Mu3e electrical readout chain

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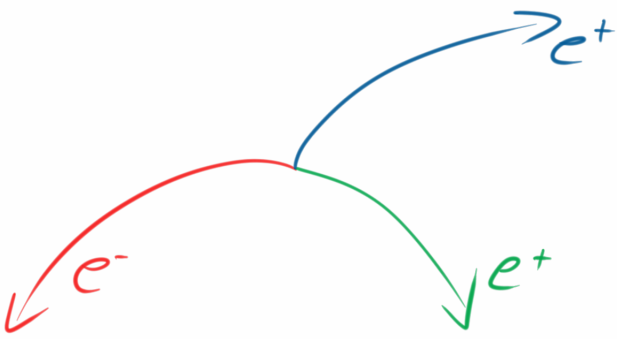
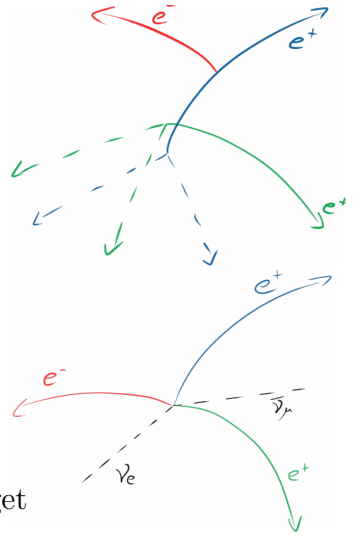
Mu3e experiment - $\mu^+ \to e^+e^-e^+$

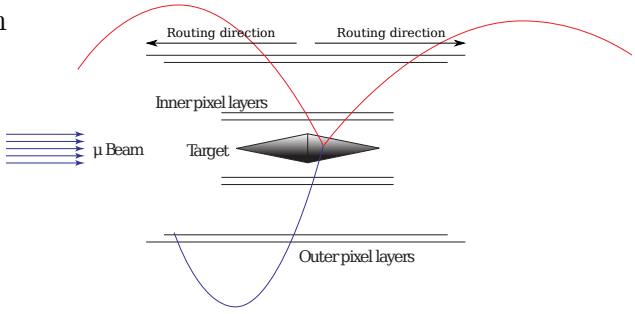




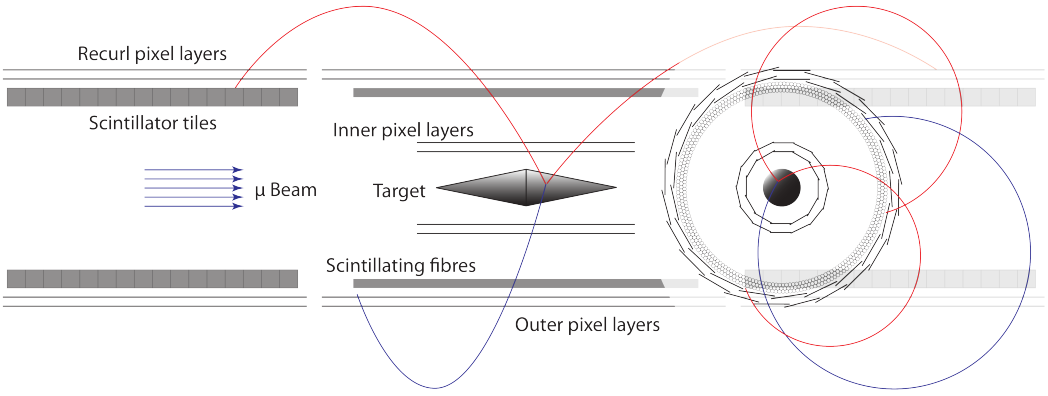
- Charged lepton flavor violating decay
- High vertex and momentum resolution needed
- Low momentum $p_e \leq 53\,\mathrm{MeV/c}$
- Multiple scattering demands low material budget

Mu3e detector - tracker

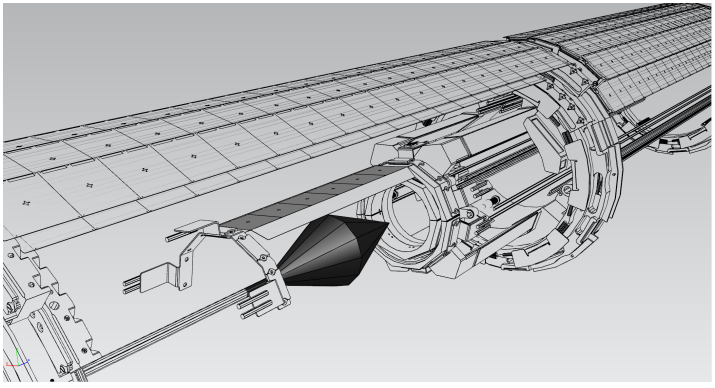
- Four tracking layers
- Divided into ladders with length 6 (inner) and 17/18 (outer) MuPix chips
- Electrically separated in the middle
- Routed from the center to the end of the barrel



Mu3e detector



Readout chain + requirements



- $X/X_0 = 0.115\%$ per layer
- 1.25 Gbit/s
- Continuous data stream
- 3060 differential links

- Trace length
  - $\sim 24\,cm$ over HDI + flex prints
  - $\sim 2\,m$ over twisted pairs

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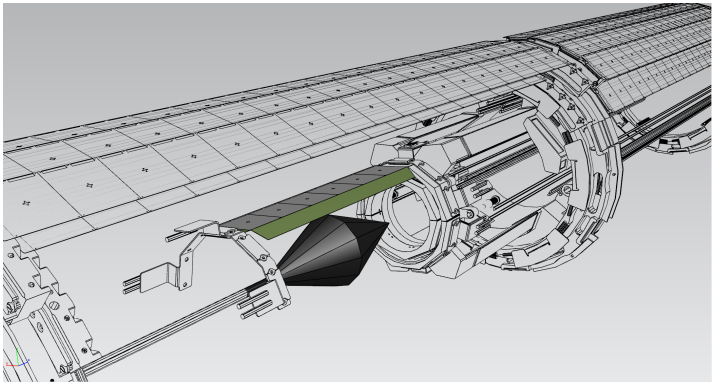

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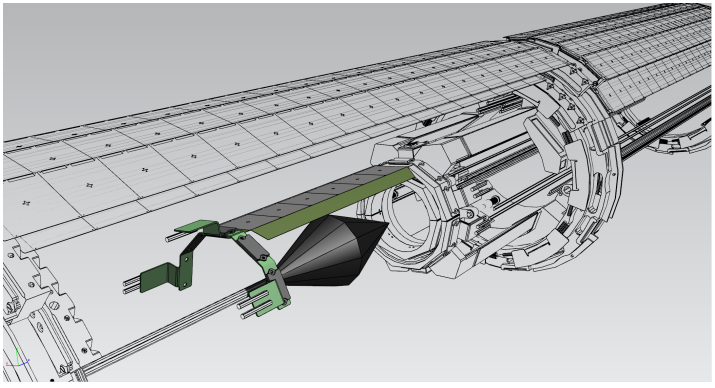

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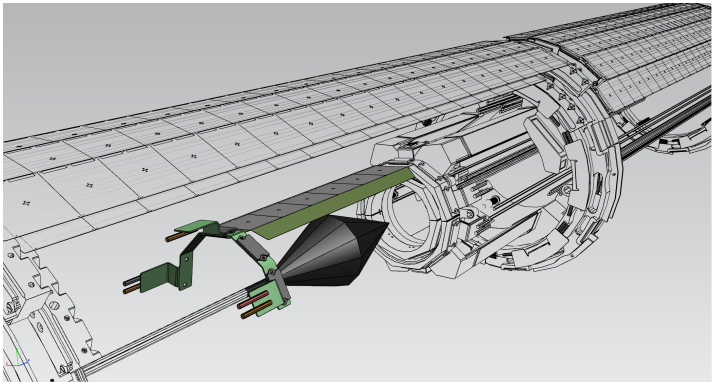

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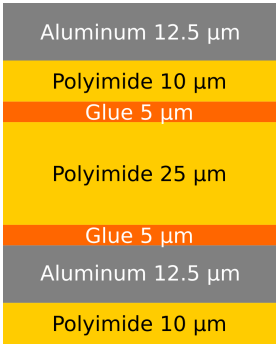
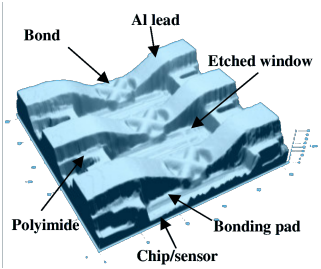
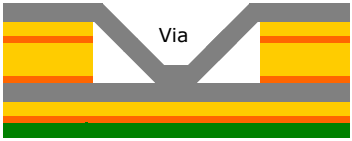
Aluminum High Density Interconnects (HDI) technology

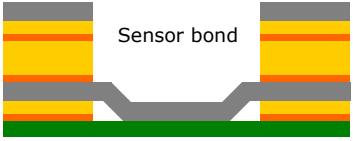
- Two layers polyimide aluminum laminate
- Single-point Tape Automated Bonding (SpTAB)
  - Ultra sonic induced welding
  - No extra material
  - Bonding yield close to 100%
  - Small risk of intermetallics



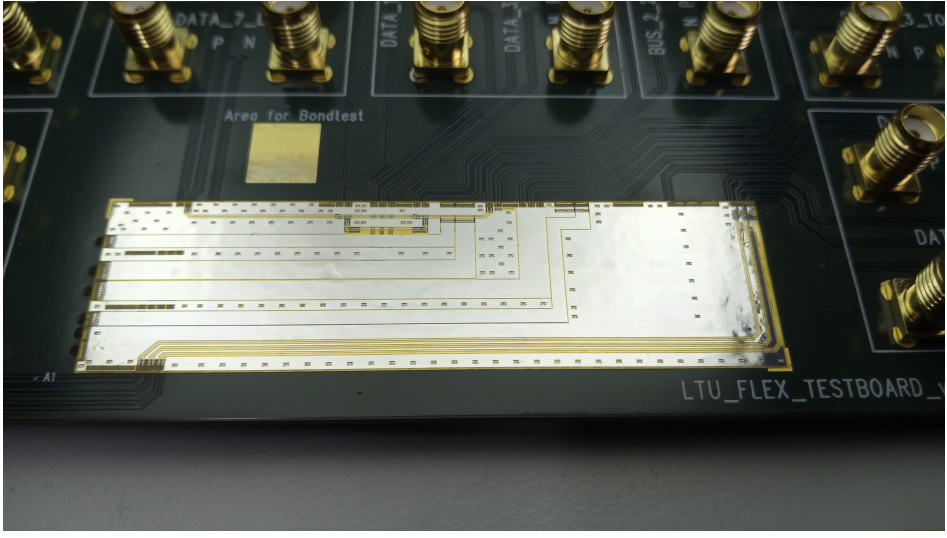


ALICE Silicon Strip Detector Module Assembly with Single-Point TAB Interconnections M.Oinonen





LTU HDI



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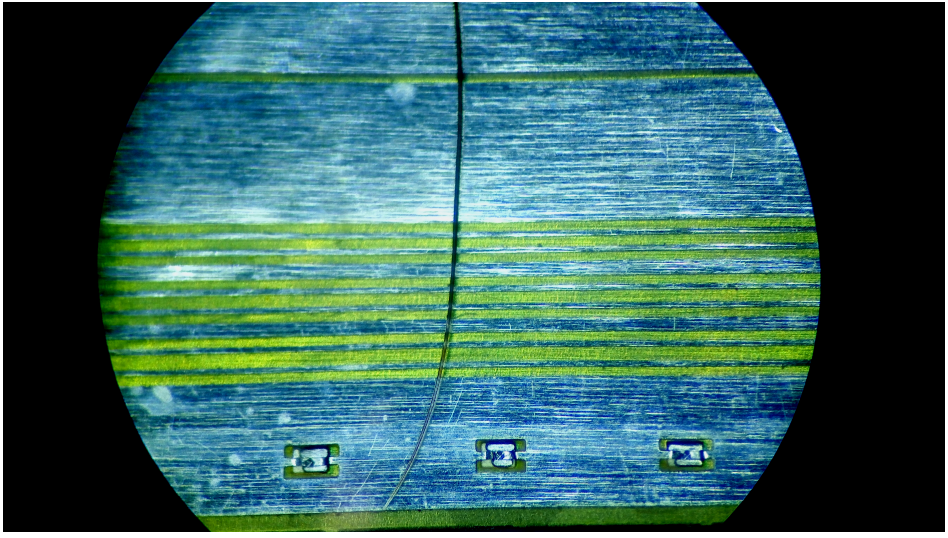
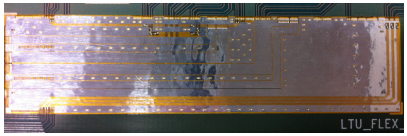
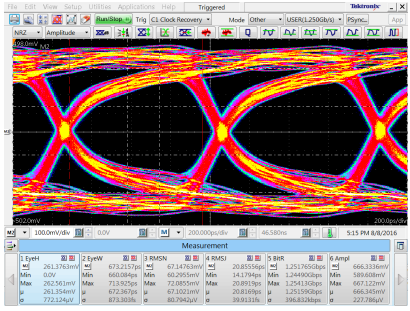


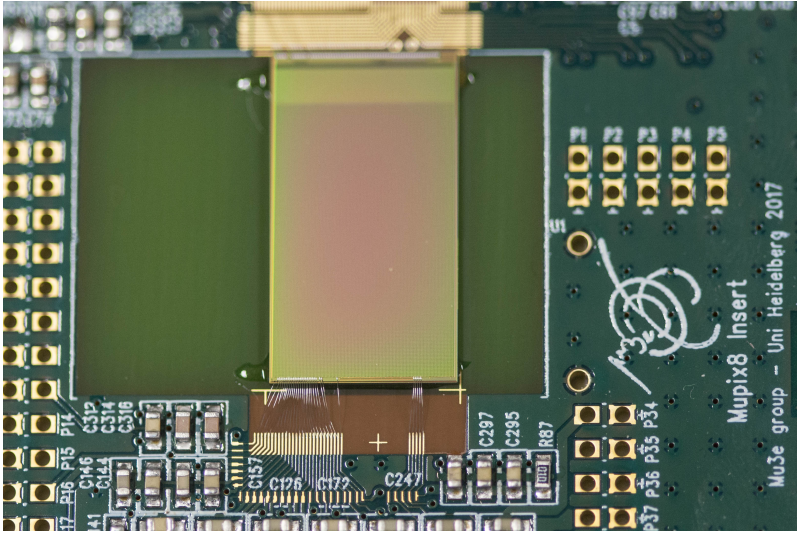
HDI Measurements

- BERT at 95% CL
  - @ 1.25 GBit/s: $\leq 4.28 \times 10^{-14}$
  - @ 2.50 GBit/s: $\leq 2.56 \times 10^{-13}$
- @ 625 MHz attenuation at $-(12.3 \pm 0.2)\,\mathrm{dB/m}$
- Impedance Z_{diff} between $80\,\Omega$ and $135\,\Omega$
- No crosstalk detected even after detailed jitter and noise analysis



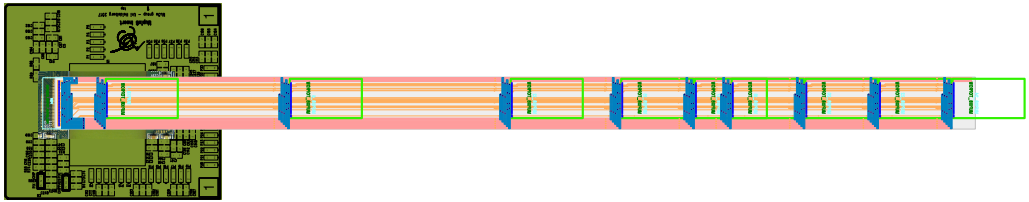


MuPix readout over wire bonds



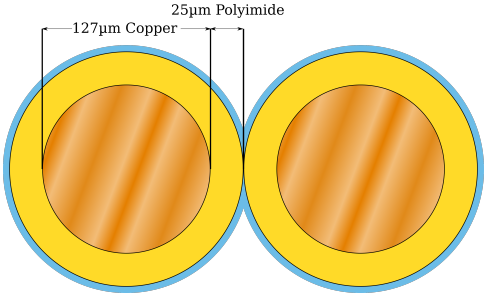
MuPix readout over HDI

- First LTU HDI bonded to a MuPix8
- Connects all necessary pads from the chip to an insertable readout PCB
- Various trace lengths possible (approx. $1 - 24\,\mathrm{cm}$)
- 1.5 layer stack

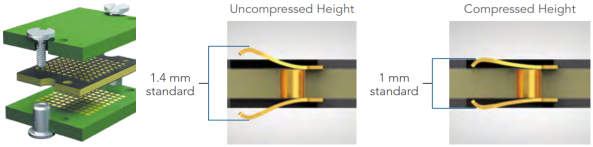


Unshielded Twisted Pair Cable (UTP)

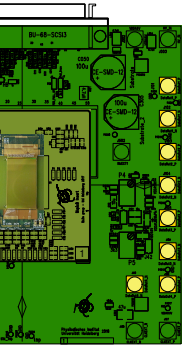
- Already used in CMS readout (up to 160 Mbit/s)
- First step: 1.25Gbit/s characterization by Beat Meier (PSI)
  - Signal loss $\sim 1.9\,\mathrm{dB/m}$
  - Differential impedance between $85\,\Omega$ and $90\,\Omega$

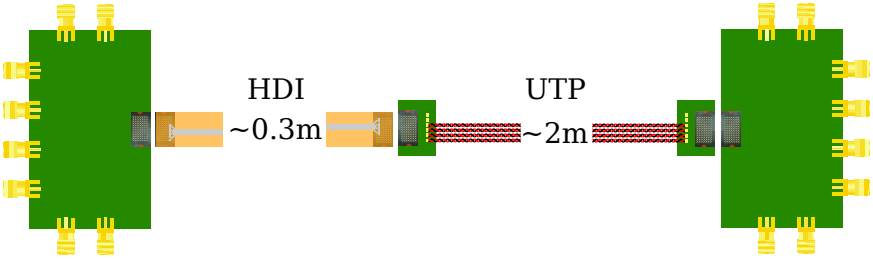


Vertical slice mockup



Samtec Zray design guide





Outlook