Timing Performance of CVD-Diamond Detectors for MIPs

- ***Introduction***
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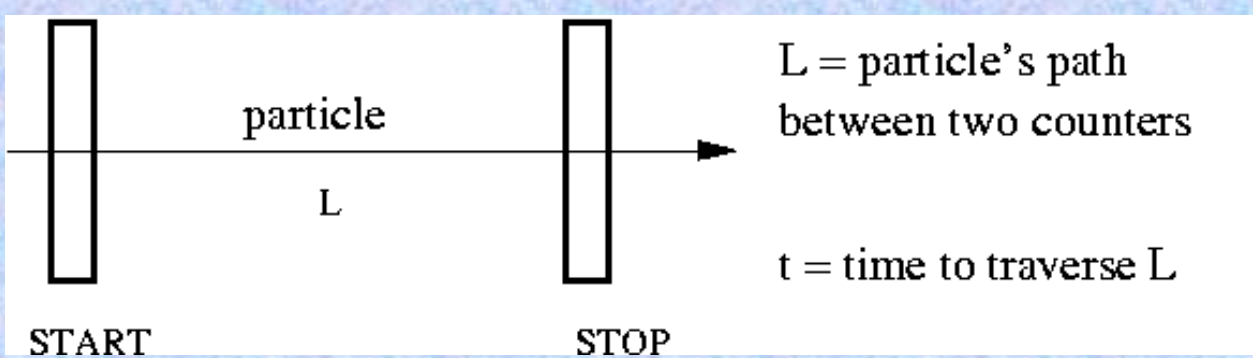
  - ***Time of Flight resolution***
  - ***Short History***
- ***Preliminary results using CVD-DD with 60 μm collection distance and DBA amplifier***
- ***Charge Collection Distance Measurements***
- ***Results obtained using two CVD-DD with d_c = 200 μm and DBA amplifiers***
- ***Summary***

Time of Flight method



$$v = \frac{L}{t} = \text{particle speed} \rightarrow m = \frac{p}{\gamma\beta c} = \frac{p}{c}\sqrt{\frac{c^2t^2}{L^2} - 1}$$

$$\Delta t_{1-2} \approx \frac{L}{2cp^2}\left(m_1^2 - m_2^2\right) \text{ for relativistic particles } (\beta \rightarrow 1)$$

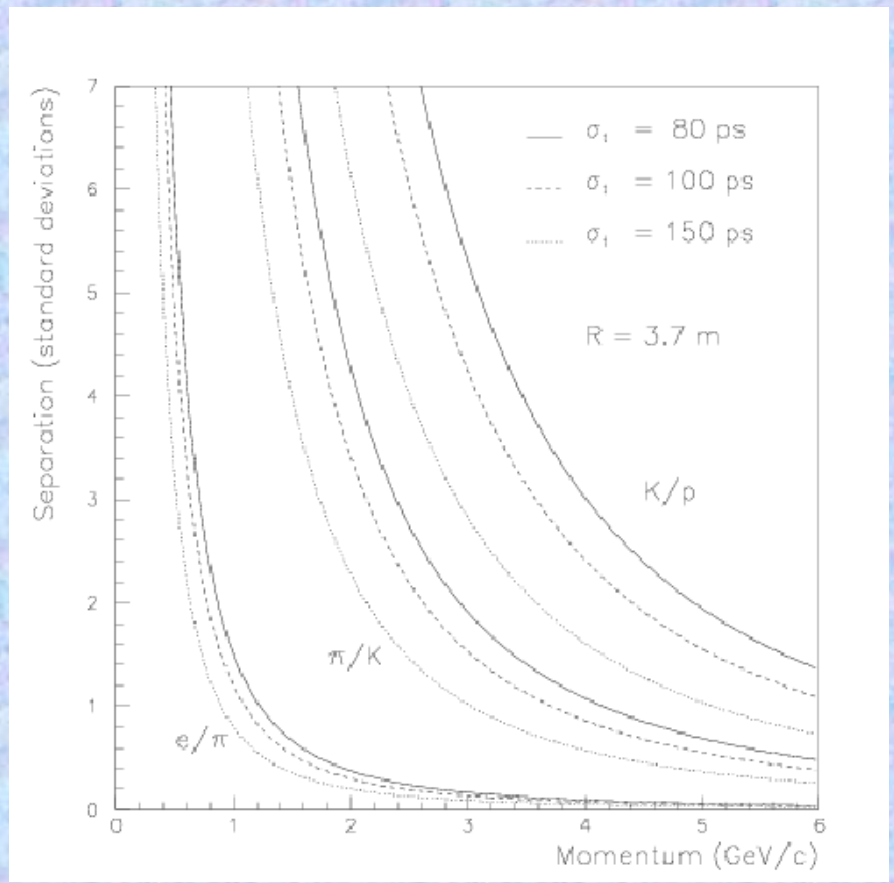
Particle separation capability :

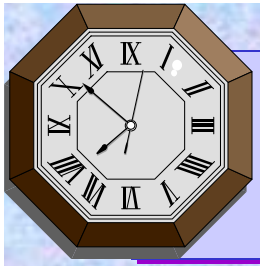
$$N_{\sigma_{ToF}} = \frac{\Delta t_{1-2}}{\sigma_{ToF}} \approx \frac{L}{2\sigma_{ToF}cp^2}\left(m_1^2 - m_2^2\right)$$

Time of Flight (ToF) resolution

$$\sigma_{ToF} = \sqrt{\sigma^2_{START} + \sigma^2_{STOP}}$$

- σ_{ToF} :Time of Flight method resolution
- $\sigma_{ToF} \leq 100$ ps for 4σ K/π
- σ_{STOP} :Stop counter resolution < 100 ps
- σ_{START} :Start counter resolution <100 ps





START Counter

Precise start signal for ToF

- **fast signals**
- **radiation hardness**
- **compact design** (minimal space, low material budget)

CVD-Diamond Properties

- ✓ *radiation hardness*
- ✓ *fast signal collection time*
- ✓ *low leakage current*
- ✓ *low dielectric constant*

CVD-DD - high resolution T0 detectors for heavy ions:
E Berdermann et al. International Winter Meeting on Nuclear Physics , Bormio (Italy), January 2000

CVD-DD - candidate for being used as T0 detectors for MIPs, with $\sigma_{START} < 100$ ***ps***

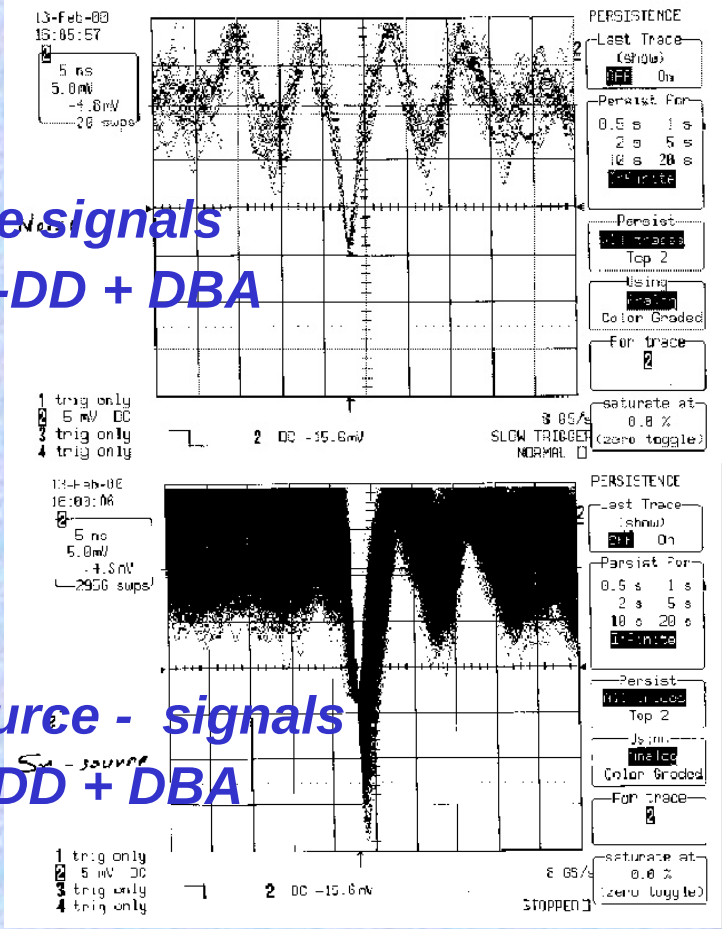
Short history

- ***Early 2000 started the collaboration along this idea between GSI-Darmstadt (Mrs. Eleni Berdermann) and NIPNE-Bucharest (Prof. Dr. Mihai Petrovici's group).***

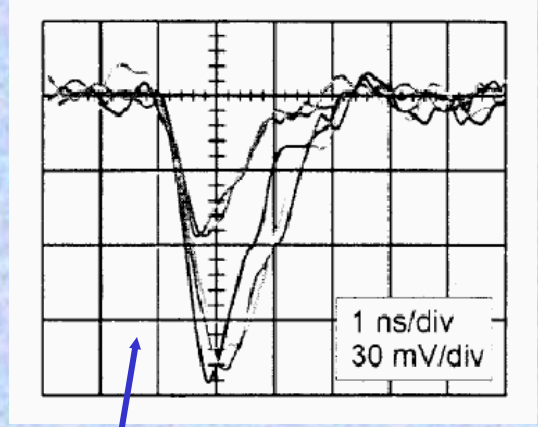
- ***Preliminary results have been already published in NIPNE Scientific Report-2000, p.60.***

- ***Detailed studies in terms of charge collection distance, time resolution and detection efficiency have been performed - NIPNE Scientific Rep.-2001, p.43, GSI Scientific Rep. 2001, p.214.***

Preliminary results using a CVD-DD with 60 μm collection distance and DBA amplifier



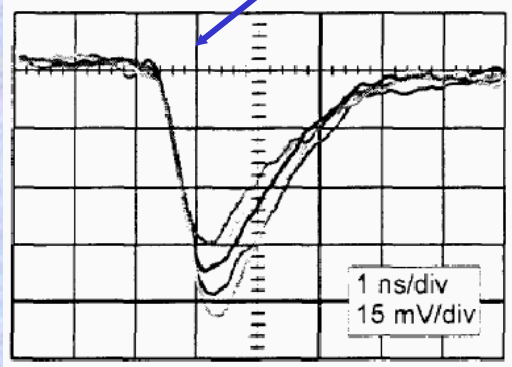
Noise signals
CVD-DD + DBA



^{241}Am -α -signals
CVD-DD + DBA

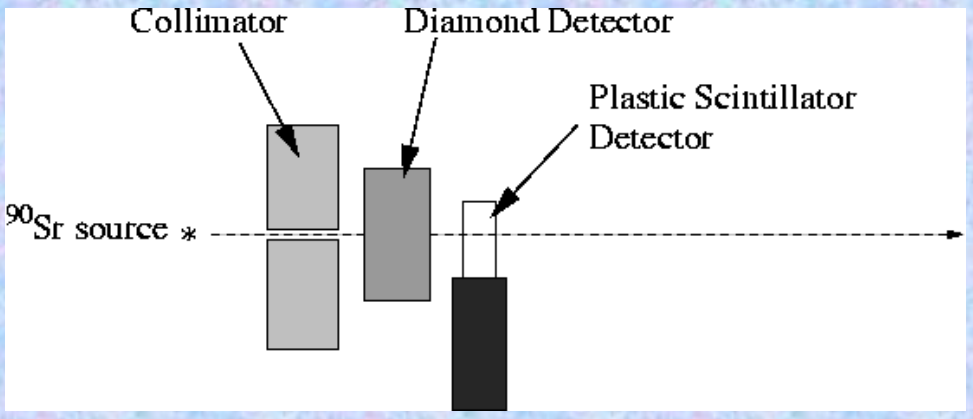
E.Berdermann et al. Nuclear Physics B (Proc.Suppl.) 61B(1998), p.399

^{90}Sr source - signals
CVD-DD + DBA



^{208}Pb ions signals (300 MeV/amu) without any amplification

Experimental Setup



- *Amplitude measurements*

FEE

- *Fast Charge Amplifier + Shaping Amplifier (0.25 μ s)*

Digitization

- *Ortec AD811 ADC*

- *Time measurements*

FEE

CVD-DD

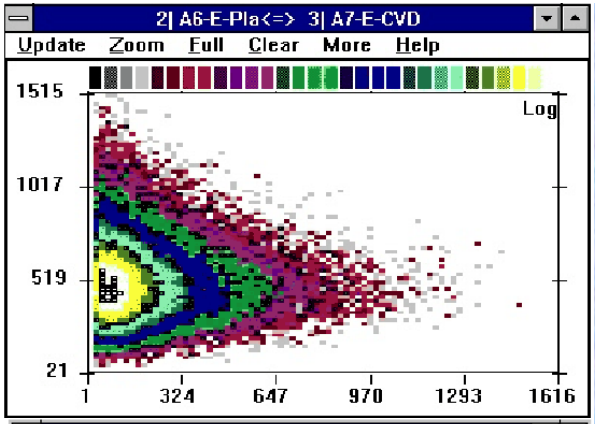
- *DBA Amplifier + FTA 420*
- *LE LeCroy 620 Discriminator*

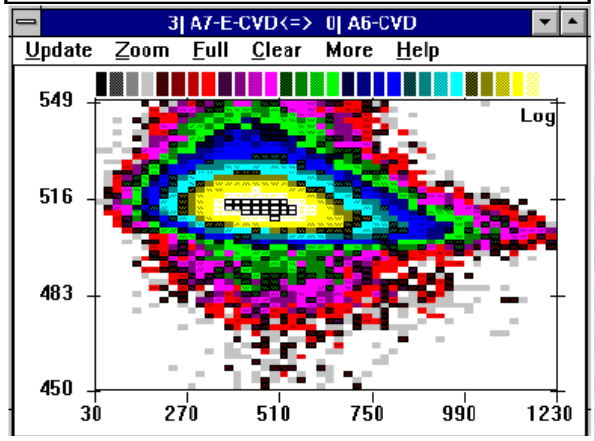
Plastic scintillator (NE102)

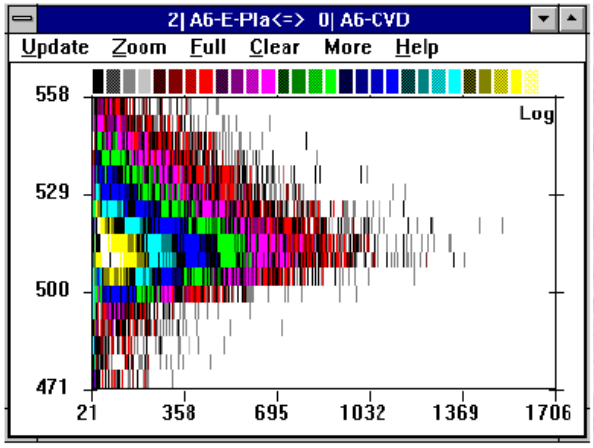
- *XP2020 PM*
- *CF4000 Discriminator*

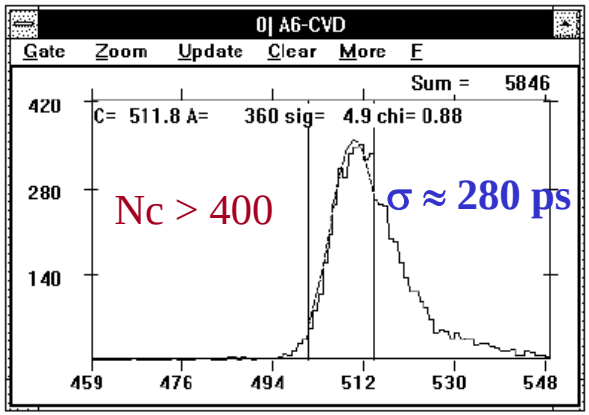
Digitization

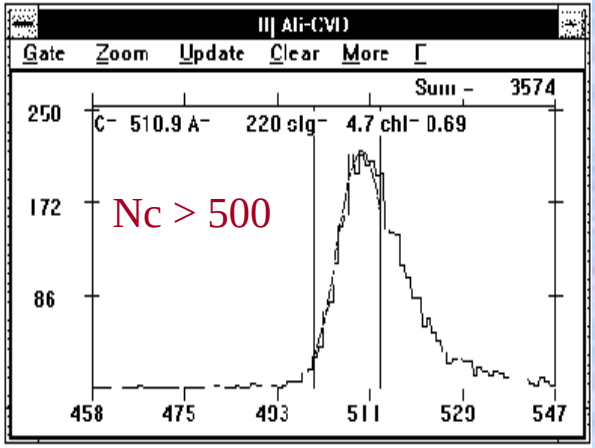
- *LeCroy 2228A TDC*

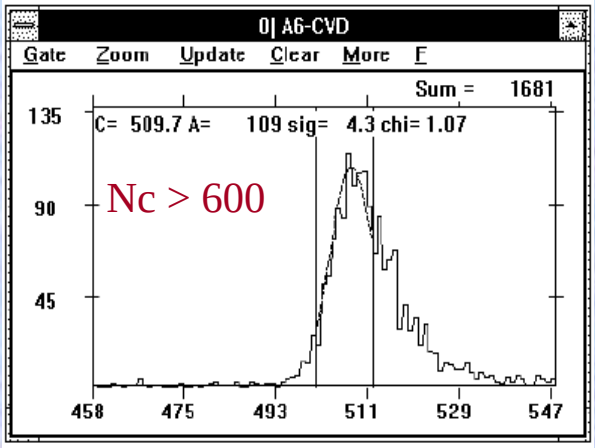

2| A6-E-Pla<=> 3| A7-E-CVD
Update Zoom Full Clear More Help
1515
1017
519
21
Log
1 324 647 970 1293 1616

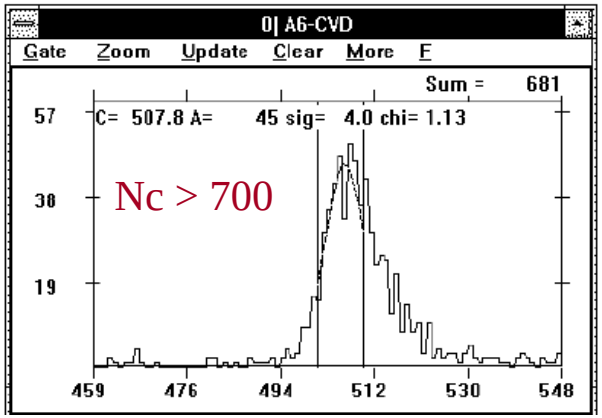

3| A7-E-CVD<=> 0| A6-CVD
Update Zoom Full Clear More Help
549
516
483
450
Log
30 270 510 750 990 1230

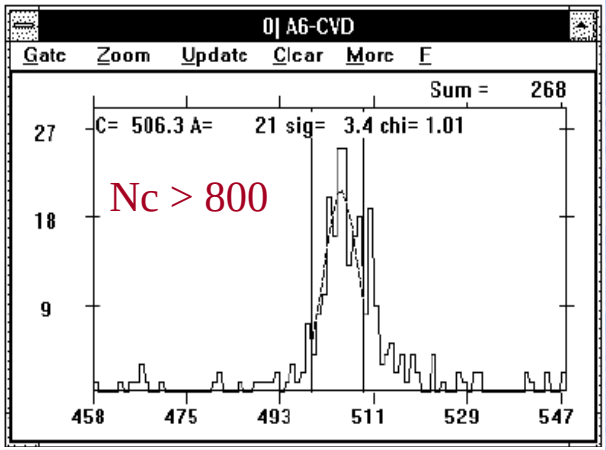

2| A6-E-Pla<=> 0| A6-CVD
Update Zoom Full Clear More Help
558
529
500
471
Log
21 358 695 1032 1369 1706

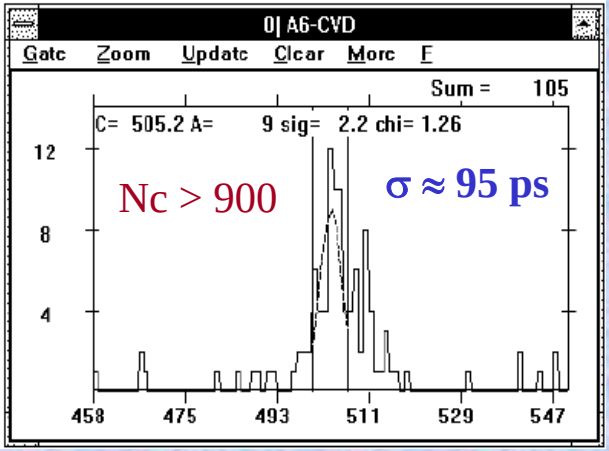

0| A6-CVD
Gate Zoom Update Clear More F
Sum = 5846
C= 511.8 A= 360 sig= 4.9 chi= 0.88
420
280
140
Nc > 400
σ ≈ 280 ps
459 476 494 512 530 548


0| A6-CVD
Gate Zoom Update Clear More F
Sum = 3574
C= 510.9 A= 220 sig= 4.7 chi= 0.69
250
172
86
Nc > 500
458 475 493 511 529 547

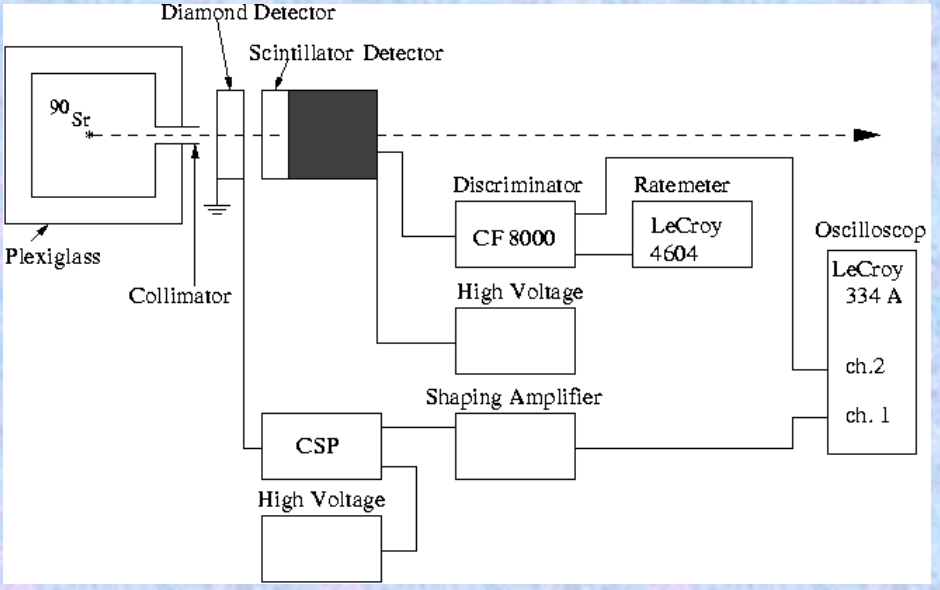

0| A6-CVD
Gate Zoom Update Clear More F
Sum = 1681
C= 509.7 A= 109 sig= 4.3 chi= 1.07
135
90
45
Nc > 600
458 475 493 511 529 547


0| A6-CVD
Gate Zoom Update Clear More F
Sum = 681
C= 507.8 A= 45 sig= 4.0 chi= 1.13
57
38
19
Nc > 700
459 476 494 512 530 548


0| A6-CVD
Gate Zoom Update Clear More F
Sum = 268
C= 506.3 A= 21 sig= 3.4 chi= 1.01
27
18
9
Nc > 800
458 475 493 511 529 547


0| A6-CVD
Gate Zoom Update Clear More F
Sum = 105
C= 505.2 A= 9 sig= 2.2 chi= 1.26
12
8
4
Nc > 900
σ ≈ 95 ps
458 475 493 511 529 547

Charge collection measurements



$$d_{coll} = \frac{Q_{coll}}{Q_{gen}} D = \frac{V_{PH}/G}{36 \frac{e}{\mu m}} D$$

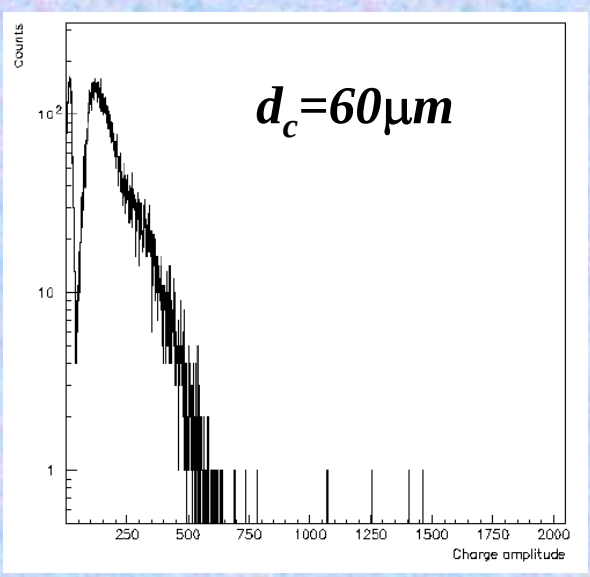
$$V_{PH} = \frac{1}{N} \sum_{i=1}^{N} V_{PH}^{i}$$

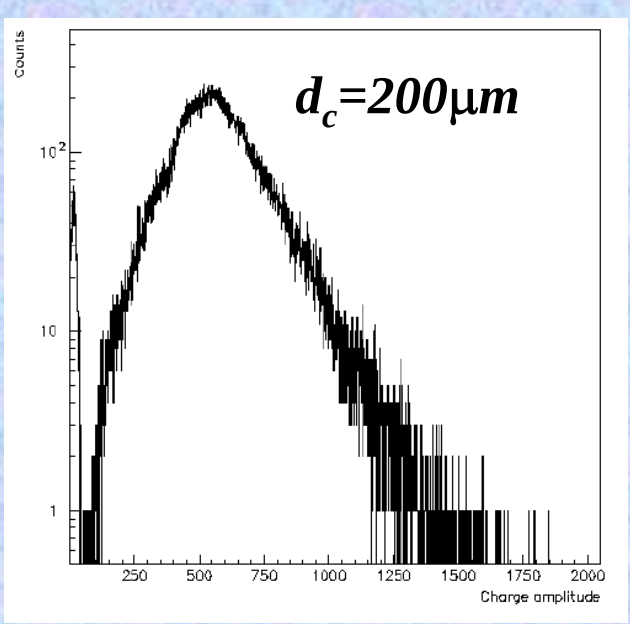
- **System Gain: G = 272 μV/e**

Detector	HV(V)	V_{PH}(mV)	Collection distance (μm)
DD-1 (700 μm)	-700	647.4	64.4
	-800	640.6	63.8
	-900	628.2	62.6
	-1000	650.6	64.8
DD-1 (700 μm)	-500	799	83.4
(pumped state)	-600	934	97.5
	-700	1017	106.2
	-800	1072	111.9
	-900	1114	116.3
	-1000	1148	119.8
DD-2 (1200 μm)	-500	1345	104.4
	-700	1600	167.0
	-1000	1650	172.2
DD-3 (500 μm)	-500	1990	207.7

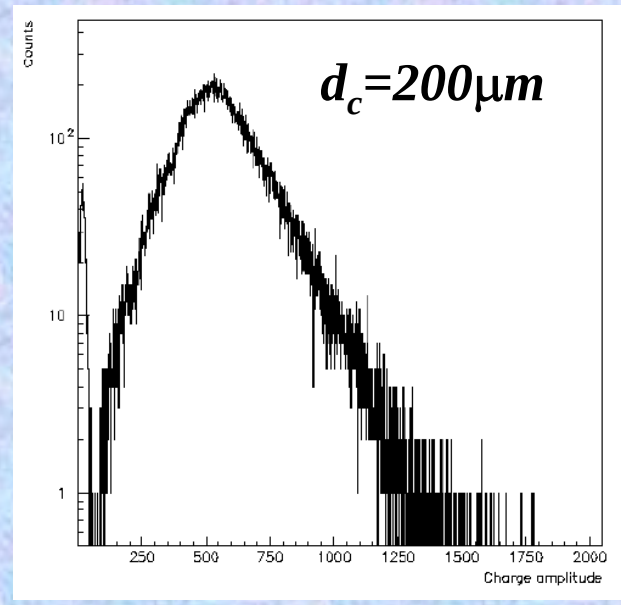
Results obtained using two CVD-DD with d_c = 200 μm and DBA amplifiers

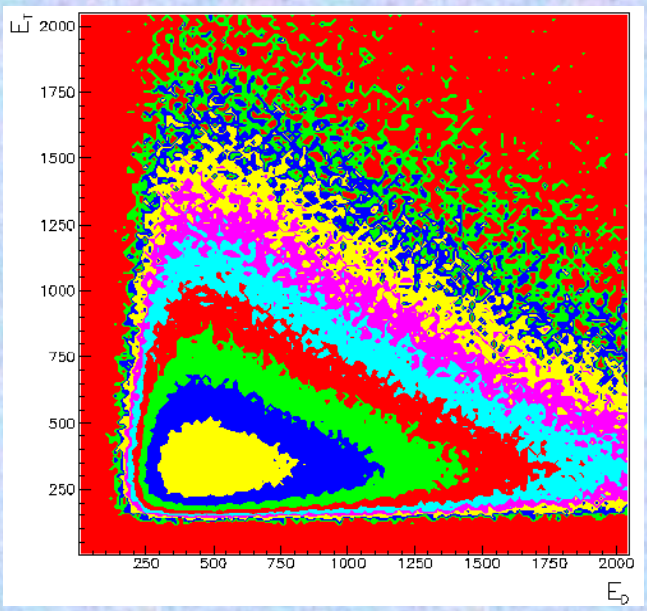
Pulse height measurements using charge sensitive preamplifier

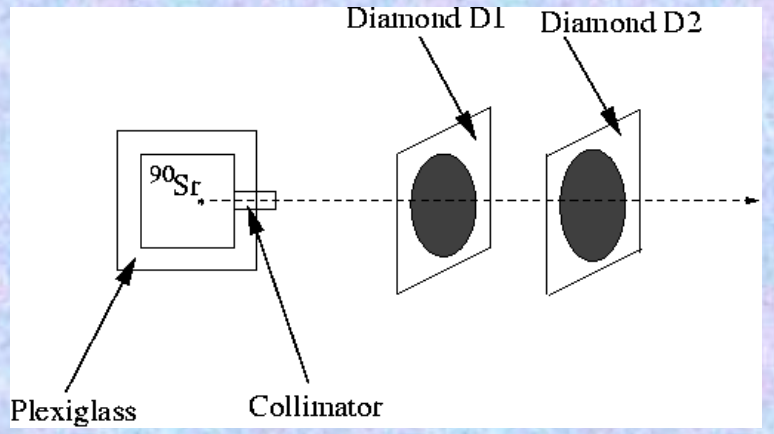




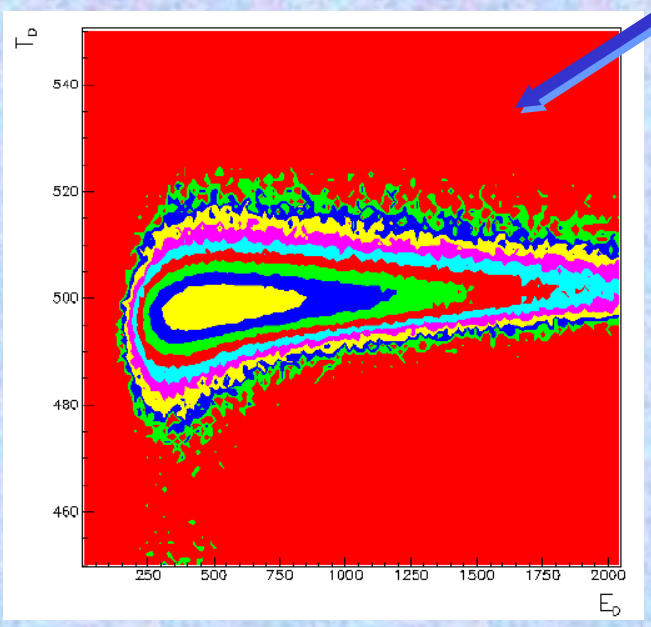
E = 1V/μm

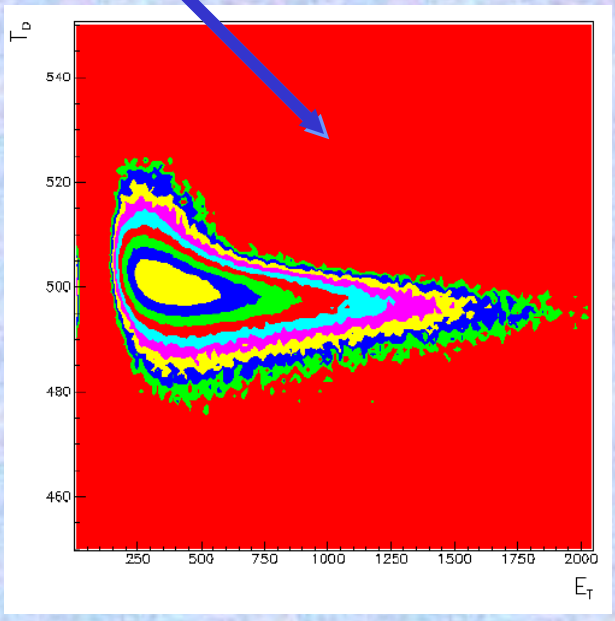




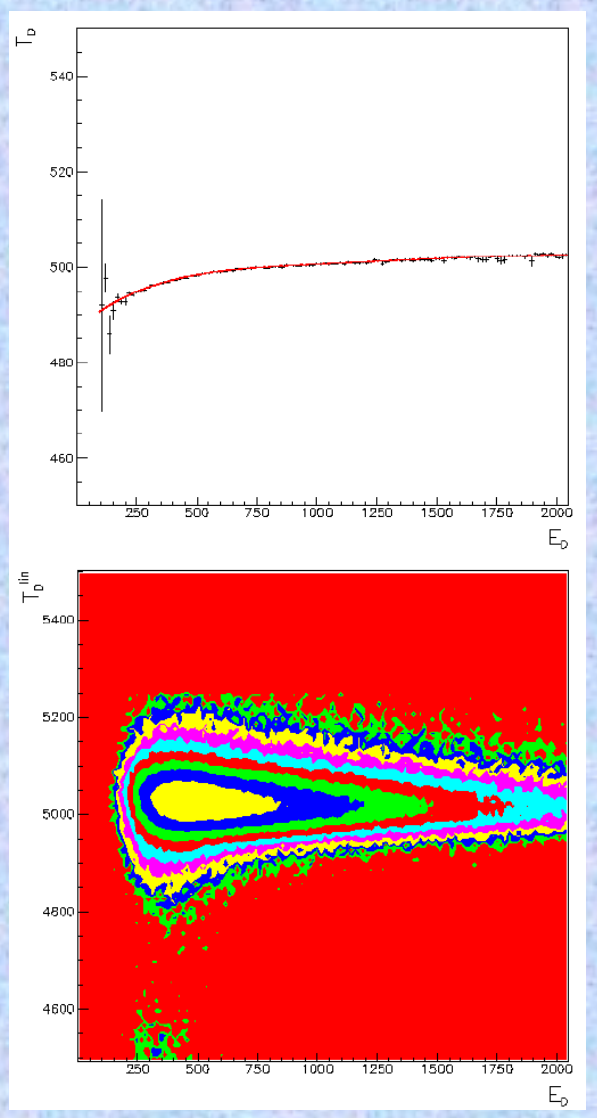


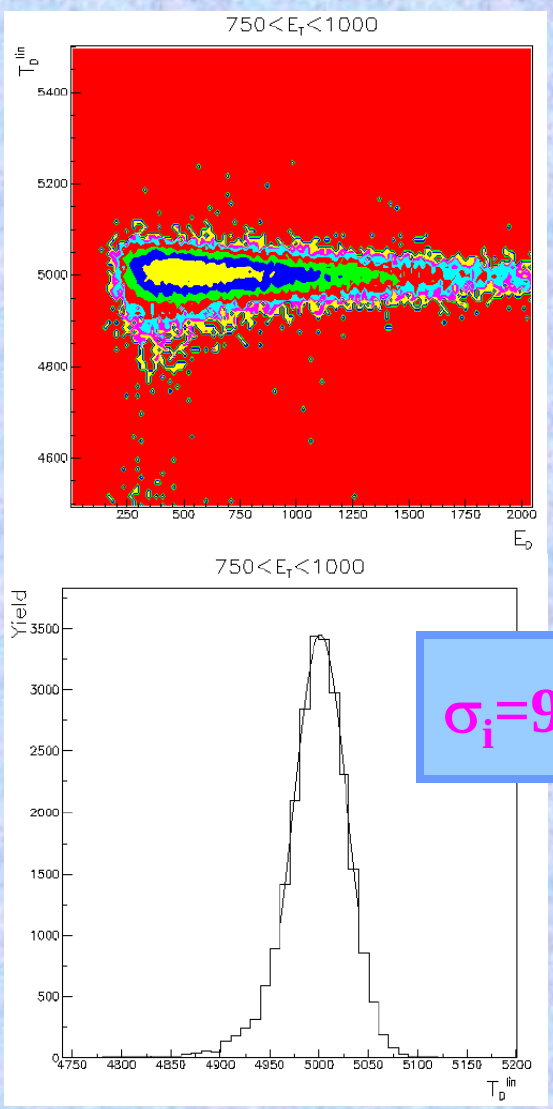
Walk effect in both detectors





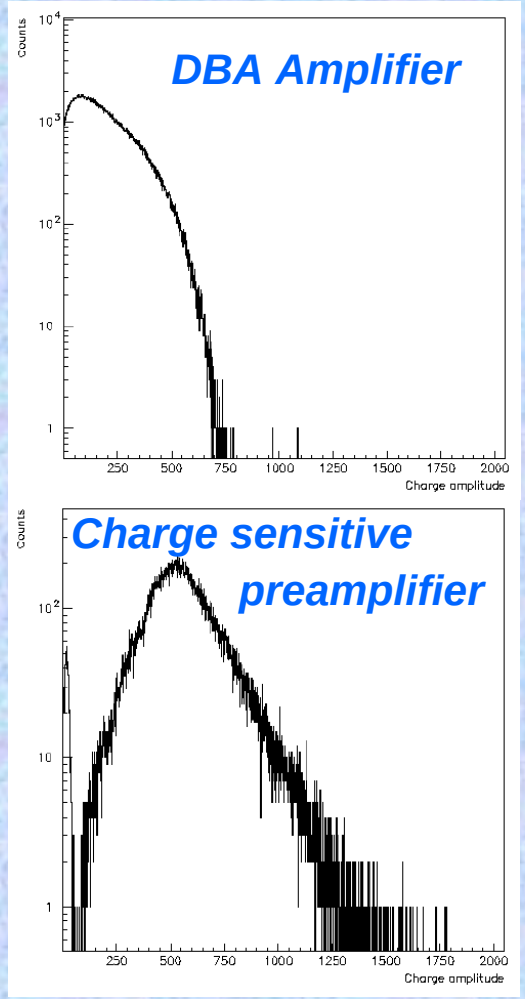
WALK CORRECTIONS





σ_i=96 ps

Detection Efficiency



- *Very low efficiency with DBA amplifier: 3%*
- *most of the signals bellow the discriminator threshold*
- *reasonable efficiency using charge sensitive preamplifier: 87 %*

⇒ a new type of preamplifier, with a much better S/N ratio, preserving the time performance is requested

Summary

- *Our results showed that using high quality CVD material and appropriate electronics for signal processing, diamond detectors are serious candidates for being used as T0 detectors for MIPs.*
- *The low efficiency results obtained using the present fast FEE showed the need of developing a new type of FEE with a much better signal to noise ratio conserving the time performance.*
- *Our main effort will be concentrated on :*
  - **characterization of the latest diamond material**
  - **further tests in terms of time resolution and efficiency**
  - **new type of FEE using hybrid technology**

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