Mosaic diamond detector for MIPs detection in HADES

Lukáš Chlad[1,2], Wolfgang Koenig[3], Jerzy Pietraszko[3], Michael Träger[3], Robert Visinka[3]

[1]Nuclear Physics Institute of the ASCR

[2]Faculty of Mathematics and Physics, Charles University in Prague

[3]GSI Helmholtzzentrum für Schwerionenforschung GmbH

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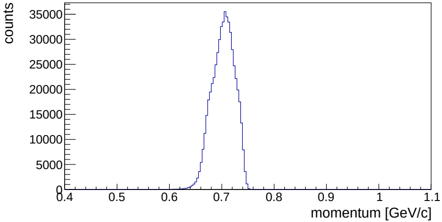
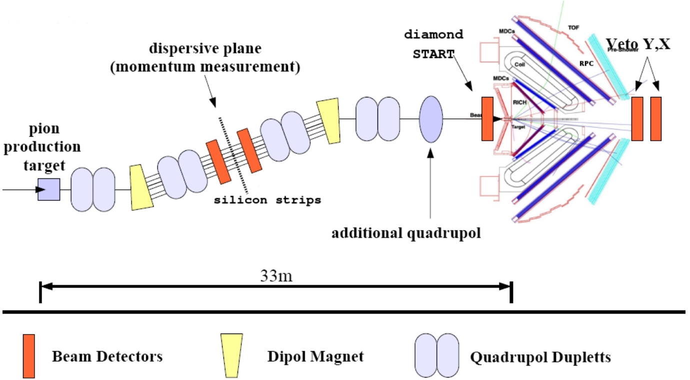
HADES π-experiment

- Strangeness program with $p_\pi = 1.7\,\mathrm{GeV/c}$ and targets
  - tungsten
  - copper
  - carbon
- Baryonic resonances program with $p_\pi = 0.69\,\mathrm{GeV/c}$ and targets
  - polyethylene
  - carbon

Pion momentum distribution



Beam detectors for HADES π-experiment



- PionTracker detector = 4 silicon strip detectors
- Start detector = 9 scCVD diamonds
- Hodoscope (Veto) = 16 scintillator rods

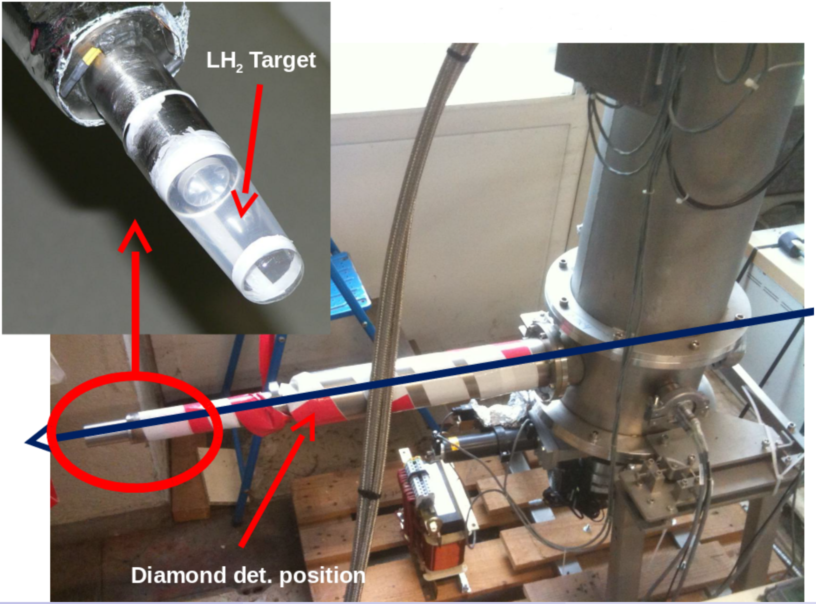
Motivation of using Start detector

Reduction of trigger rate To separate reaction of pions with other material than target.

Alignment of π^- beam To control the settings of the focusing magnets.

Vertex determination Together with PionTracker START should participate on X-, Y- vertex determination of each pion from beam. And alone it should determine the t_0 of reaction.

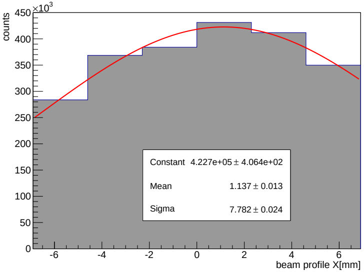
Trigger rate reduction for planned LH_2 target



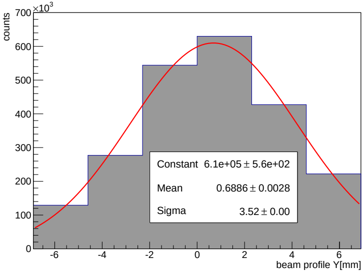
Trigger rate reduction for planned LH_2 target

Beam profiles at START detector from recent pion beam for HADES

X



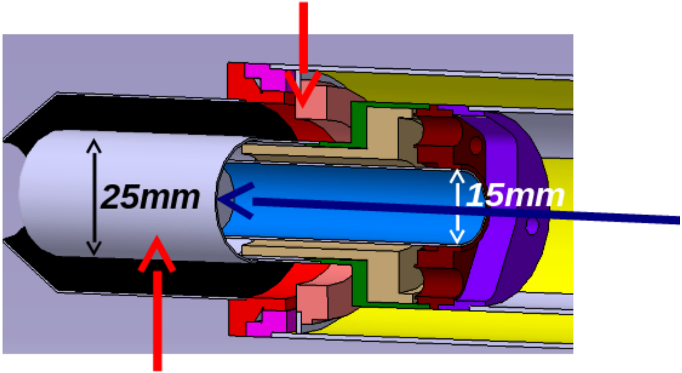
Y



Last quadrupole magnet focused the Y-direction.

Trigger rate reduction for planned LH_2 target

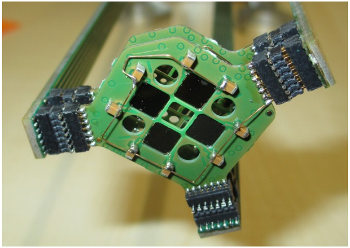
Target holder (metal)
up to 100% interaction probability !!!!

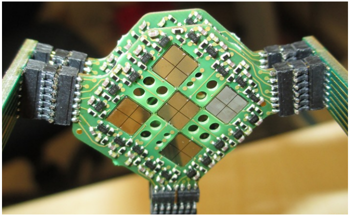


LH_2 Target
4% interaction probability

Properties of START detector

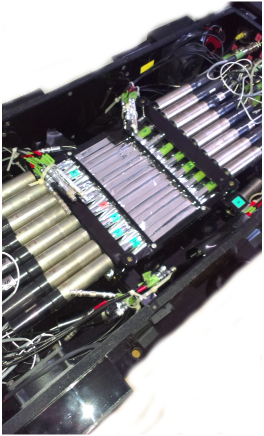
- Requirements
  - $\rightarrow$ Time resolution $< 100\,\text{ps}$
  - $\rightarrow$ Tracking resolution $\approx 2\,\text{mm}$
  - $\rightarrow$ High detection efficiency and rate capability
- Technical Solution
  - $\rightarrow$ 9 diamonds in two planes
  - $\rightarrow$ Each diamond $4.6 \times 4.6\,\text{mm}^2$ and $300\,\mu\text{m}$
  - $\rightarrow$ Segmentation of diamond into 4 independent readout channels
  - $\rightarrow$ Two stage amplification of signals because of low energy losses





Properties of HODOSCOPE detector

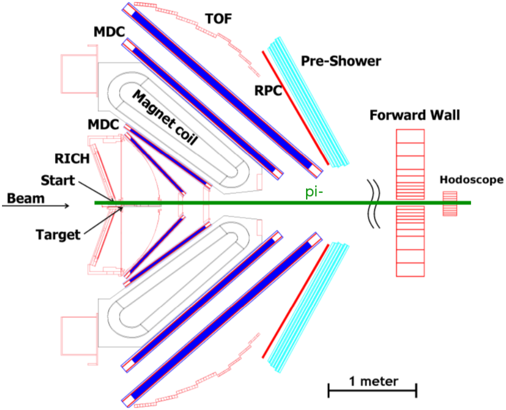
- Requirements
  - → High detection efficiency and rate capability
- Technical Solution
  - → 16 scintillator rods
  - → On both sides of a rod are PMTs



Time Resolution of START detector

Two independent methods:

1. Using pions
   (no interactions)
2. Using electrons
   (from interactions)



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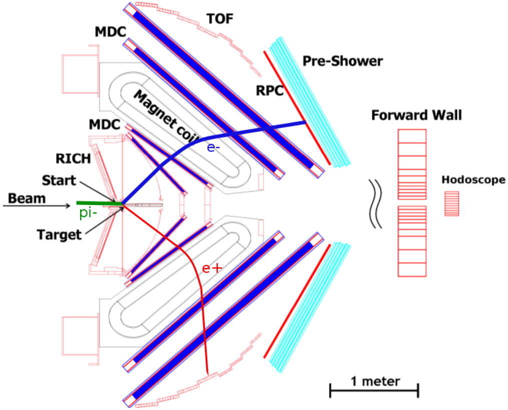
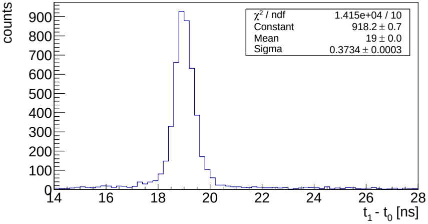


Time Resolution - Using pions

Idea:

- For each hit compute $t_1 - t_0$
- Fit the distribution of $t_1 - t_0$ with Gauss function



Time Resolution - Using pions

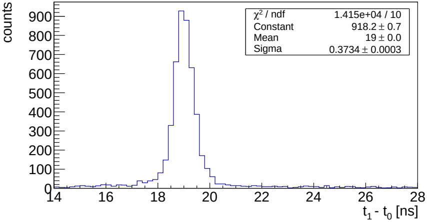
- Since we do not know σ_{HODO} nor σ_{START} we assume:

$$\sigma^2 = \sigma^2_{\mathrm{HODO}} + \sigma^2_{\mathrm{START}}$$

$$\sigma_{\mathrm{HODO}} = \sigma_{\mathrm{START}} \Rightarrow$$

$$\sigma_{\mathrm{START}} = \frac{\sigma}{\sqrt{2}}$$

- Two possibilities to improve the time resolution
  1. Hit position cut on Hodoscope
  2. Timewalk corrections for Start

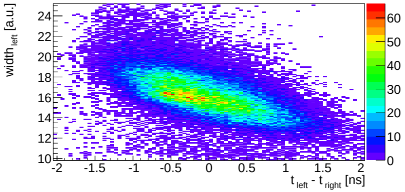


Result: $\sigma_{\mathrm{START}} = 265\,\mathrm{ps}$

Time Resolution - Using pions

1. Hit position cut on Hodoscope

- For time difference $t_1 - t_0$ we use average time from Hodoscope PMTs
  $t_1 = \frac{1}{2}\left(t_{\text{left}} + t_{\text{right}}\right)$
- Due to attenuation of light in scintillator we see dependence of signal amplitude (=width) on $t_{\text{left}} - t_{\text{right}}$
- We can choose pions that goes through the middle of scintillator ($\pm 2\,\text{cm} \quad \pm 200\,\text{ps}$)



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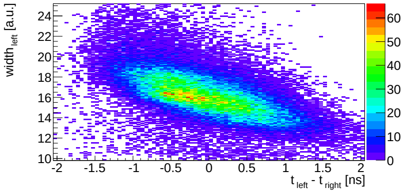

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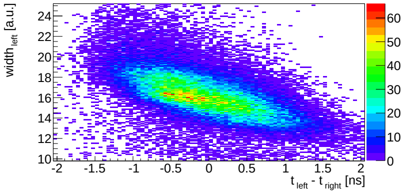

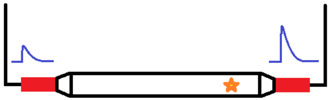

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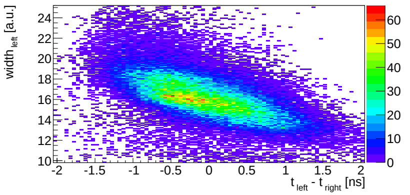
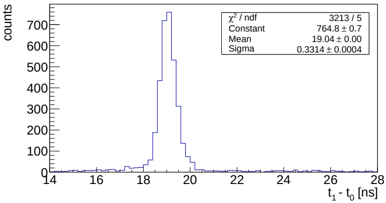
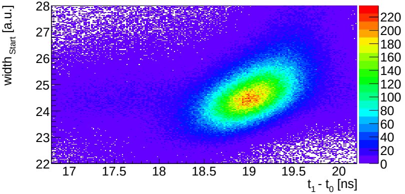


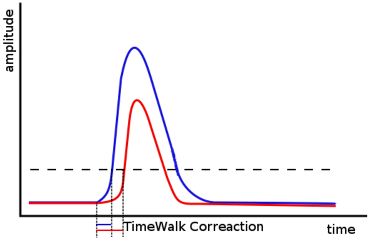


Result: $\sigma_{\text{START}} = 235\,\text{ps}$

2. Timewalk corrections for Start

- Needed in case of using the leading edge discriminator in the readout electronics
- Correcting t_0 by taking into account amplitude (=width) of the signal (unwanted dependence of time measurement on the slope of the leading edge of the signal)





Time Resolution - Using pions

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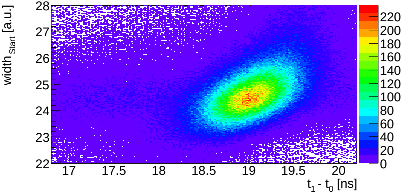
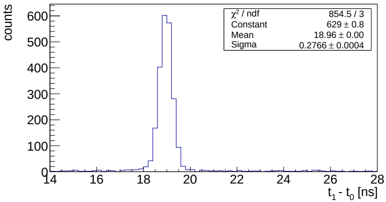




Result: $\sigma_{\mathrm{START}} = 190\,\mathrm{ps}$

Time Resolution - Using pions

- Result $\sigma_{\mathrm{START}} = 190\,\mathrm{ps}$ is worse than expected
- Advantages
  - \+ Good statistics (only 4% probability of interaction pion+target)
  - \+ Easy and fast (no need of particle identification)
- Disadvantages
  - \- Uncertainty in Hodoscope contribution to total time resolution σ

Time Resolution - Using electrons

Idea:

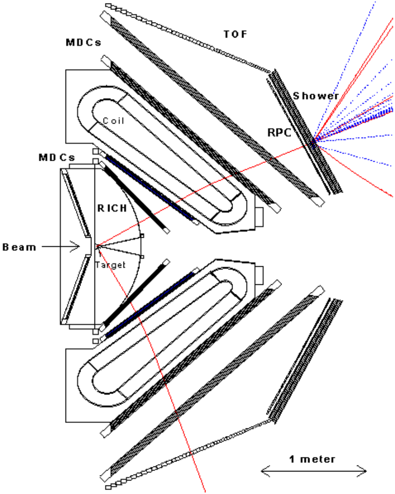
- To obtain pure Start time resolution we must use dielectron events (measuring Time of Flight for electrons)

$$\sigma_{\mathrm{START}} = \sqrt{\sigma^2 - \sigma^2_{\mathrm{ToF}}}$$

- By using dielectron events we can determine the contribution of ToF detectors (TOF/RPC)

$$t_{\mathrm{e}^\pm} = t_{\mathrm{ToF}^\pm} - t_{\mathrm{START}} \Rightarrow$$

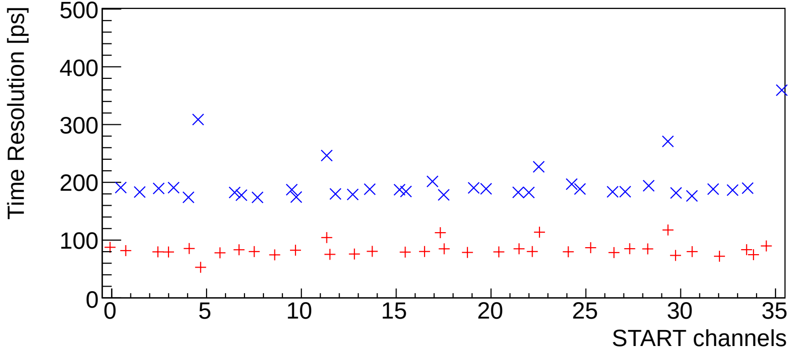
$$t_{\mathrm{e}^+} - t_{\mathrm{e}^-} = t_{\mathrm{ToF}^+} - t_{\mathrm{ToF}^-}$$



Time Resolution - Using electrons

Symbols used in pictures: RPC = $+$, TOF = $\times$

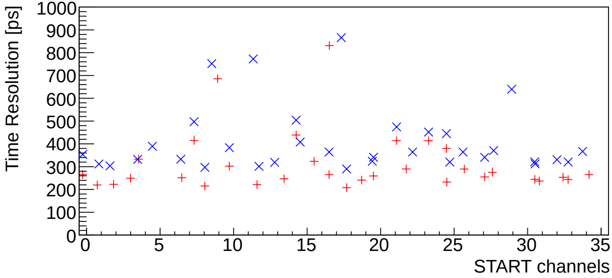
From distribution of $t_{e^+} - t_{e^-}$ we obtained $\sigma_{\mathrm{RPC}} = 80\,\mathrm{ps}$ and $\sigma_{\mathrm{TOF}} = 180\,\mathrm{ps}$.



Time Resolution - Using electrons

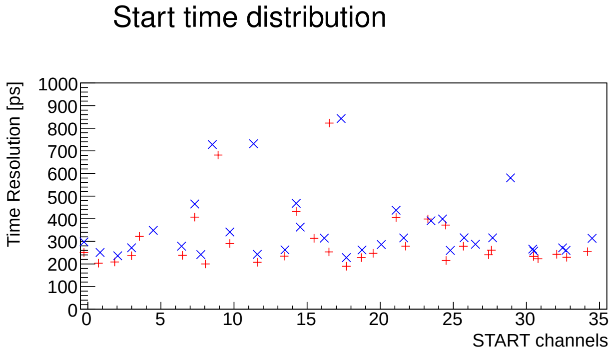
Symbols used in pictures: RPC = + , TOF = ×

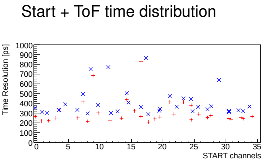
Start + ToF time distribution



Time Resolution - Using electrons

Symbols used in pictures: RPC = + , TOF = ×

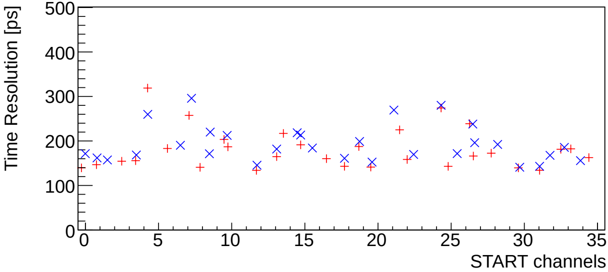




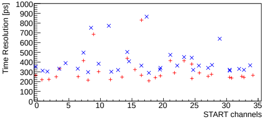
Time Resolution - Using electrons

Symbols used in pictures: RPC = + , TOF = ×

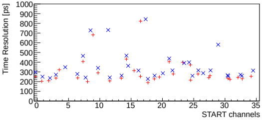
Start time distribution after timewalk correction



Start + ToF time distribution



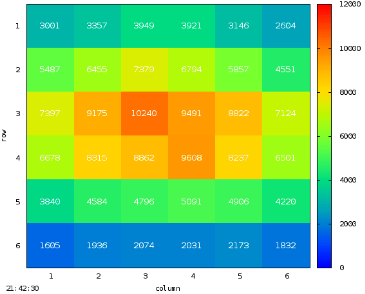
Start time distribution

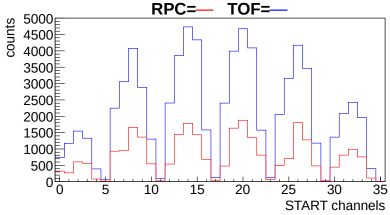


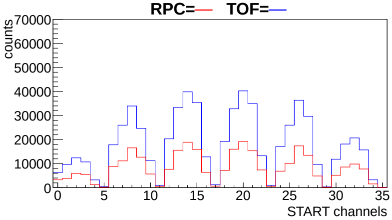
Time Resolution - Using electrons

The reason why some START channels have very different time resolution is in statistics.

The 6-structure of histograms is due to numbering of channels:







Time Resolution - Using electrons

- After timewalk corrections the result for Start time resolution $\sigma_{\mathrm{Start}} = 180\,\mathrm{ps}$ is in good agreement with the result from *Using pions* part ($\sigma_{\mathrm{Start}} = 190\,\mathrm{ps}$)
- Advantages
  + Possibility to subtract σ_{ToF}
- Disadvantages
  - More complicated analysis is needed to identify electrons (information from other detectors)
  - A lot of data is needed to be analysed to obtain enough statistic (rare decays, probability of interaction)

Summary and Outlook

- Two different and independent ways of analysis of time resolution have been presented
- Time resolution of Start was determined $\sigma_{\mathrm{START}} \approx 185\,\mathrm{ps}$

- Known problems:
  - Not sufficient HV on diamonds (only $200\,\mathrm{V} \approx 0.67\,\mathrm{V}/\mu\mathrm{m}$)
  - Too high external noise in the system
  - $\Rightarrow$ For HADES π-experiment the main importance was the trigger

- Another test is planned to determine time resolution with MIPs

Acknowledgement

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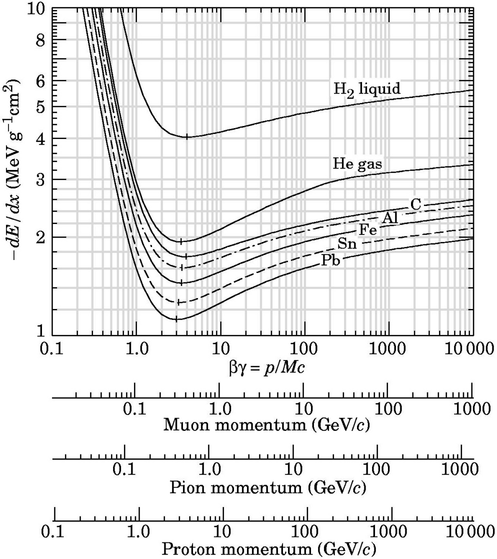
HADES collaboration: INFN-LNS Catania (Italy); LIP Coimbra (Portugal): PTDC/FIS/113339/2009; SIP JUC Cracow (Poland): 2013/10/M/ST2/00042 and NN202198639; GSI Darmstadt (Germany): Helmholtz Alliance HA216/EMMI; TU Darmstadt (Germany): VH-NG-823, Helmholtz Alliance HA216/EMMI; HZDR, Dresden (Germany): 283286, 05P12CRGHE; Goethe-University, Frankfurt (Germany): Helmholtz Alliance HA216/EMMI, HIC for FAIR (LOEWE), GSI F&E, BMBF 06FY9100I; TU Muenchen, Garching (Germany): BMBF 06MT7180; JLU Giessen (Germany): BMBF:05P12RGGHM; University Cyprus, Nicosia (Cyprus): UCY/3411-23100; IPN Orsay, Orsay Cedex (France): CNRS/IN2P3; NPI AS CR, Rez, (Czech Republic): MSMT LG 12007, GACR 13-06759S.

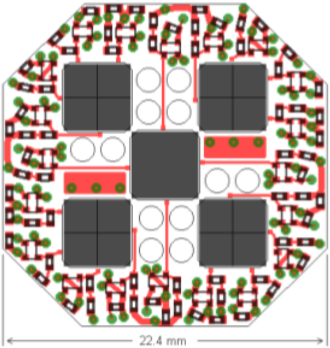
Thank you for your attention

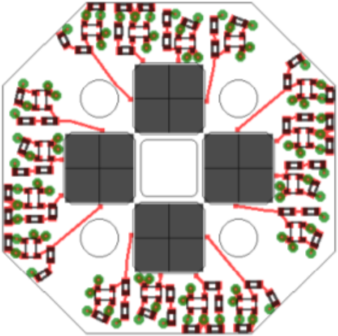
BACKUP

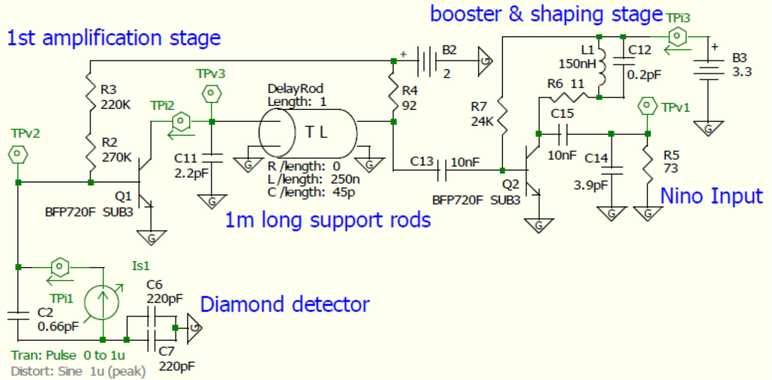


H2 liquid
He gas
C
Al
Fe
Sn
Pb
−dE/dx (MeV g−1cm2)
βγ = p/Mc
Muon momentum (GeV/c)
Pion momentum (GeV/c)
Proton momentum (GeV/c)

BACKUP






booster & shaping stage
1st amplification stage
TPi3
B2
2
B3
3.3
L1
150nH
C12
0.2pF
R6 11
R3
220K
TPv3
DelayRod
Length: 1
R4
92
R7
24K
TPi2
TL
C15
TPv1
TPv2
R2
270K
C11
2.2pF
R /length: 0
L /length: 250n
C /length: 45p
C13
10nF
10nF
C14
R5
73
Q1
BFP720F SUB3
Q2
BFP720F SUB3
3.9pF
Nino Input
1m long support rods
Is1
C6
220pF
TPi1
C2
0.66pF
Diamond detector
C7
220pF
Tran: Pulse 0 to 1u
Distort: Sine 1u (peak)