# *SNS Diagnostic Review*
# *Base-band BPM Electronics*
# *Detailed Design Phase*

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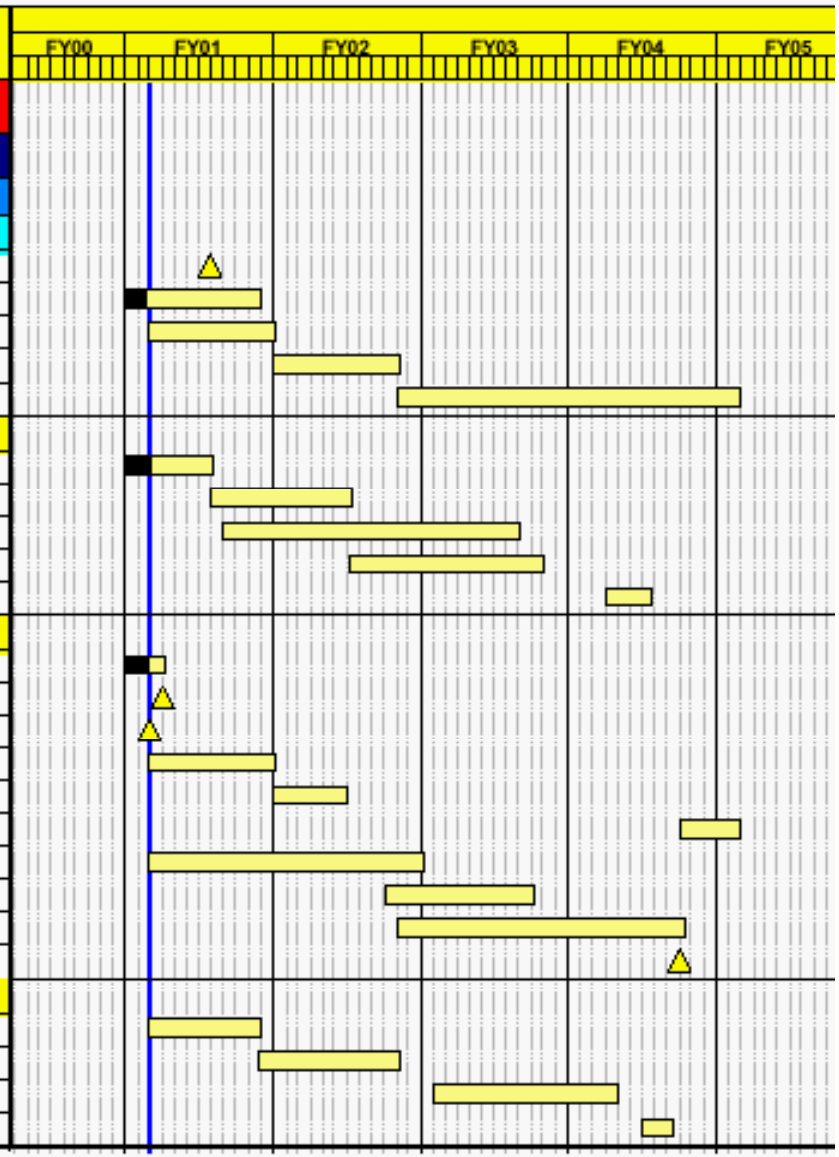
12-14-00 and 12-15-00

# BPM Schedule

| Activity Description | Early Start | Early Finish |
|---|---|---|
| **1.0 Spallation Neutron Source Project** | | |
| **1.5 Ring and Transport System** | | |
| **1.5.7 Ring Systems Diagnostics Instrumentation** | | |
| **1.5.7.1 Beam Position Monitor [BPM]** | | |
| B P M Final Design Review [FDR] | 30APR01 | |
| B P M Detail Design - Summary [FY01] | 02OCT00A | 29AUG01 |
| B P M Procure, Fab & Assy - Summary [FY01] | 01DEC00 | 28SEP01 |
| B P M Procure, Fab & Assy - Summary [FY02] | 01OCT01 | 06AUG02 |
| B P M Install & Test - Summary | 08AUG02 | 23NOV04 |
| HEBT | | |
| HEBT B P M Detail Design (FY01) | 02OCT00A | 30APR01 |
| HEBT B P M Procure/Fab/Assy | 01MAY01 | 05APR02 |
| HEBT B P M Electronics Fab/Assy | 31MAY01 | 30MAY03 |
| HEBT B P M Elec Test | 08APR02 | 30JUL03 |
| HEBT B P M Elec Comp. Test @ Site | 02JAN04 | 19APR04 |
| RING | | |
| B P M Detail Design (FY01) | 02OCT00A | 29DEC00 |
| Ring BPM Detailed Design Complete | | 29DEC00 |
| RING B P M Procurement Start | 01DEC00 | |
| B P M Procure/Fab/Assy (FY01) | 01DEC00 | 28SEP01 |
| B P M Procure/Fab/Assy (FY02) | 01OCT01 | 29MAR02 |
| RING B P M Component Test @ Site | 05JUL04 | 23NOV04 |
| B P M Electronics Design (FY01+) | 01DEC00 | 30SEP02 |
| B P M Electronics Procure/Fab/Assy | 05JUL02 | 02JUL03 |
| B P M Electronics Test | 08AUG02 | 05JUL04 |
| B P M Electronics Install & Test Compl | 05JUL04 | |
| RTBT | | |
| RTBT BPM Detail Design (FY01) | 01DEC00 | 29AUG01 |
| RTBT BPM Detector Procure/Fab/Assy | 30AUG01 | 06AUG02 |
| RTBT BPM Test | 06NOV02 | 30JAN04 |
| RTBT BPM Comp. Test @ Site | 01APR04 | 10JUN04 |



# *SNS DESIGN PARAMETERS*

- Energy……..1 GeV
- Intensity……..……. 1(2) x $10^{14}$ protons
- Repetition Rate…….....60 Hz
- Number of Bunches…..……... 1
- Injection duration……. 1.0 msec
- Revolution Period…….…. 945 nsec
- Bunch Length…….... 695 nsec
- Number of turns……. 1060

# *BPM Ring - RTBT Requirements*

## Taken from SNS Diagnostics AP Requirements (10/20/00)

- Intensity 5e10 to 2e14 Protons
- Range +/- 20 mm
- Accuracy +/- 1 mm
- Resolution 0.15 mm (except .5mm for 15mA)
- Data Structure turn-by-turn (except during gain switching)
- dual plane PUE at each quad

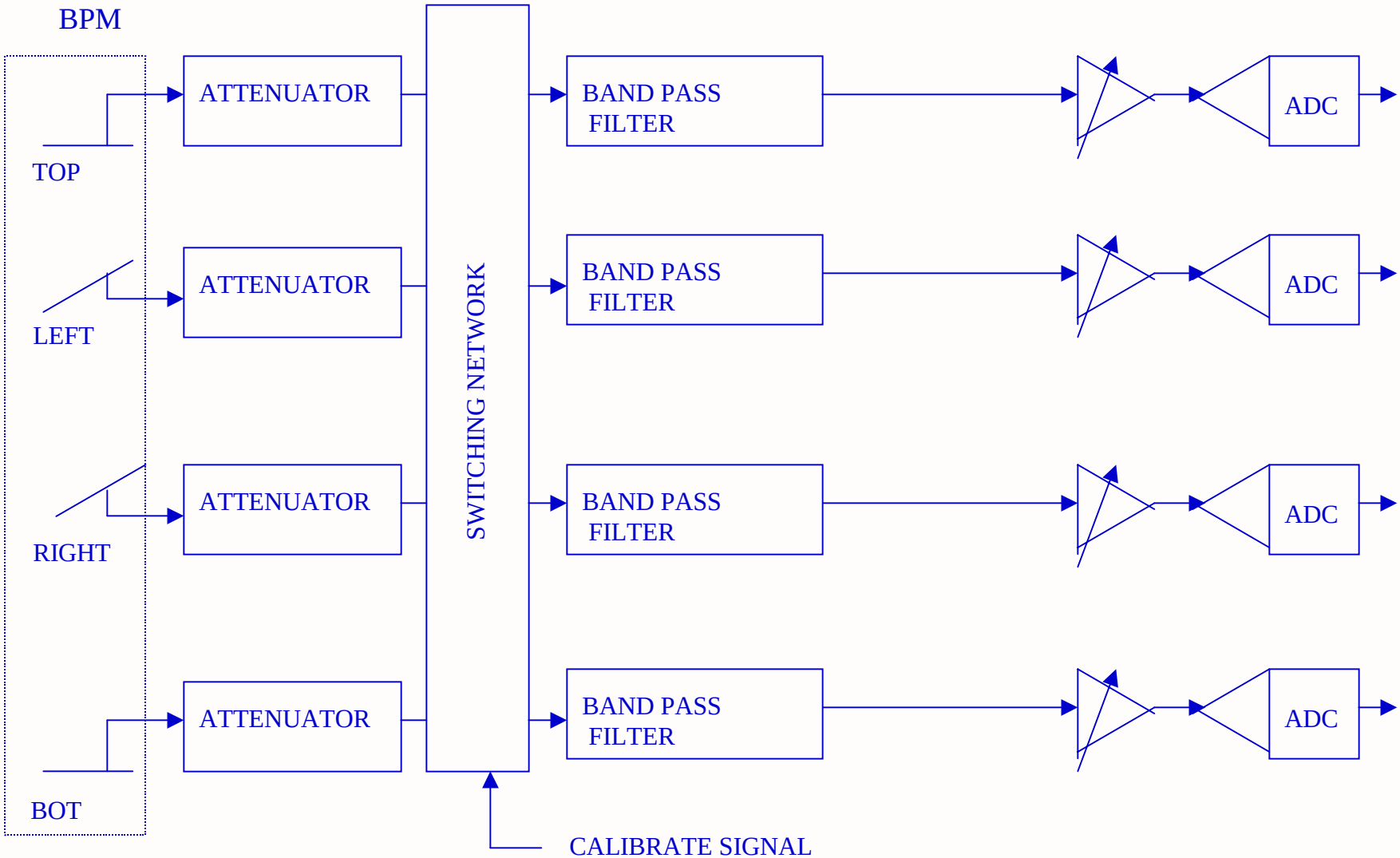
# *Status and Goals*

- Cutting metal for PUE
- LANL digital interface efforts nearing initial tests
- Analog Front End electronics in preliminary design phase
- Goal to prepare for testing with LANL digital interface Summer 2001

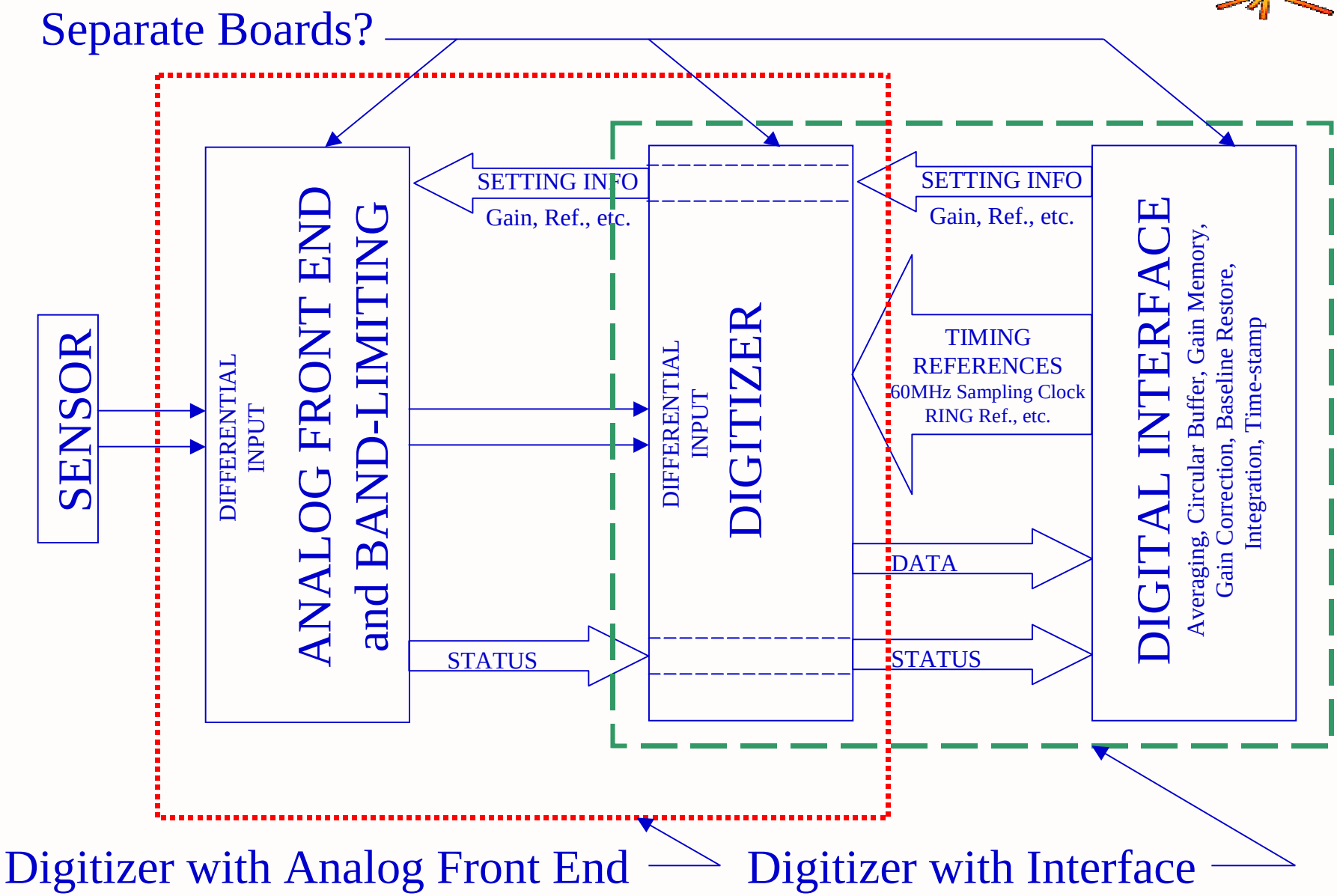
# *Basic System Philosophy*

- Maintain a linear system
- Digitize as soon as practical
- Do all calibration (except beam-based), channel matching, and signal processing digitally

# BPM Block Diagram



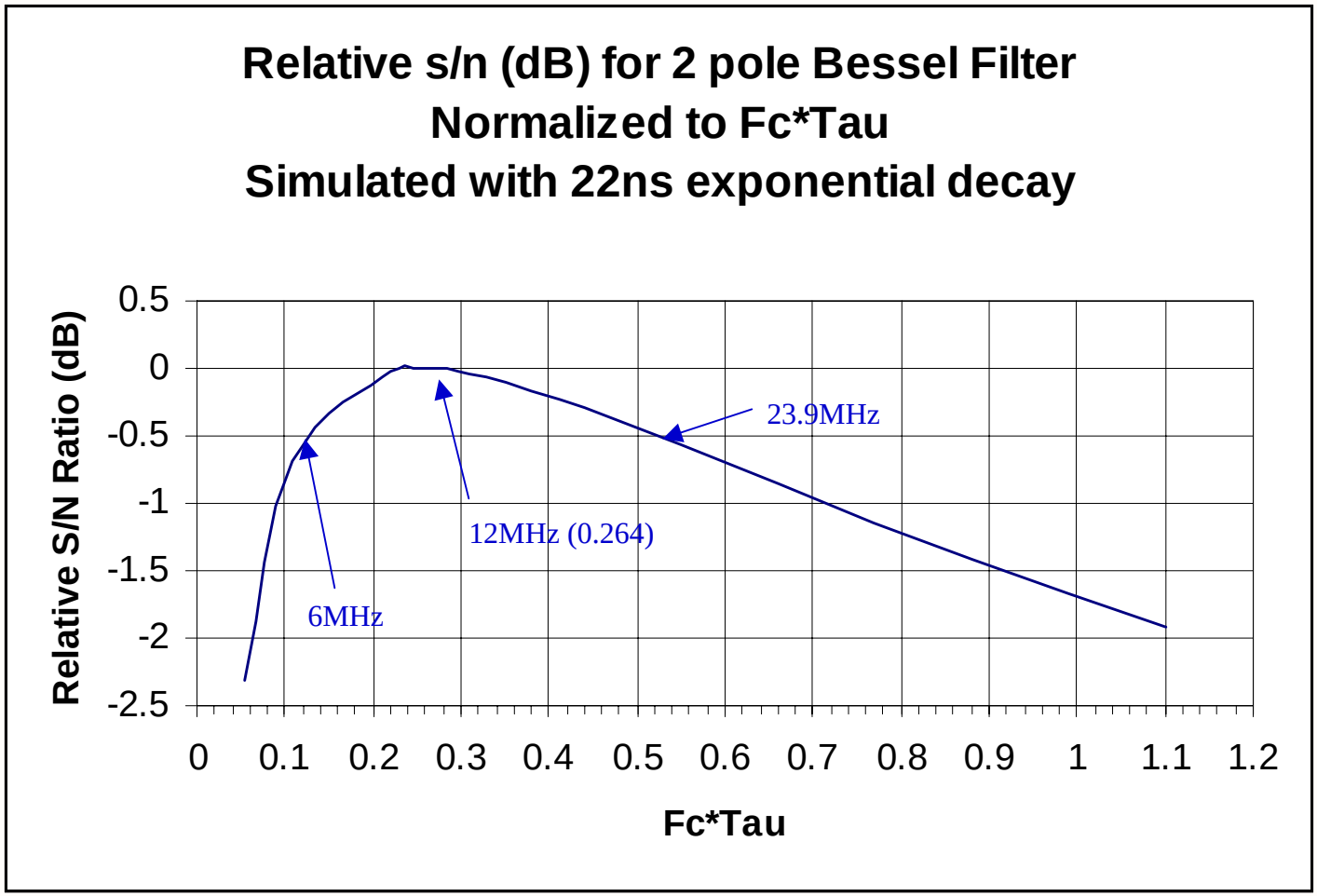
# *BCM & BPM Partitioning Options*



# *Analog-Digital Partitioning*

- Presently, prototyping of other diagnostics is taking place at both LBNL and LANL.
- To use these efforts to advantage, the present prototyping configuration will be partitioned to permit the use of a digital interface under development at LANL.
- Can employ separate boards, or grouping Analog front end with digitizer.

# *Relative Signal To Noise for 2 Pole Bessel Response to an Exponential Decay*



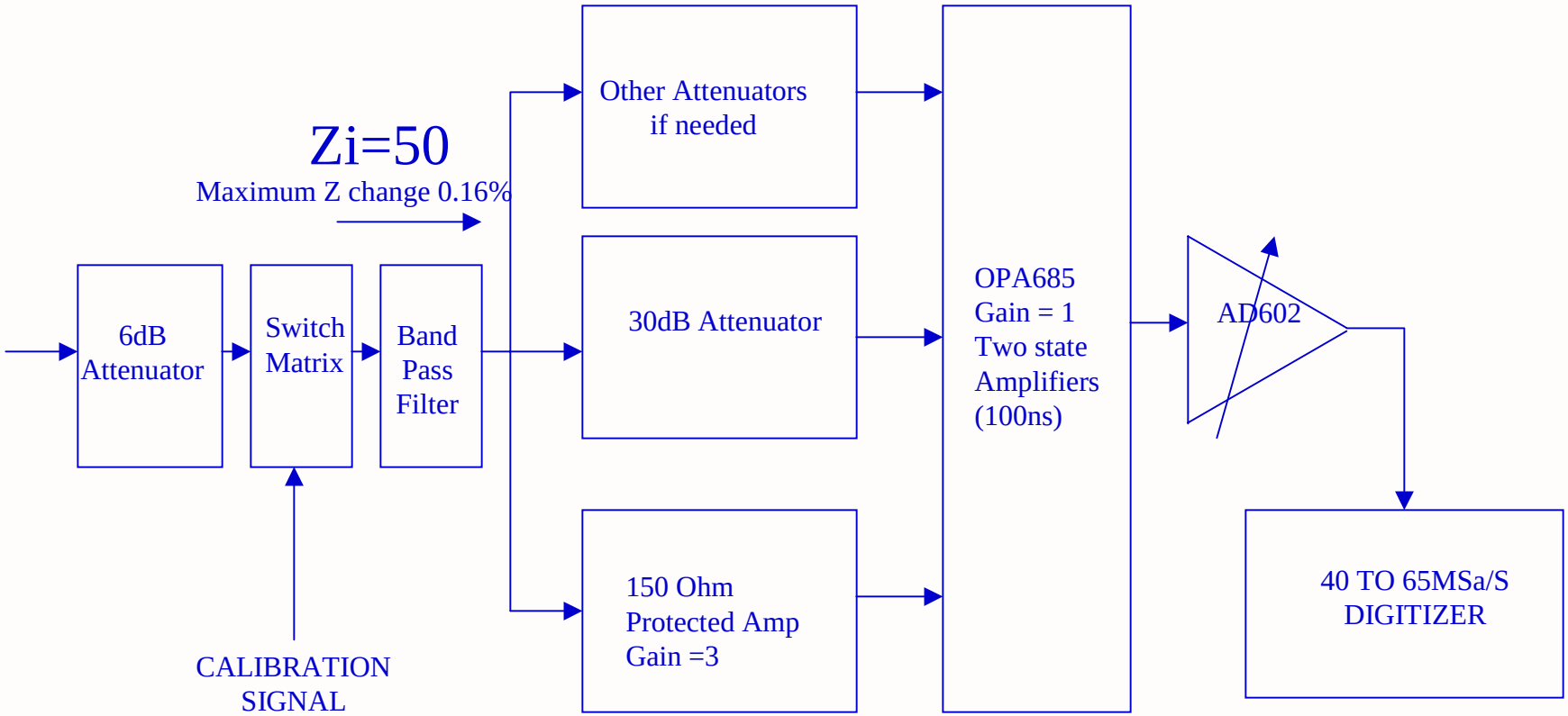
# *Selection of Filter Bandwidth*

- **Undergoing a selection trade-off study**
  - **Beam rise time is changing during the 1ms pulse**
    - **about 10ns at first turn, and 50ns at last turn**
    - **for a 10ns edge , best s/n is achieved with a 48MHz bandwidth. Creates digitizer difficulties, requires compromise**
  - **Recent turns will contribute differently to BPM signal due to their shorter rise times and less time influenced by RF**
    - **recent turns will skew position calculations for first number of turns**
    - **Sampling rate and signal shape must be examined more to match data to signal processing methods**

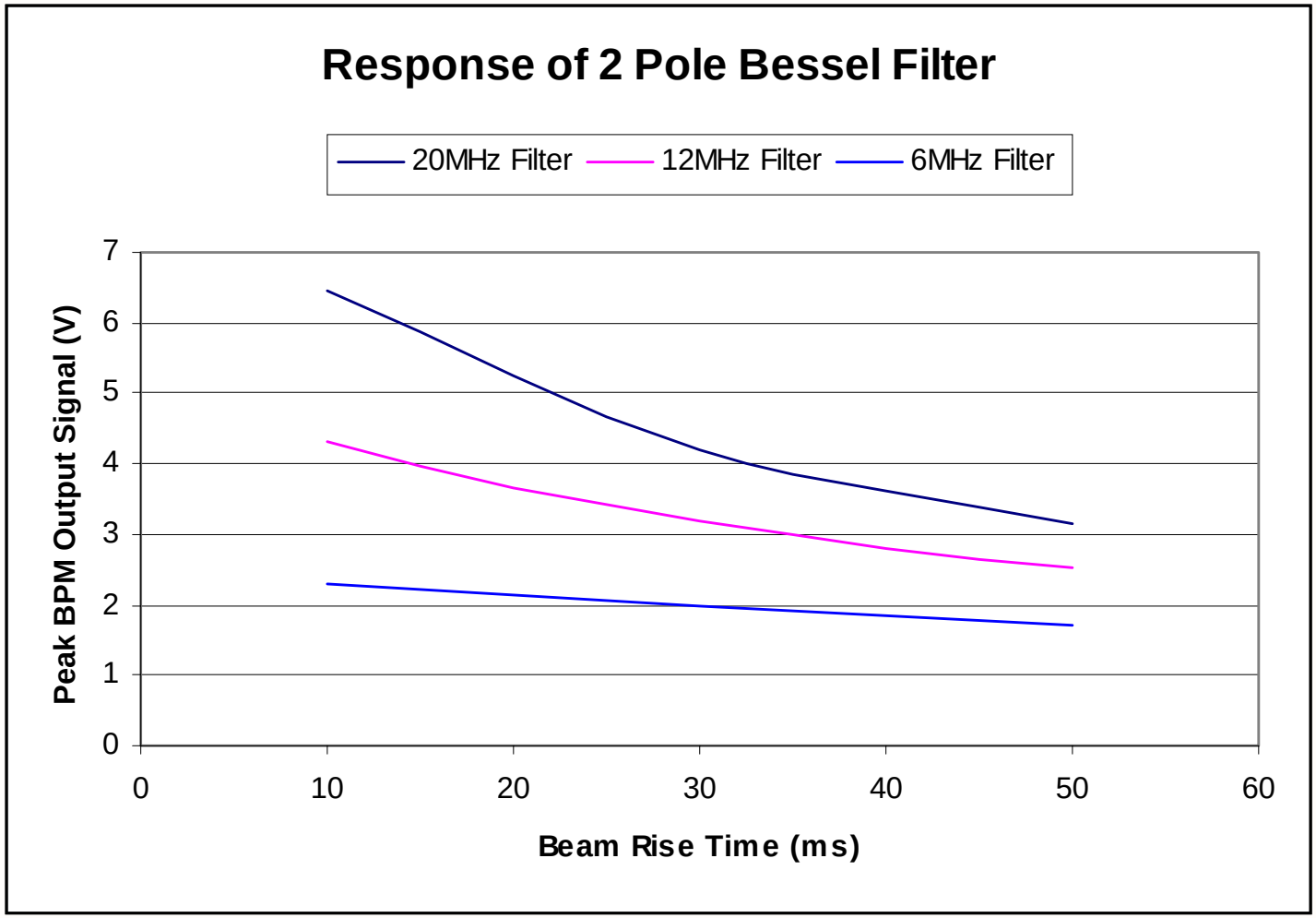
# *Large Dynamic Range Issues*

- BPM signal can be nearly 40 volts for a 100A beam (no filter)
- To change gain with no loss of turn data requires fast solid state switches
- Calibration switches must handle the large voltage with little distortion (compression)
- Amplifiers must handle large signals without exceeding input specifications, scheme must provide “fail-safe” protection

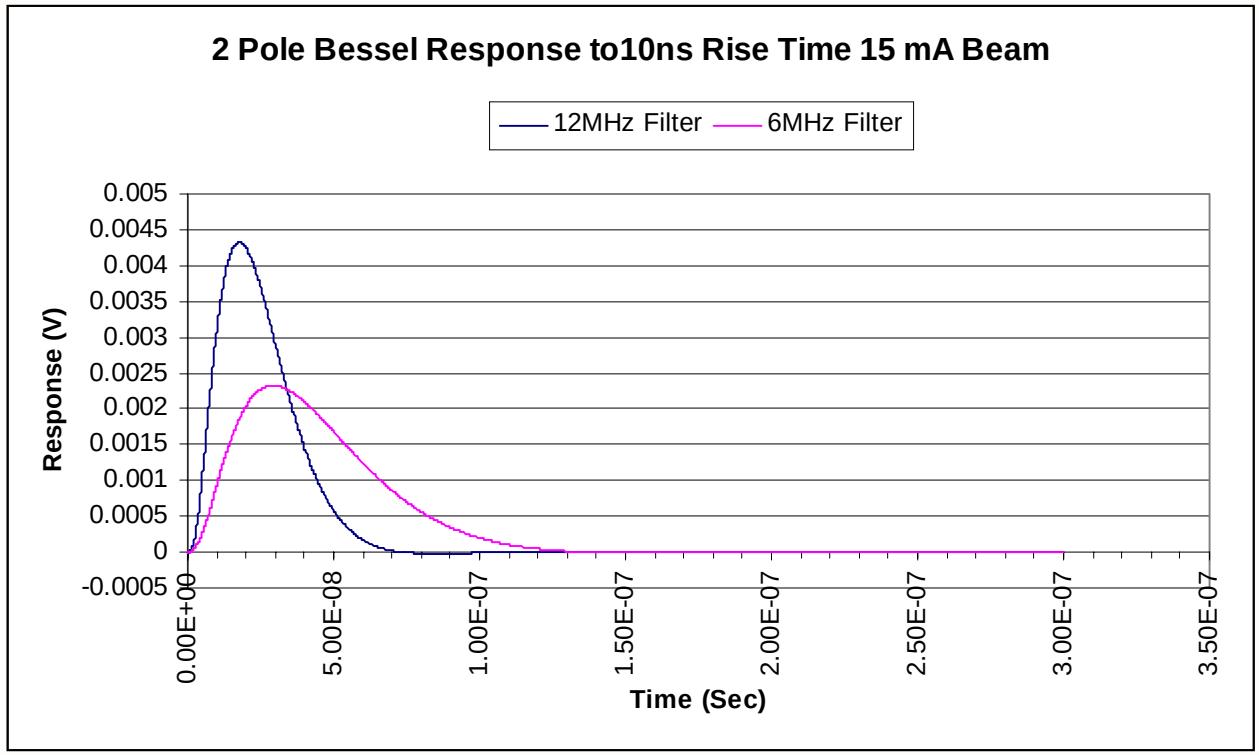
# *Protected Amplifier Front-End*



# *Peak BPM Signal Out of 2 Pole Bessel Filter for 15mA Beam vs. Beam Rise Time*



# *Effect of Bandwidth on Response*



# *Resolution for AD8009*
# *In Protected Amplifier configuration*

$$\delta x/b \approx [1/(2\sqrt{2})]* \sqrt{Pn/Ps}\ ^{**}$$

- $\delta x$ = displacement from center
- b= half aperture (100mm)
- Pn= Noise Power or 7.3uVrms (12MHz)
- Ps= Signal Power (assuming 10ns edge/largest signal)
  or 4.3mVpk*0.12(or -18.5dB)=514uV
- Resolution=0.35 $\sqrt{53.3/263794}$=0.005

**15mA yields 0.0029*100mm=0.5mm**

**50mA yields 0.15mm**

**-8dB loss yields for 15ma → 0.15mm**

**50mA yields 0.044mm**

** Schafer, "Beam Positioning Monitoring", AIP212, Accelerator Instrumentation 1989

# *Calibration*

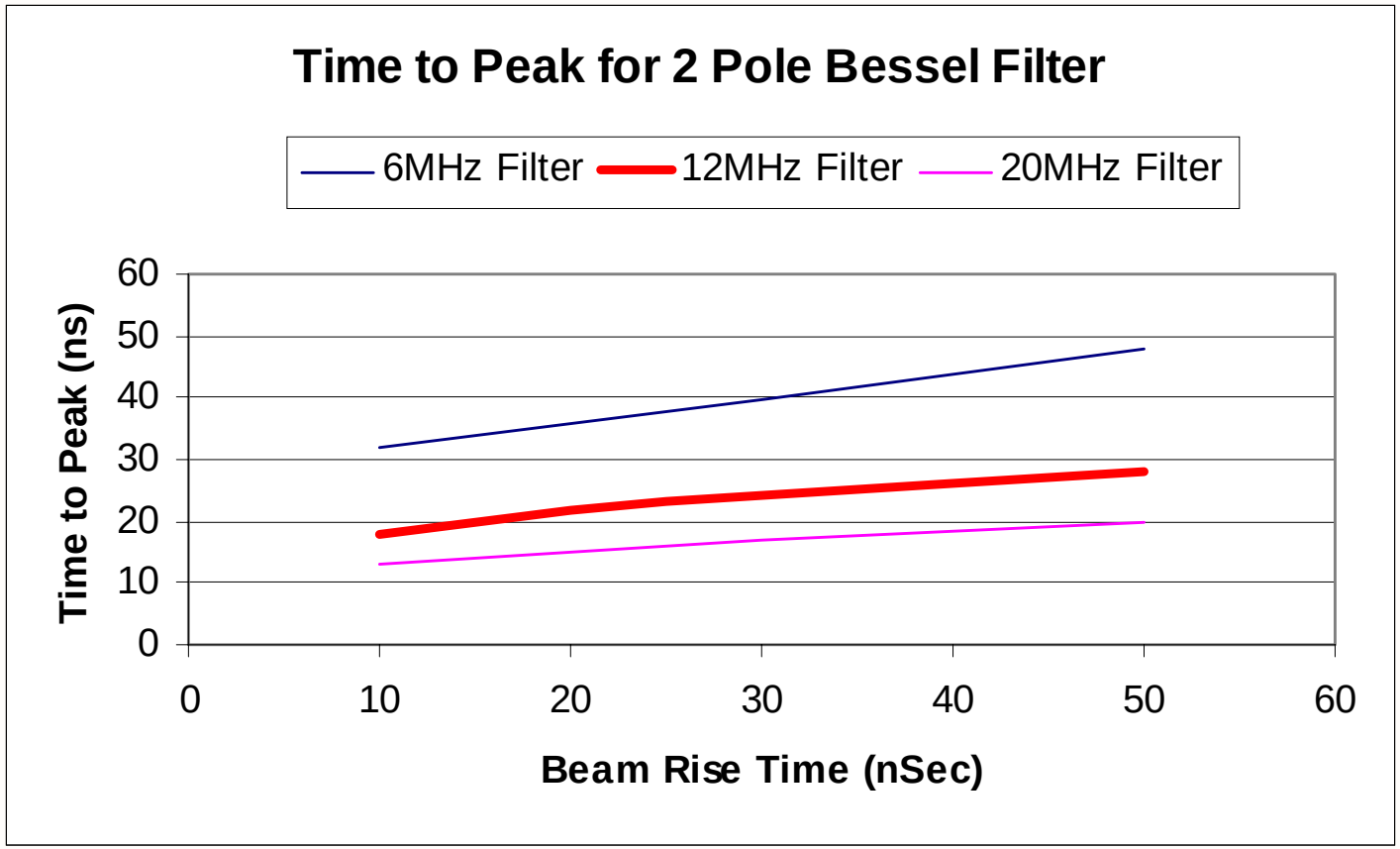
- **Verification using wire scanner**
- **In-situ on-board signal injection into differential channels**
- **In-situ signal injection into PUE orthogonal plane**
- **Beam based alignment is planned**

# *Base-band BPM Electronics Summary*

- Philosophy is to maintain linearity, digitize as soon as practical, use digital signal processing for calibration, channel matching,  and calculations.
- Provide protected amplifiers with two state capability for gain switching.
- More work required to select bandwidth, gain selection and calibration system.

# *BACK-UP SLIDES*

# *Time to Peak*


Time to Peak for 2 Pole Bessel Filter
6MHz Filter
12MHz Filter
20MHz Filter
Time to Peak (ns)
60
50
40
30
20
10
0
0
10
20
30
40
50
60
Beam Rise Time (nSec)

# *Signal Loss that still yields 0.15mm Resolution for 15ma Beam Current*

| | 6MHz | 12MHz |
|---|---|---|
| Vn | 4.7uV | 7.3uV |
| Vs | 1.1mV | 1.7mV |
| Pk Vin(10ns) | 2.2mV | 4.3mV |
| Allowable Loss for 0.15mm resolution | 6dB | 8dB |
| FWHM | 51ns | 27ns |