LEIR INJECTION BPMs update

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Specifications

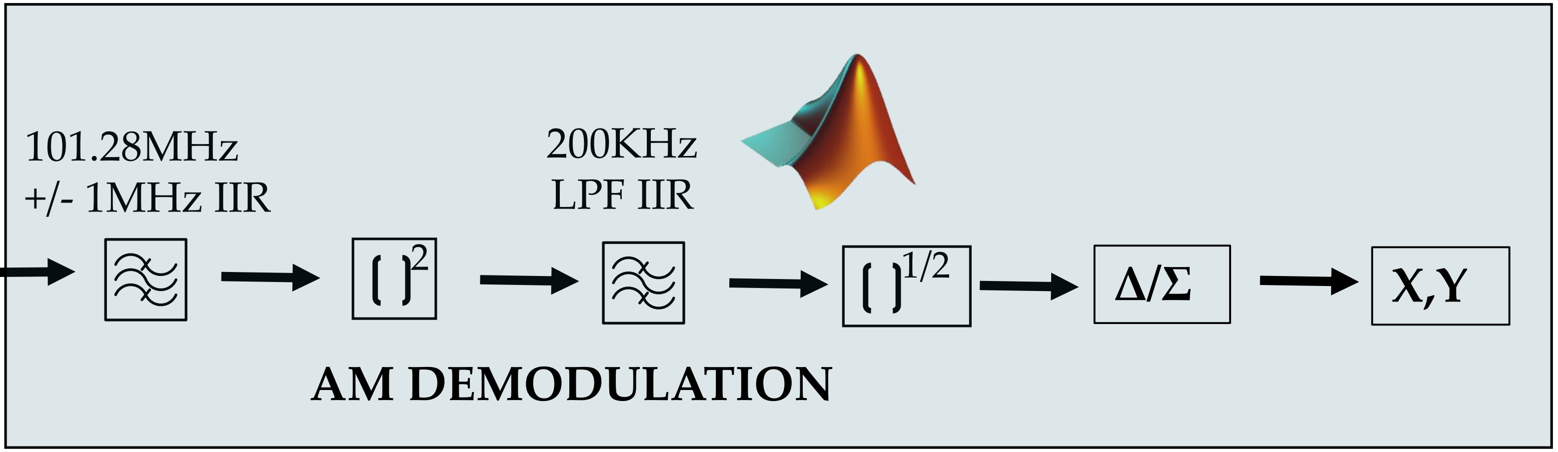
The required accuracy of the average beam position during the pulse should be better than 0.5 mm with a precision of 0.2 mm for a minimum intensity of 0.5e+10 charges (4uA) at a b of 0.094 for the 200 us spills. The accuracy should be maintained over +/- 15 mm of aperture (around the centre of the beam pipe assuming a maximum beam size of 10 mm). The system should not suffer any saturation effects up to 40uA. **<u>During a pulse, the position data should be available at 1us intervals, with the same accuracy.</u>**

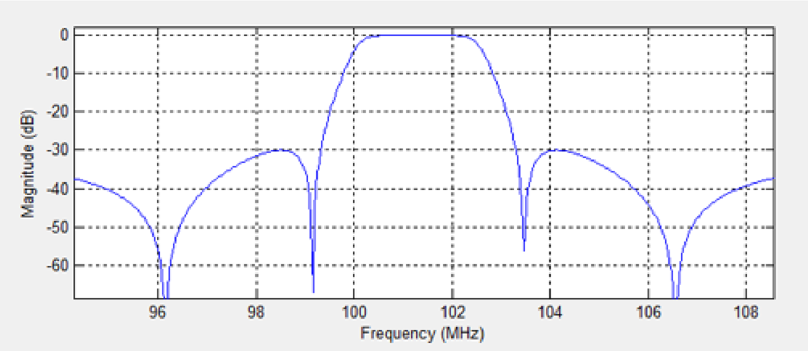
SPECIFICATION FOR THE AVERAGE POSITION

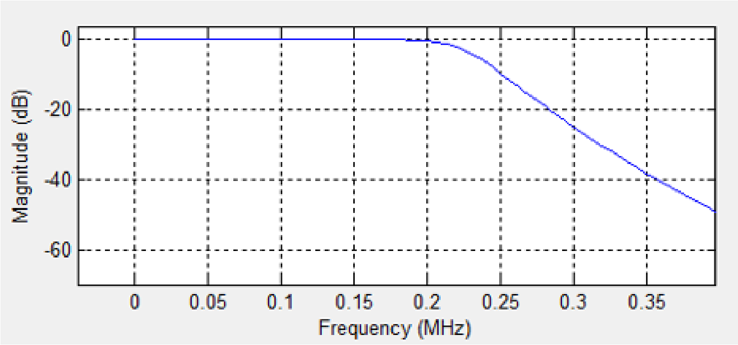
Accuracy	**<0.5mm**	**depends on the electrical and mechanical offset**
Precision	**<0.2mm**	**depends on S/N → tradeoff between BW and precision**

101MHz acquisition

8bit, 500Msps



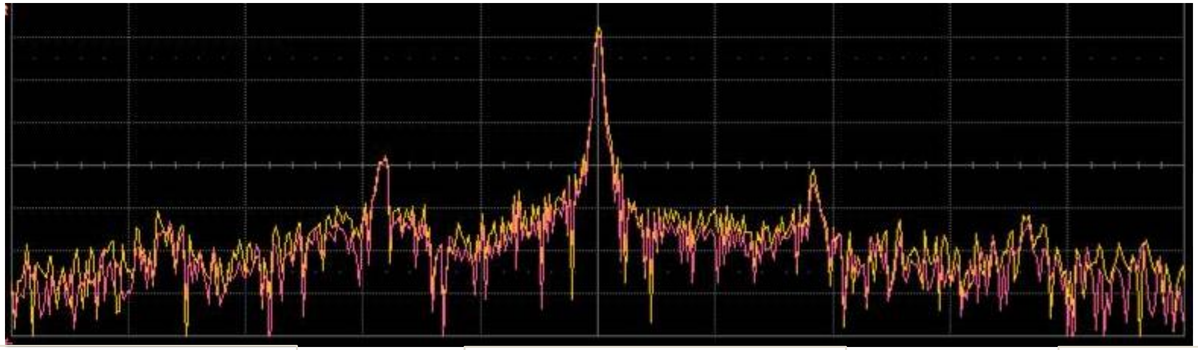




- LECROY 8 bit scope running @ 500Msps + matlab DSP
- 20dB amplifier in front of the scope to have sufficient signal level
- S/N ratio probably dominate by the scope (12bit scope, now broken, should perform quite better)

El.BPMl30 signals (last BPM in the line)

80dB



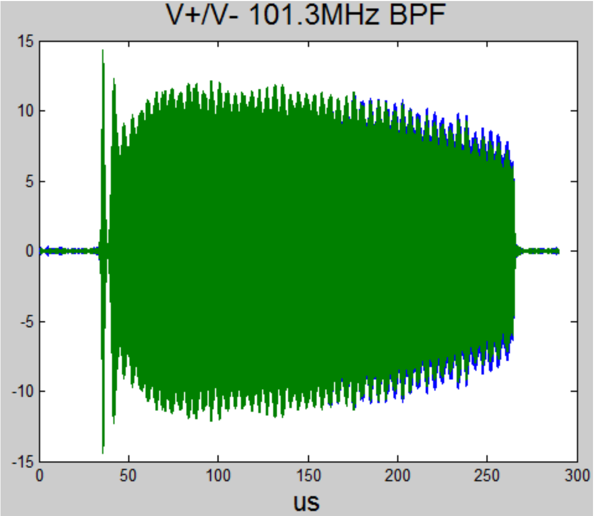
Power spectrum of electrode signals

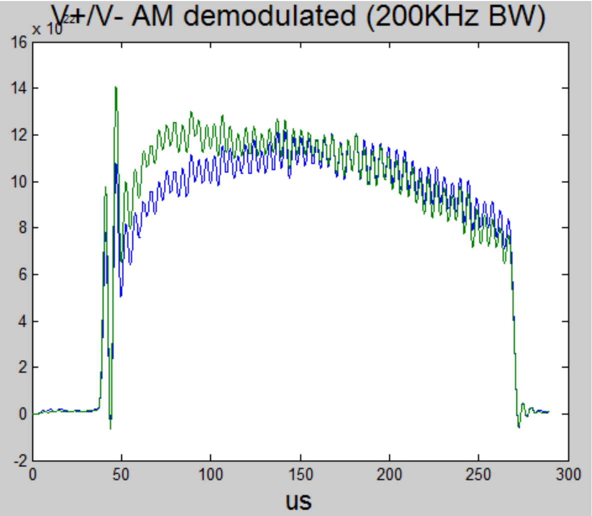
→ RBW=2KHz

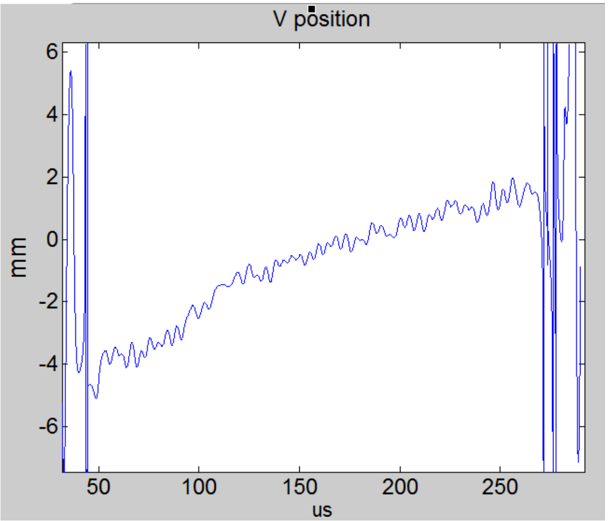
-500KHz

101.29MHz

+500KHz



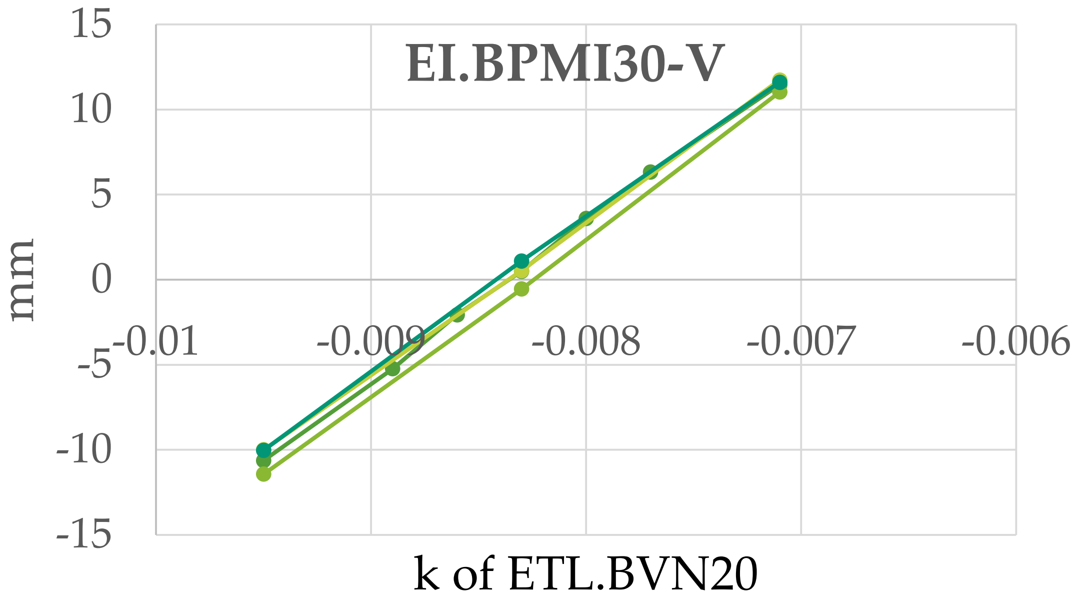




- Bunching stay almost constant all along the line
- At this conditions, resolution expected to be better than 0.5mm over 5us time average

Dipole scan (HF measurement)

Dipole scan (+/- 10mm) for different settings of the debuncher (actually working as rebuncher) (phase off up to 20° and amplitude down to 80%)



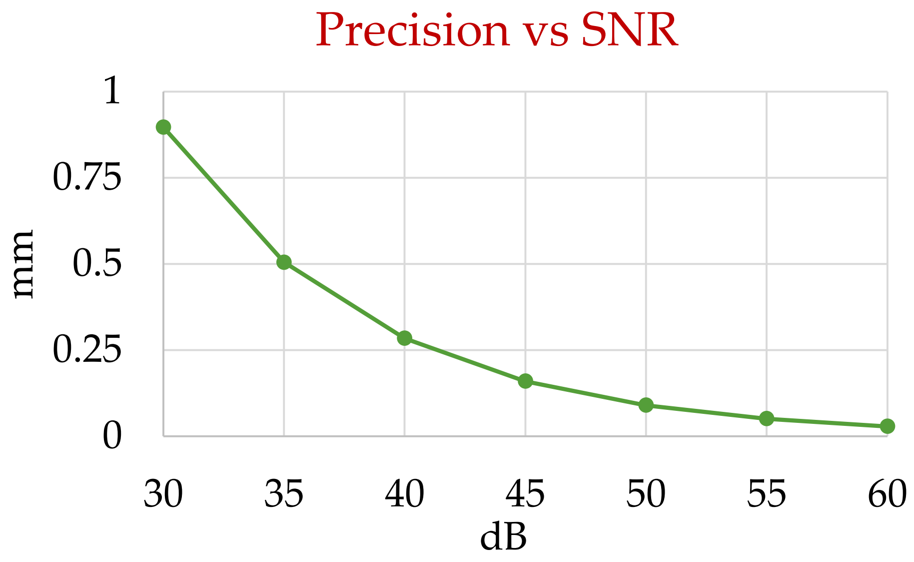
- Position values are the average over the central region of the LINAC pulse
- Measurements are (at first sight) indipendent of clearing voltage and magnetic field
- BPM response stay linear over the range
- With the debuncher off the signals become very weak (not shown)
- Similar scans for ITE.10, ITE.20, ETL.20 and EI.10 were successful

Error (precision) estimation

$$Position = S \cdot \frac{\Delta_M}{\Sigma_M} = S \cdot \frac{\Delta_{BEAM} + \Delta_{NOISE}}{\Sigma_{BEAM} + \Sigma_{NOISE}} \cong S \cdot \frac{\Delta_{BEAM}}{\Sigma_{BEAM}} + \underbrace{S \cdot \frac{\Delta_{NOISE}}{\Sigma_{BEAM}}}_{\textbf{error}}$$

$$\boldsymbol{error} = S \cdot \frac{n_+ - n_-}{(V_+ + V_-)} = S \cdot \left(\frac{\sqrt{2} \cdot n}{2 \cdot V}\right) = \frac{S}{\sqrt{2}} \cdot SNR^{-1} \qquad \begin{cases} (V_+ + V_-) + n_+ + n_- \cong V_+ + V_- \\ E[n_+ n_-] = 0 \end{cases}$$

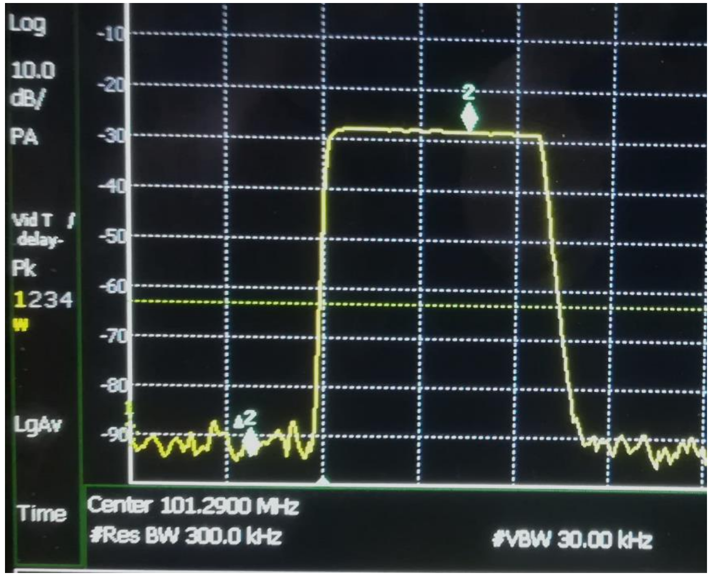
With $S \cong 40mm$



Filter bandwidth and precision

Rule of thumb : $t_{RISE} = \frac{0.35}{f_{3dB}}$

Position rate (from specifications): **2μs** → Minumum bandwidth= 175kHz



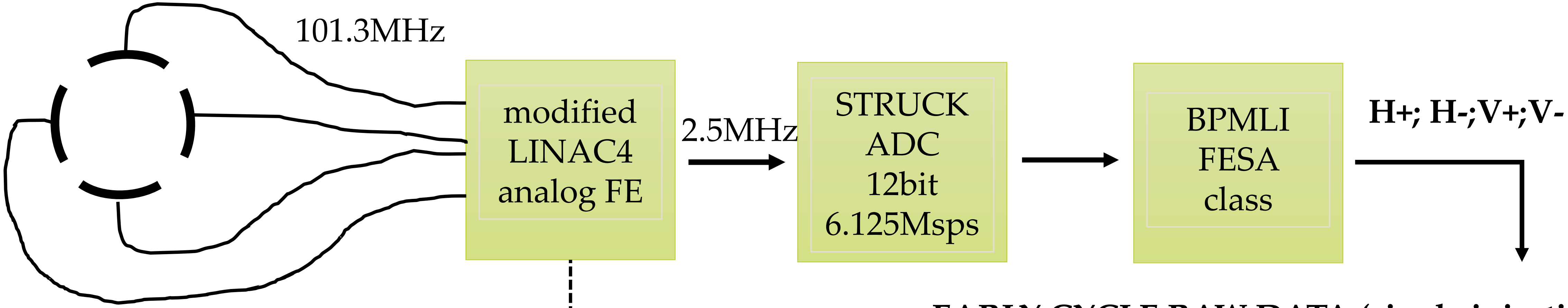
@300kHz RBW **S/N ≈ 60dB** for EI.30 and ITE.10

BPM	Cable len. [m]	Att[dB]
ITE.10	121	3
ETL.22	99	2.5
EI.30	41	1

- @300kHz RBW **S/N ≈ 60dB** for EI.30 and ITE.10

- **With these buncher settings the requested precision is reasonable**

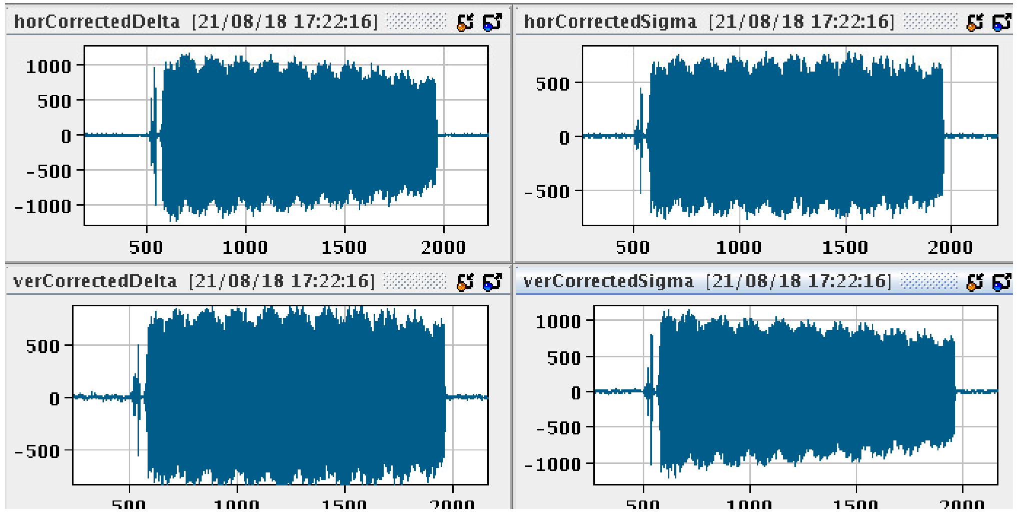
EI.BPM30 from 20th August



NO head amplifier

- 65dB GAIN
- >25dB input match
- ~ 4dB noise figure
- NO input filter
- 98.8MHz LO
- 4MHz LPF output filter

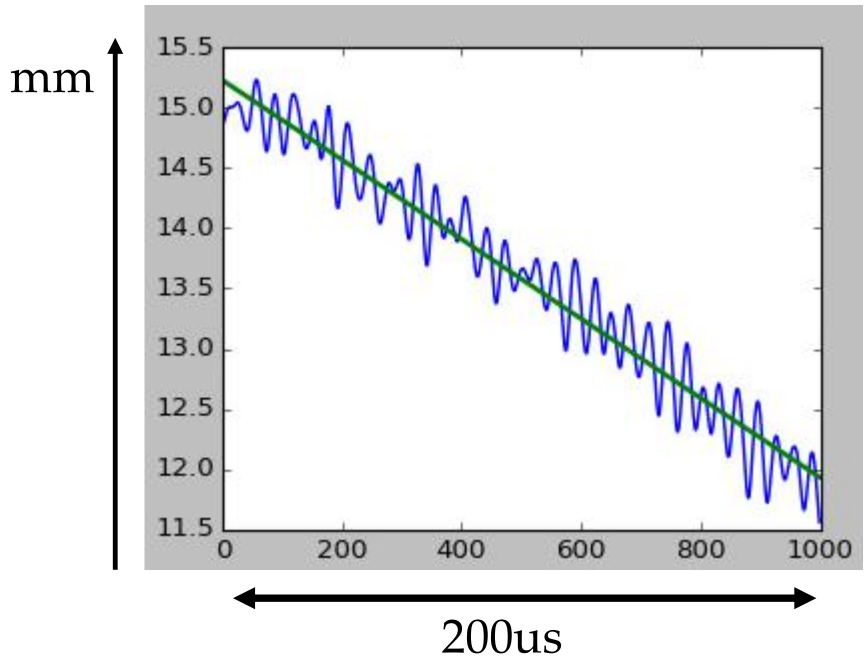
EARLY CYCLE RAW DATA (single injection)



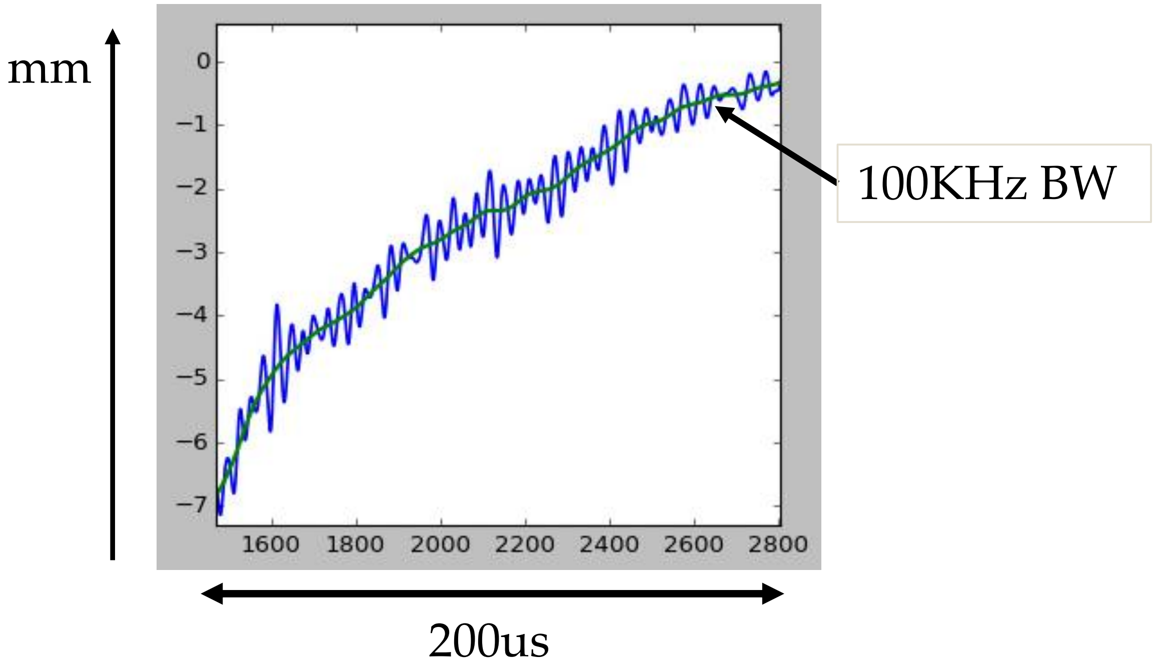
- **5dB better performance expected from a dedicated analog front end**

El.BPM30 EARLY CYCLE @ 300KHz BW (~1μs rise time)

H position



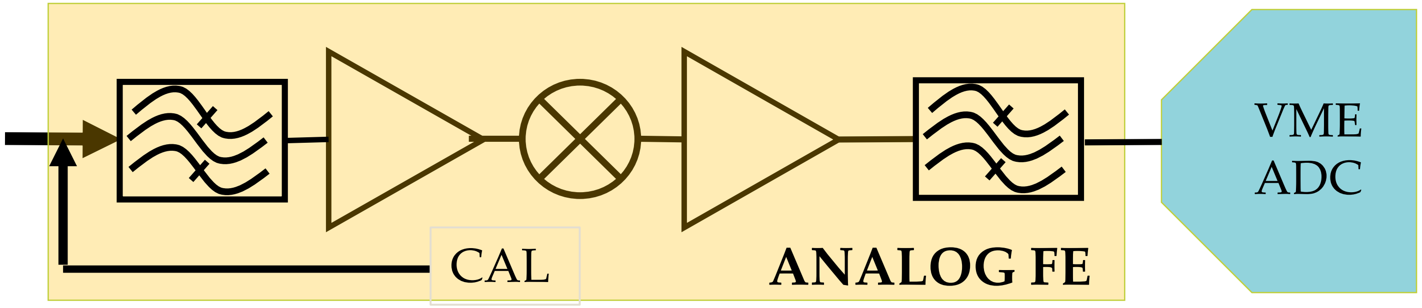
V position



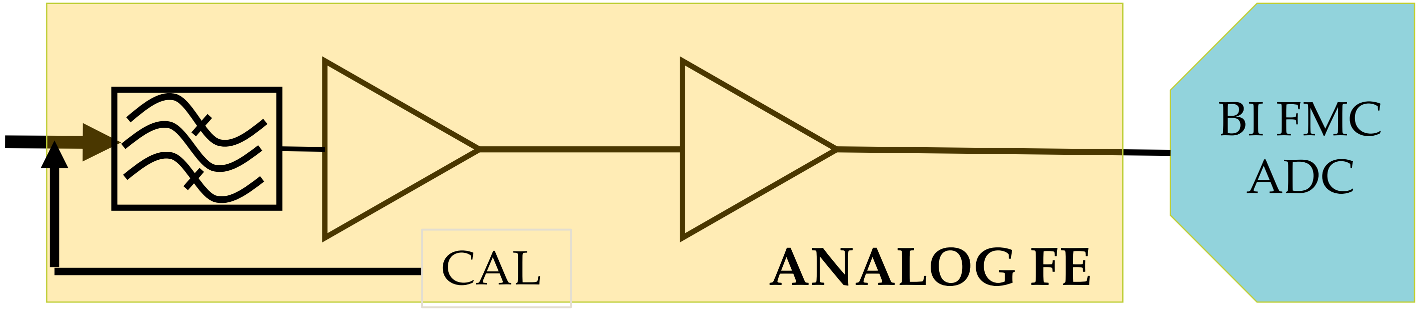
H_{NOISE}(RMS)=0.2mm

V_{NOISE}(RMS)=0.3mm

Acquisition chain



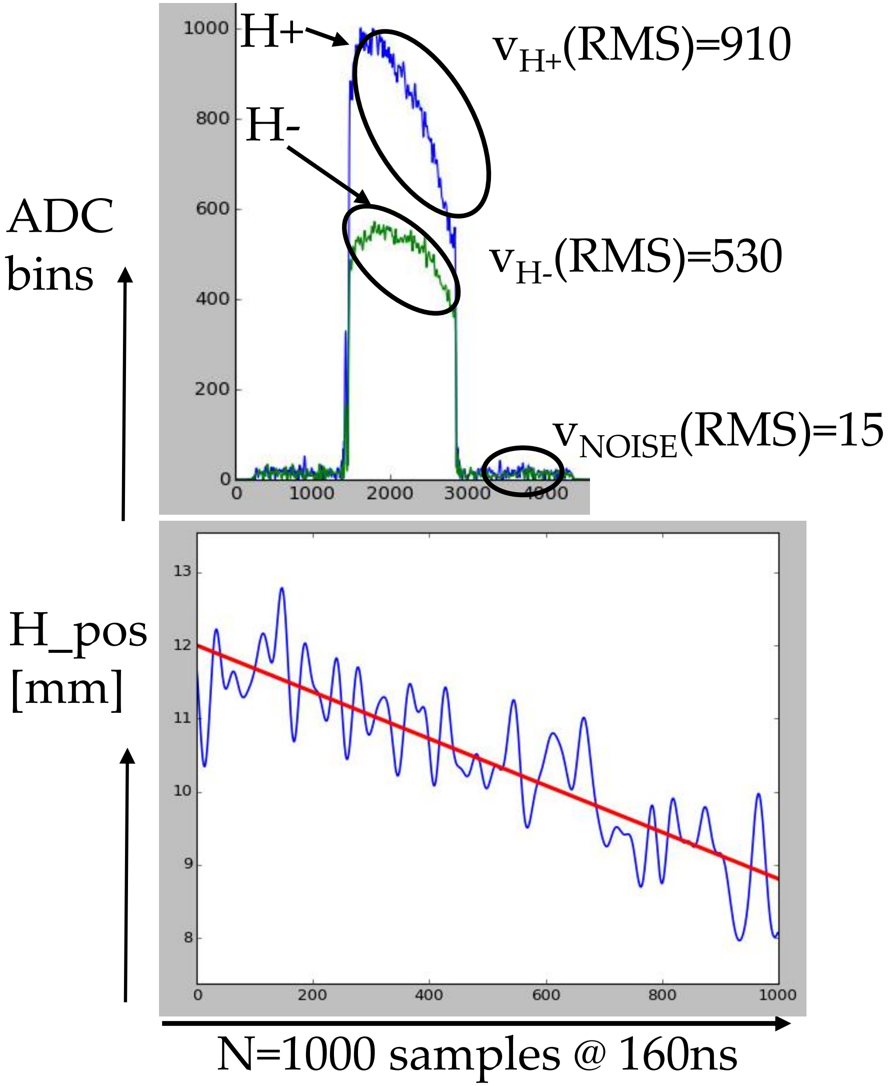
Current solution



“Standard” BI solution

- **In both cases a custom analog front end (~60db gain & calibration) is needed**
- **Narrow BW (<10MHz) → undersampling is a good choice for lower cost (in that case we would undersample and oversample at the same time)**
- **125MSps / 16bit mezzanine used in LEIR orbit (but on BE/RF carrier) can be a solution**

Precision calculation with linear fitting



$$SNR \approx 20 \cdot log\left(\frac{\frac{910+530}{2}}{15}\right) = 33dB$$

```
[a,b]=np.polyfit(linspace(0,N-1,N), H_pos[s:s+N], 1)
Hfit=linspace(b,b+a*N,N)
H_pos_error=(sqrt(mean((H_pos[s:s+N]-Hfit)**2)))
```

$$H_{pos_{ERROR}}(RMS) = \sqrt{\frac{1}{N} \cdot \sum (H_{pos} - H_{fit})^2} = 0.5mm$$