Sr90-Beta Setup at CERN SSD

Hardware and Data Analysis

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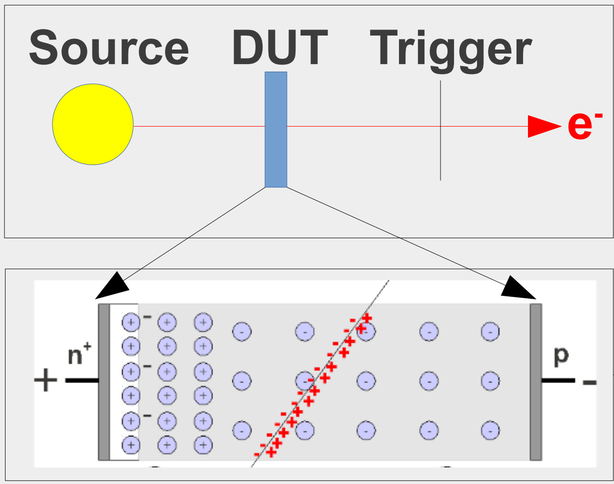
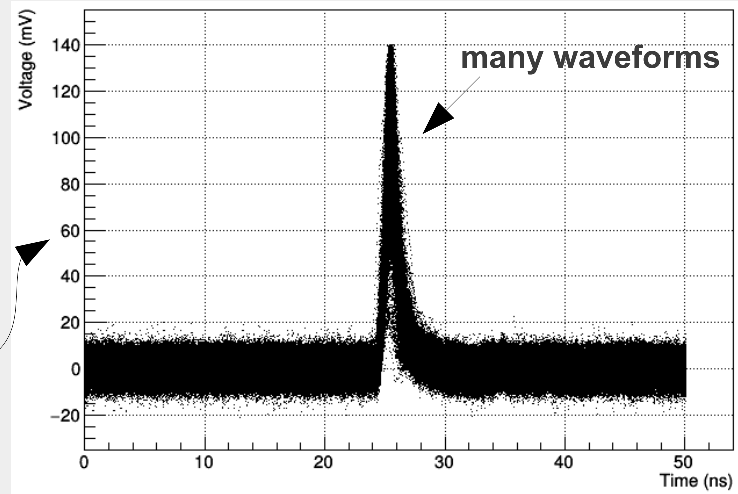
Beta Setup
Concept and Fundamentals

Idea:



collect waveforms via amplifier and scope



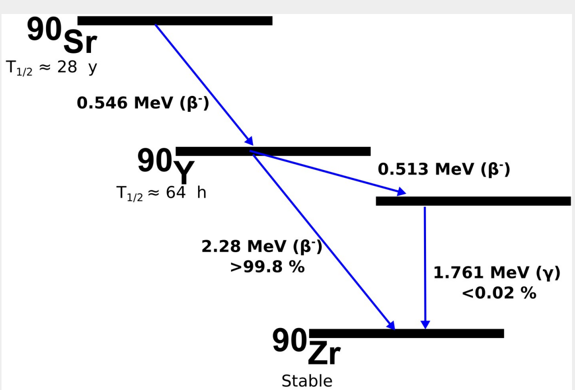
Analyze Data Waveform by Waveform:

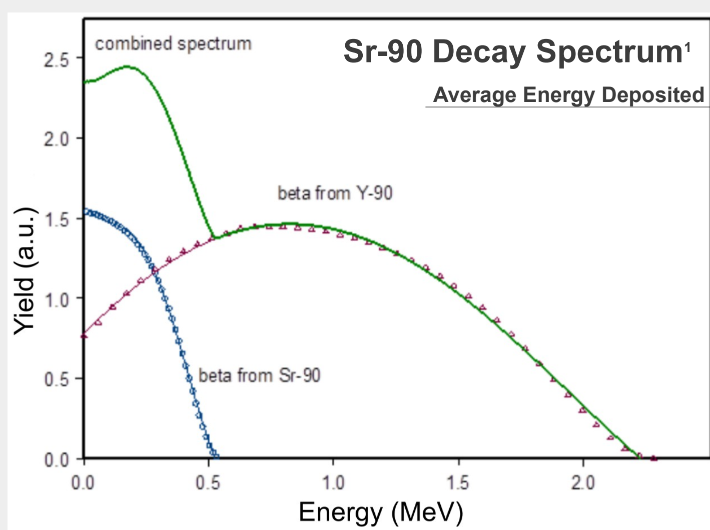
-Timing Parameters (TOT, ToA, Time Walk, Slew Rate, Rise Time, Base Line Noise [RMS, mean], etc)

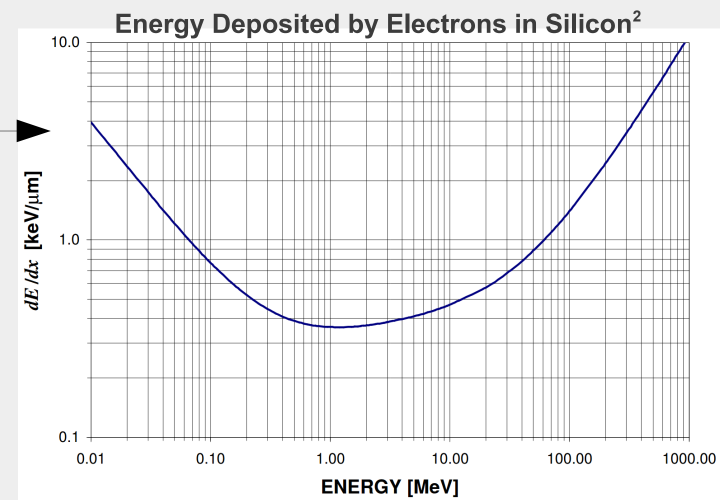
-Pulse parameters (Maximum Voltage, Charge Collection Time, etc)

β-Source Characteristics (Sr-90)

Decay of $^{90}_{38}Sr$





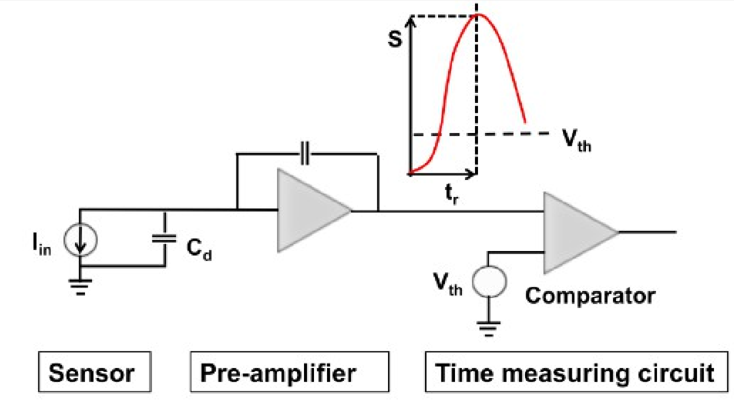


Maximum e- yield of Y-90 decay ≈ 1 MeV → MIP

Silicon Detector
Time Resolution

<u>**Concept**</u>

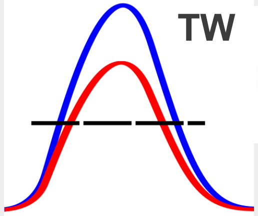
(1) Traversing particle generates e-h pairs through charge ionization
→ Drift to respective electrodes through electric field → Signal Current
(2) Signal is shaped with pre-amplifier
(3) Amplified signal is compared to threshold then digitized
→ Time resolution measures: Time Over Threshold
Time Of Arrival



<u>**Time resolution contributions:**</u>

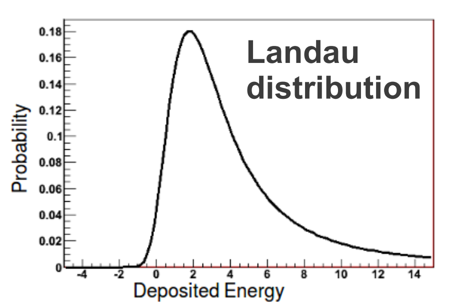
$$\sigma_t^2 = \sigma_{\text{Time Walk}}^2 + \sigma_{\text{Landau Noise}}^2 + \sigma_{\text{Distortion}}^2 + \sigma_{\text{Jitter}}^2 + \sigma_{\text{TDC}}^2$$

Time Walk: larger signals cross threshold earlier than smaller ones
→ Elimination via Constant Fraction Discrimination



$$\sigma_{\text{Time Walk}} = [t_d]_{\text{RMS}} = \left[\frac{V_{\text{th}}}{S/t_{\text{rise}}}\right]_{\text{RMS}} \propto \left[\frac{N}{\mathrm{d}V/\mathrm{d}t}\right]_{\text{RMS}}$$

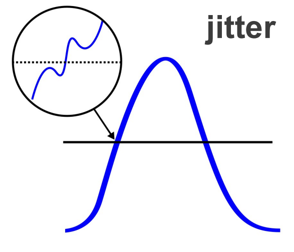
Landau Noise: Energy deposited through charge ionization follows universal asymmetric probability density function
→ Fundamental physical limit to signal uniformity



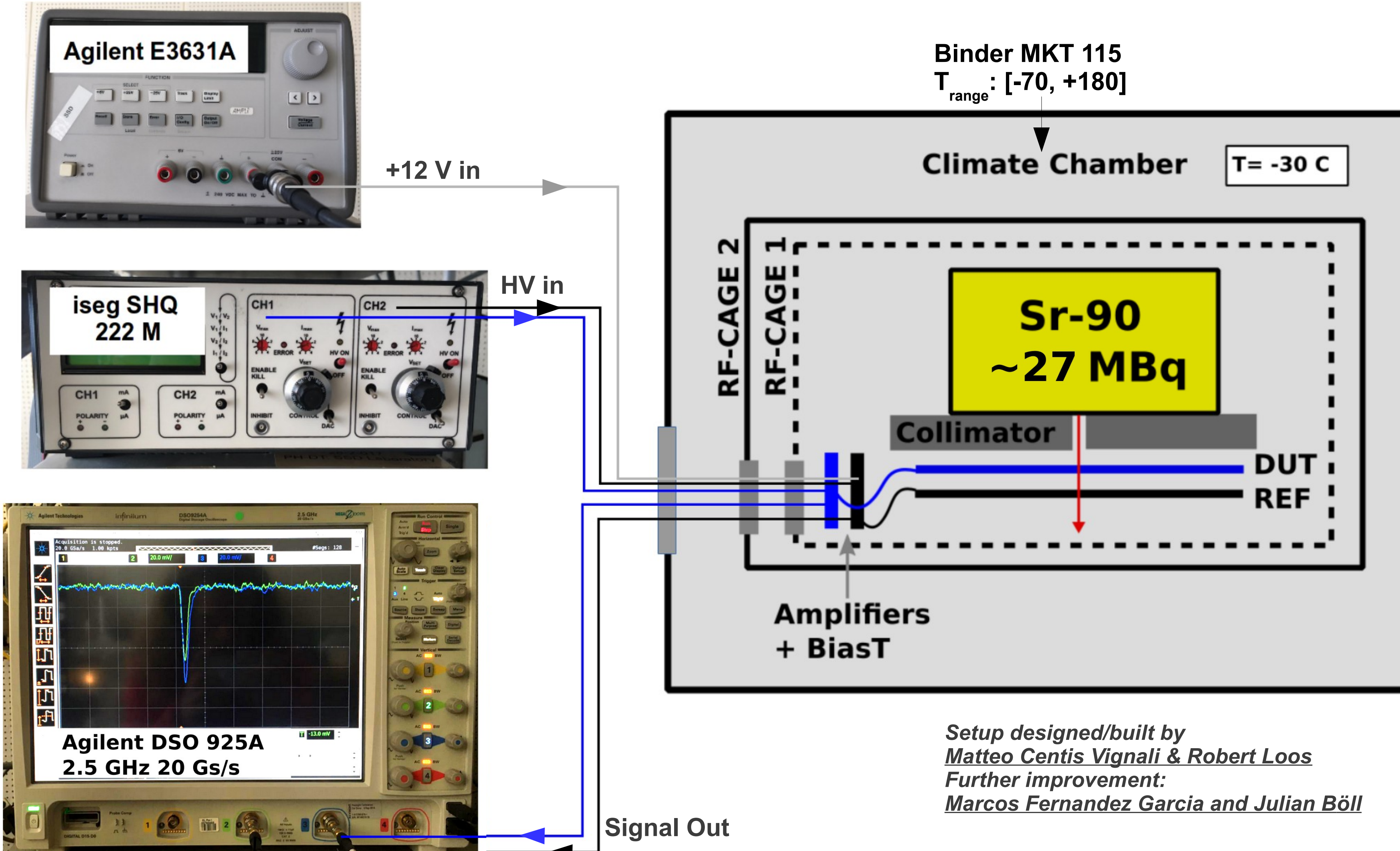
Jitter: Time uncertainty caused by time deviation of comparator due to fluctuations within individual signals

$$\sigma_{\text{Jitter}} = \frac{N}{\mathrm{d}V/\mathrm{d}t} \approx t_{\text{rise}} / \left(\frac{S}{N}\right)$$

Holds for constant slope



CERN SSD Sr-90 Beta Setup
Power Sources and Scope



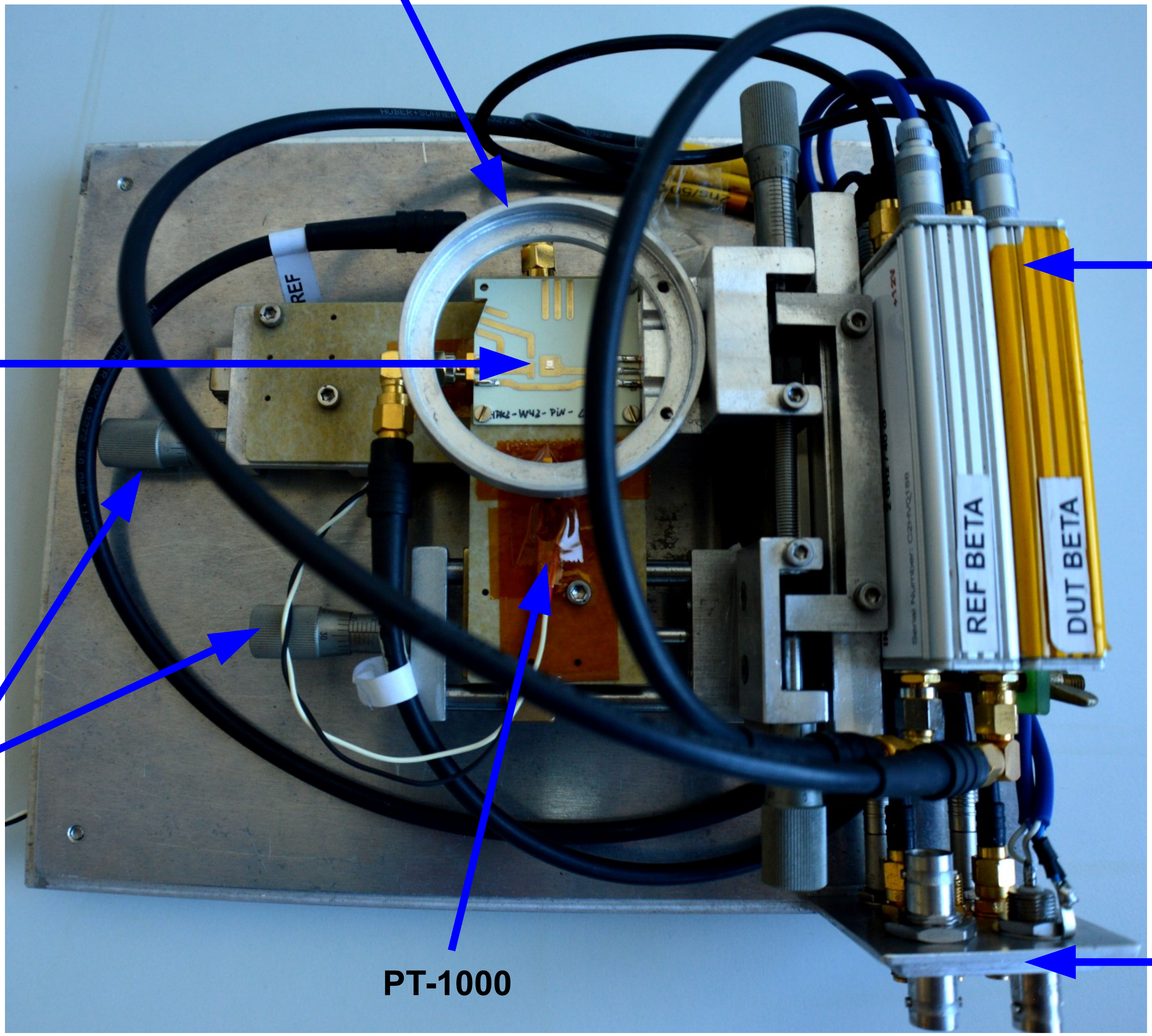
Setup designed/built by
Matteo Centis Vignali & Robert Loos
Further improvement:
Marcos Fernandez Garcia and Julian Böll

CERN SSD Sr-90 Beta Setup
Inner Setup

Source and collimator holder (devices not in picture)

Sensor wire-bonded on PCB

CIVIDEC Bias-T Current Amplifiers 2 GHz, Gain ~ 180x

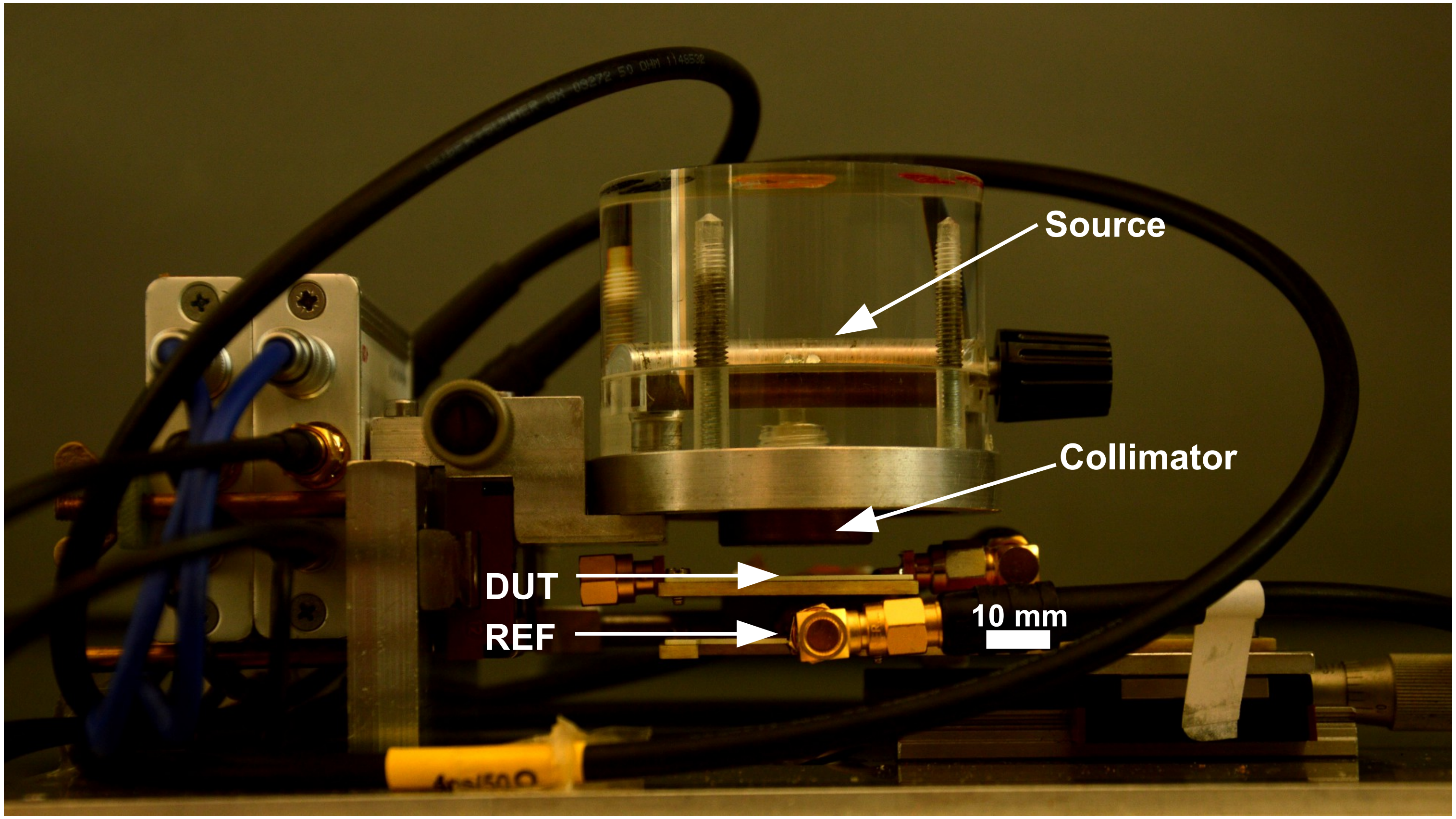


XY- planar stages for sample alignment

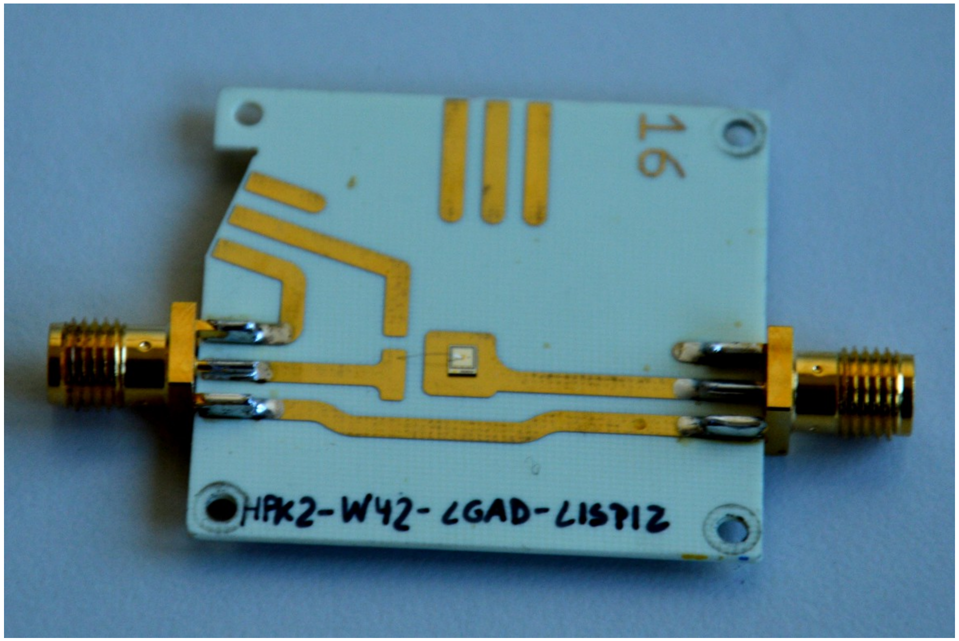
PT-1000

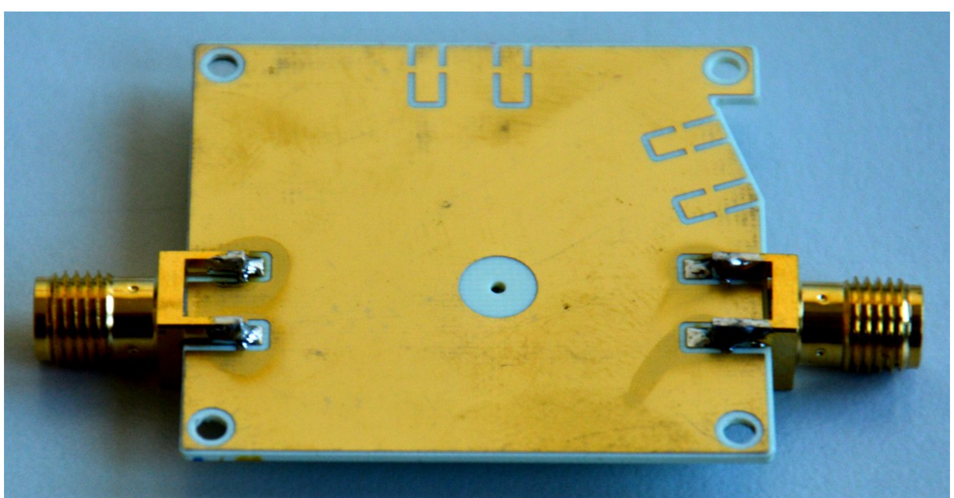
Cable pass through for inner RF-Cage

CERN SSD Sr-90 Beta Setup Close-Up



CERN SSD Sr-90 Beta Setup PCBs





- Sensors glued to PCB with silver paste and subsequently wire-bonded

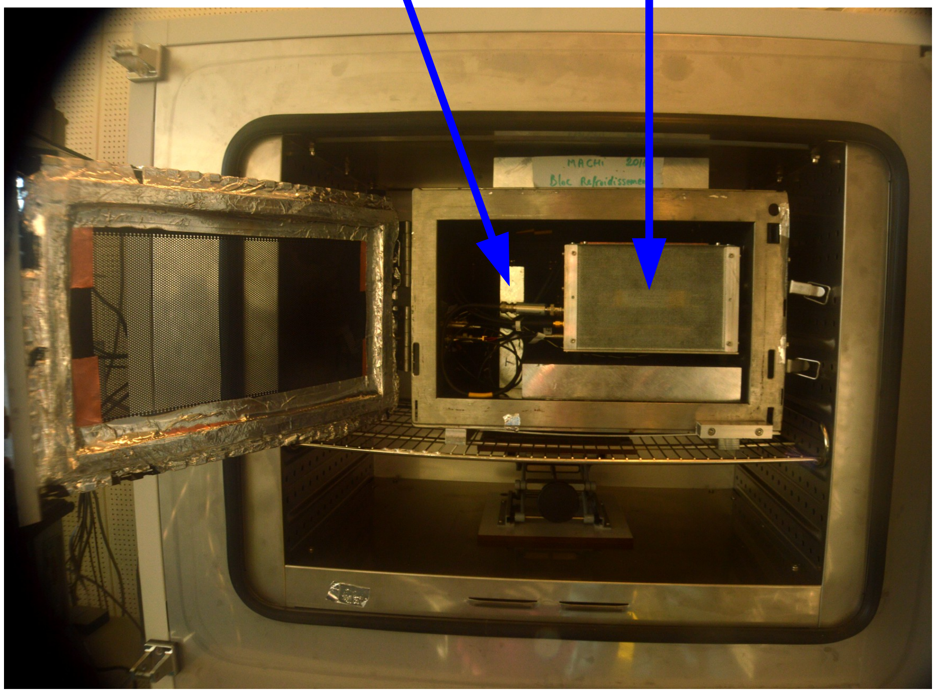
- Back and front-side bias possible (Measurements via front side bias due to noise-pick up)

- Sensors mounted over 1 mm diameter hole to avoid unwanted absorption (loss of rate through absorption and unfavorable electron scattering)

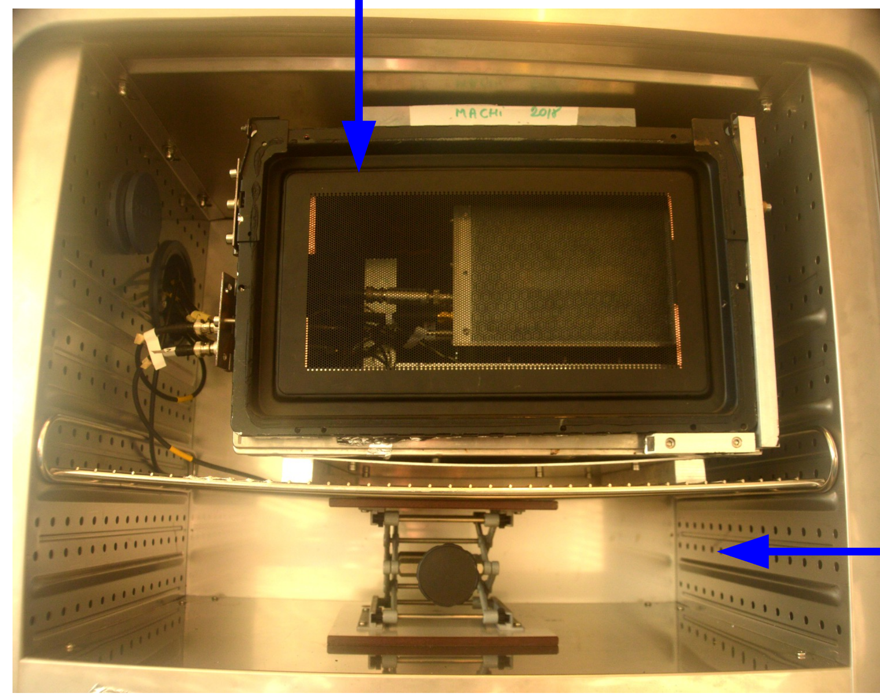
Sensors aligned with Laser placed in source mounting

CERN SSD Sr-90 Beta Setup
Triple Cage Design

Metal plates **Inner RF cage**



Modified microwave oven used for additional shielding



Climate chamber

- Sensors pick up high RF noise in lab if not adequately shielded
- Initial 'small' RF cage didn't provide sufficient shielding
- Setup was set into bigger RF cage (modified former micro-wave)
→ Noise figures improved substantially
- Mesh in back of MW-RF-cage aligned with fan of climate chamber
→ Dry, cold air blown into inner RF cage

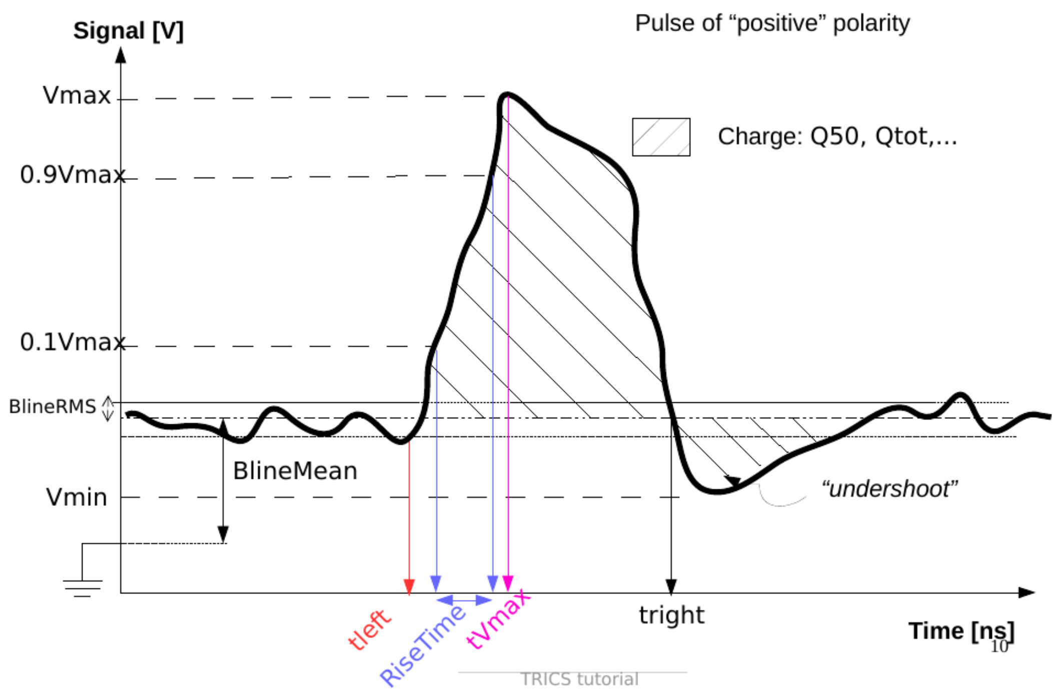
Data Processing with TRICS
Overview

(1) Measure Waveforms
c++ script (via LAN connection to Scope) records data in binary, python script logs temperature, bias and leakage

(2) Parse Data to Root
c++ script parses binary measurement file into root and creates Tree with two branches (Raw and Processed Data) by analyzing each waveform

(3) Plot non-timing Data
Waveforms are plotted via Root::Draw() for initial viewing of raw data

(4) Run Timing analysis
Timing analysis executed:
-Constant Fraction Discriminator emulated
-Timing parameters calculated: Time walk, jitter, slew rate etc
- Threshold varied over 19 values defined by the voltage cut

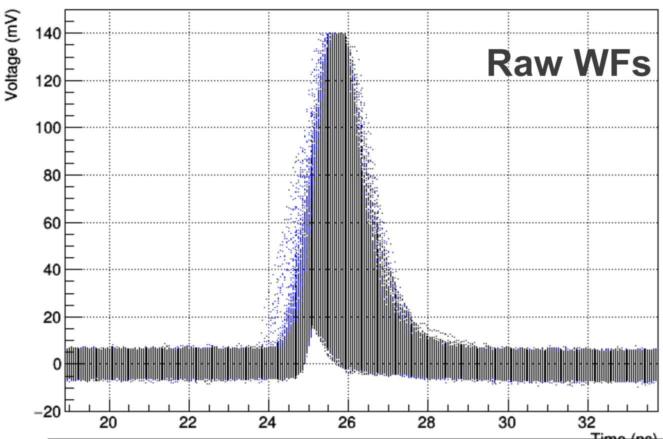


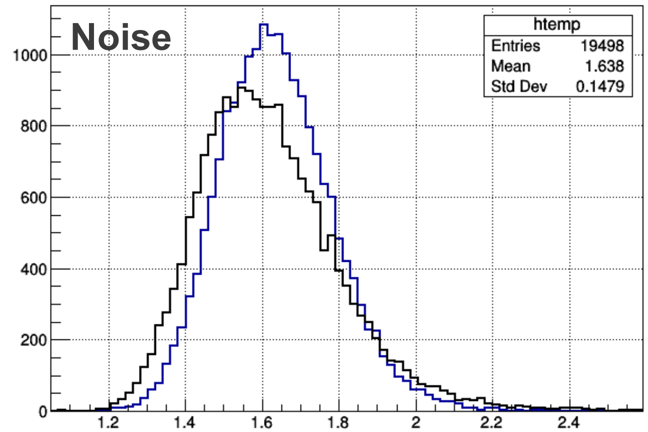
Data Processing with TRICS
Plots Illustrating Analysis

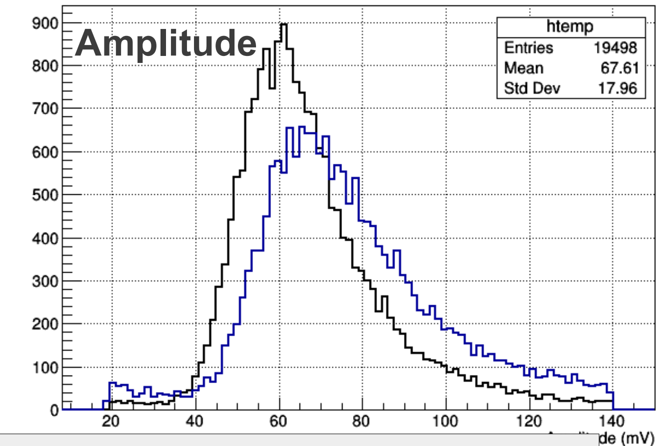
Measurement Specs:

20 mV/div
6 dB Attenuators (high amplifier gain)
Coincidental trigger on DUT and REF @ **13 mV**
Exclude saturated waveforms
No cuts otherwise

1) Initial Analysis
DUT
REF

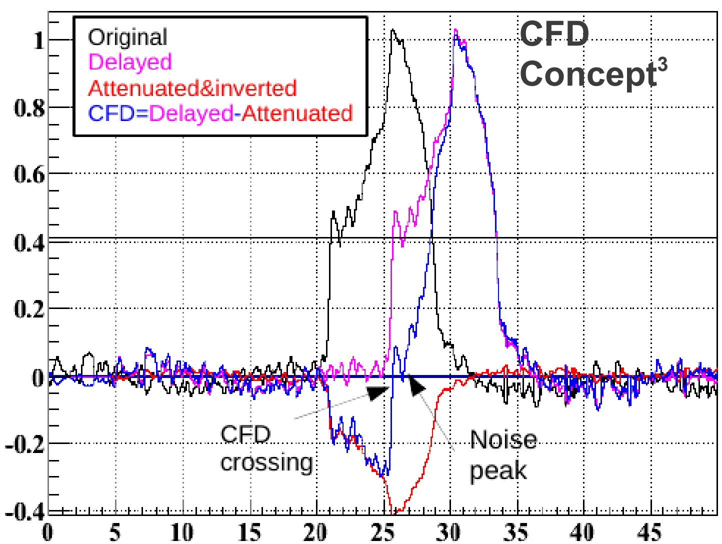






~ 1.6 mV mean baseline RMS
timing figures: See Marcos' talk Characterization of CMS-ETL HPK2 LGAD samples before irradiation

2) Timing Analysis

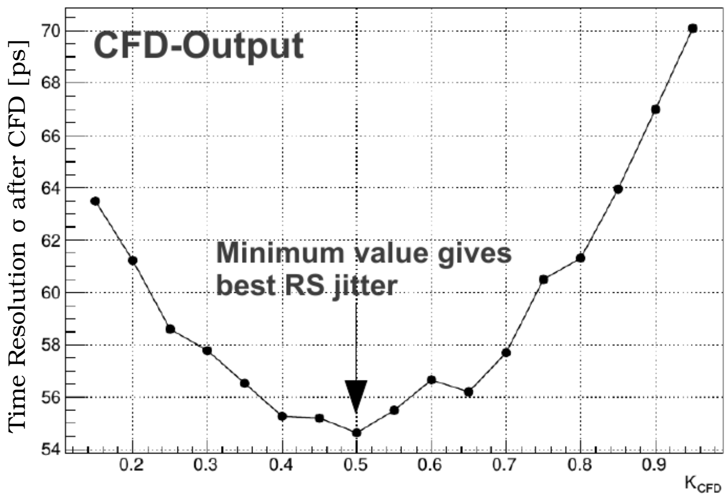


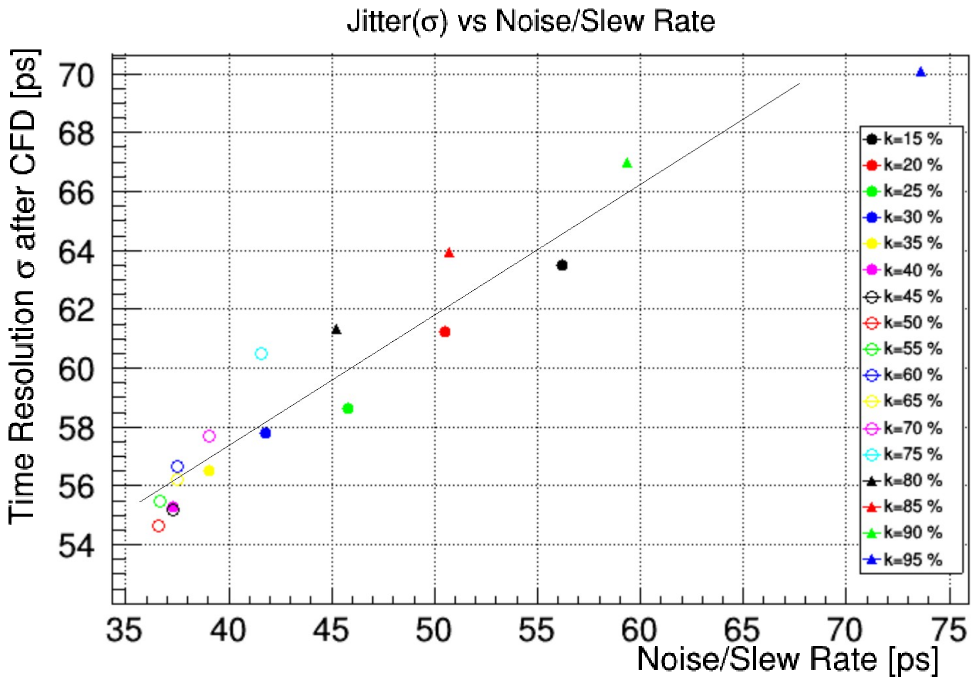
TRICS performs:
(A) **C**onstant **F**raction **D**iscrimination emulation
→ Variation over attenuation coefficients k_{cfd} 0.05-0.95
→ Elimination of time-walk effect. Jitter & Landau remain

(B) **T**ime **o**ver **T**hreshold and **T**ime **of** **A**rrival analysis

(C) Relevant timing parameters calculated
(Rise time, Slew Rate, SNR)

Data Processing with TRICS
Timing Analysis Output Examples



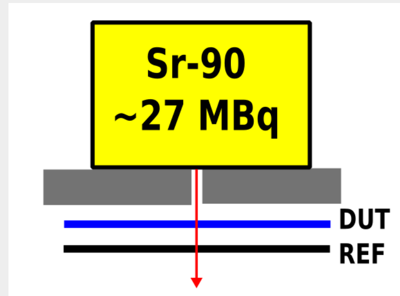


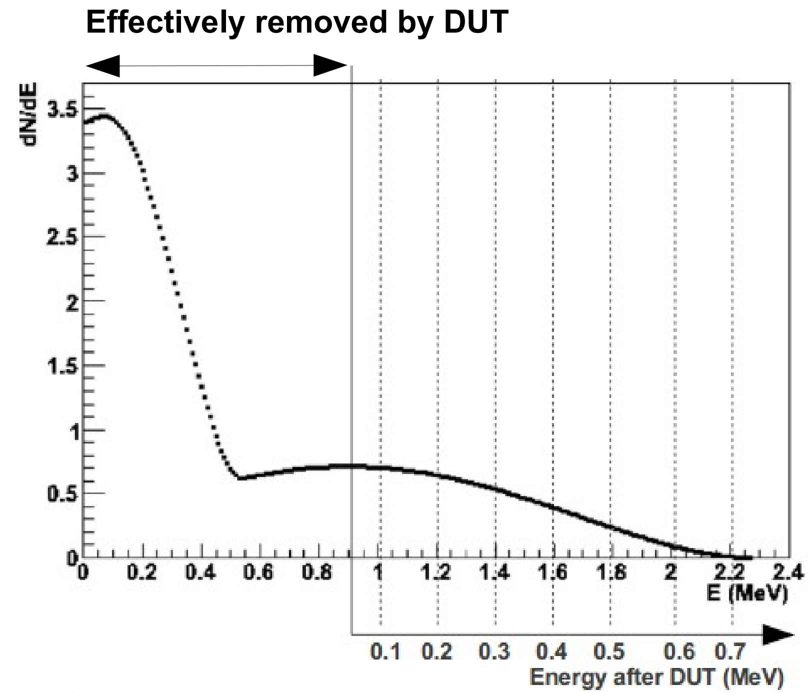
Do We Need An Absorber For MIP electrons?

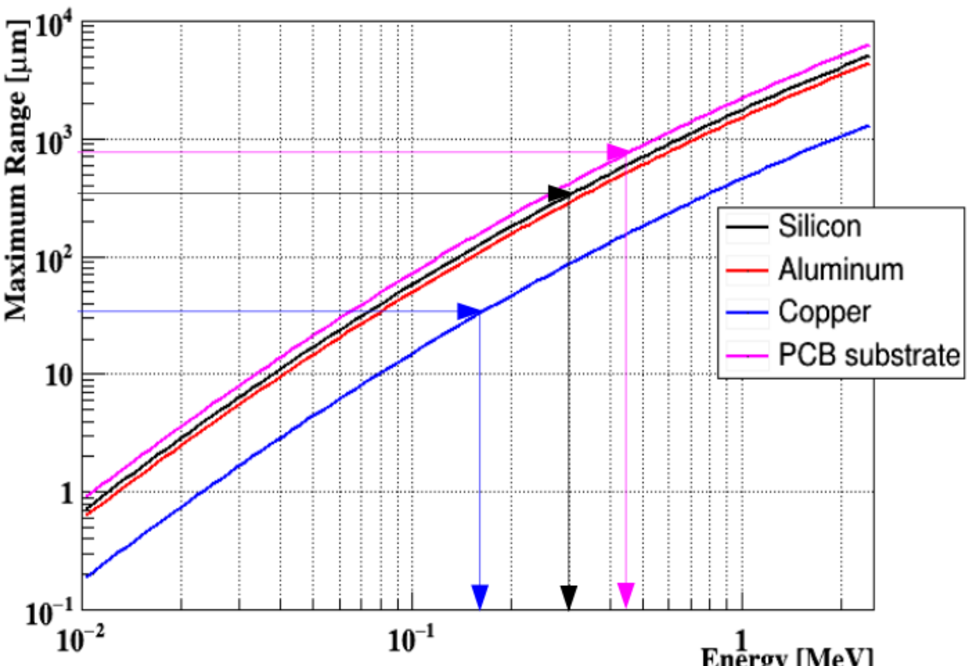
- Want to measure Wfs produced by MIP electrons → need to eliminate low energy electrons as they deposit 'more' energy
- Absorber materials with lower Z absorb more low energy electrons

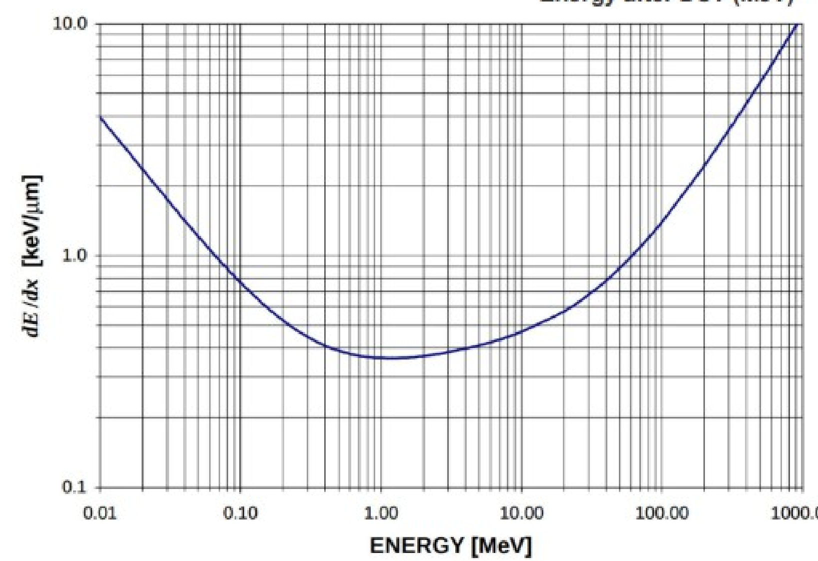
→ How to use absorber in our setup?

Setup in our configuration is inevitably using DUT sensor as absorber









Beta electrons:

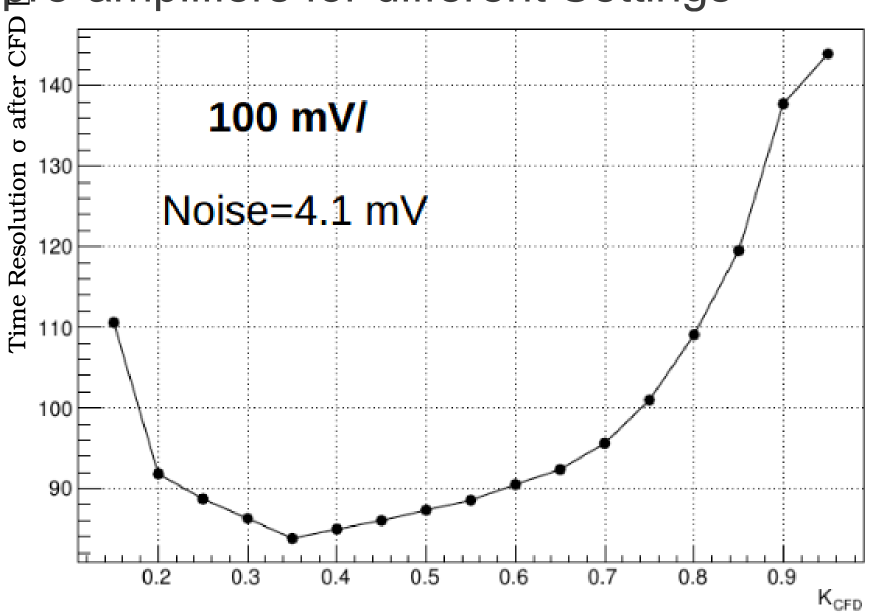
0.30 MeV lost after 350 um of Silicon

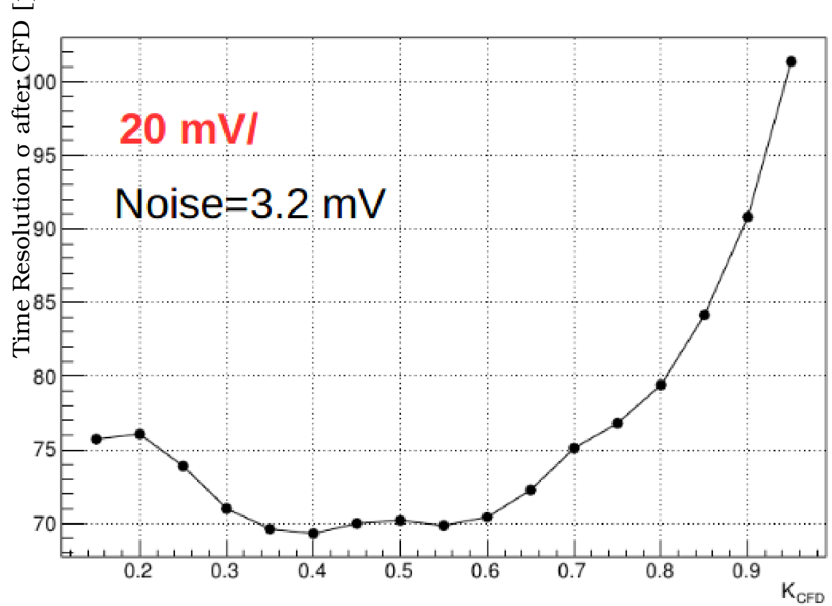
0.15 MeV lost after 35 um of Cu

0.45 MeV lost after 800 um of PCB

Lessons Learned
Scope Digitization

Strong influence of Scope voltage resolution [V/division] on Noise → due to varying pre-amplifiers for different Settings





Use 6dB **attenuators**, otherwise waveforms with high amplitude are discarded → Noise and Amplitude reduce by factor 2

Thanks For Your Attention!

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