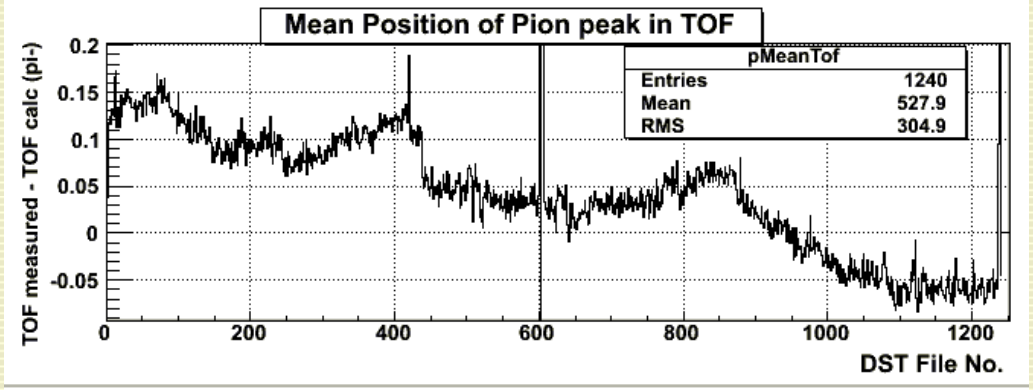
Diamond sensor, 16 stripes on each side

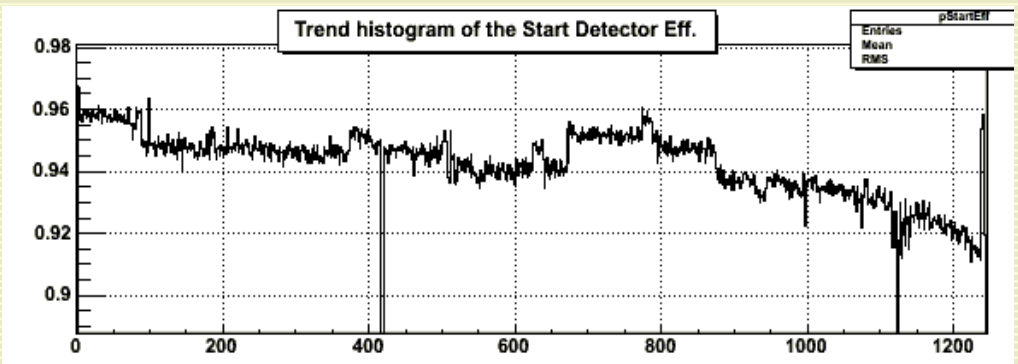


Influence on the TOF measurement

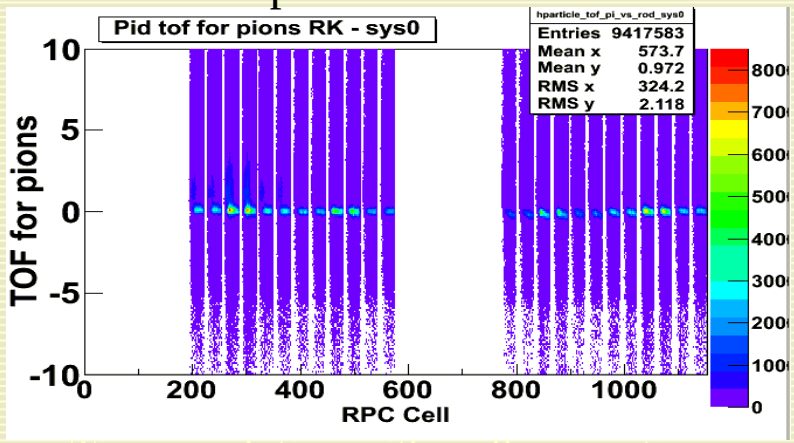
(all days of Aug11 beam time)







TOF for pions – calc - measured



Time resolution with walk correction

→ strong shift of T0, up to 200 ps

→ corrections needed