

# ESPEC BPM Energy spectrometer

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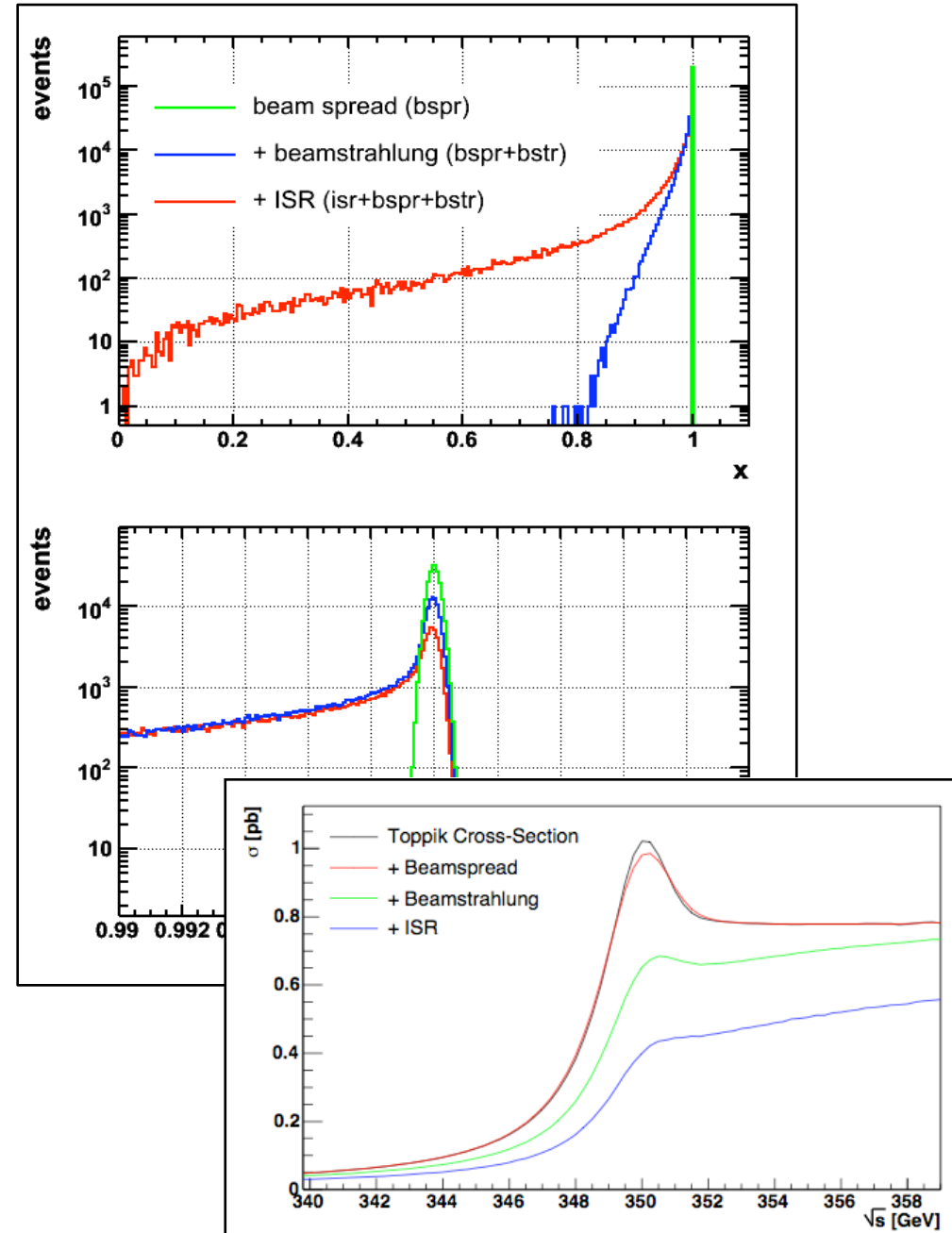
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University of Cambridge

# Motivation

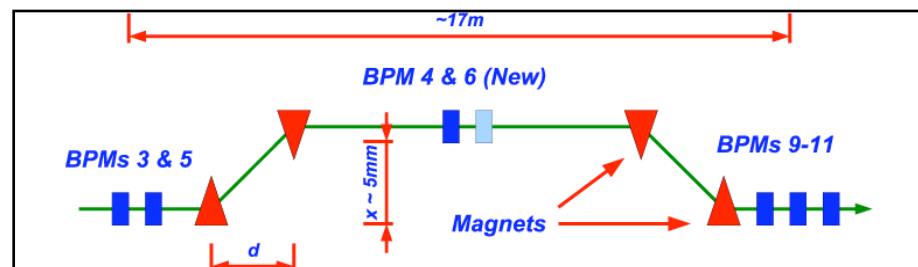
- Beam energy measurement 1 part in  $10^4$
- Top mass error  $\sim 10$ s MeV
- Average beam energy (mean for bunch)
- Spectrum complicated (post-IP diagnostics)
- Minimal impact on luminosity production
- Low systematics



# EUROTeV Deliverables

- Deliverables

- Energy spectrometer design



- 4 magnet chicane system and cavity BPMs (5mm deflection, need less than 500nm)

- High resolution BPM cavities (ESA/ATF1&2)

- Resolution achievable (20 nm)

- Stability key requirement (over order 1 day)

- Energy spectrum diagnostics

- Work completed on Bhabha scattering

- Possible to extract energy spectrum

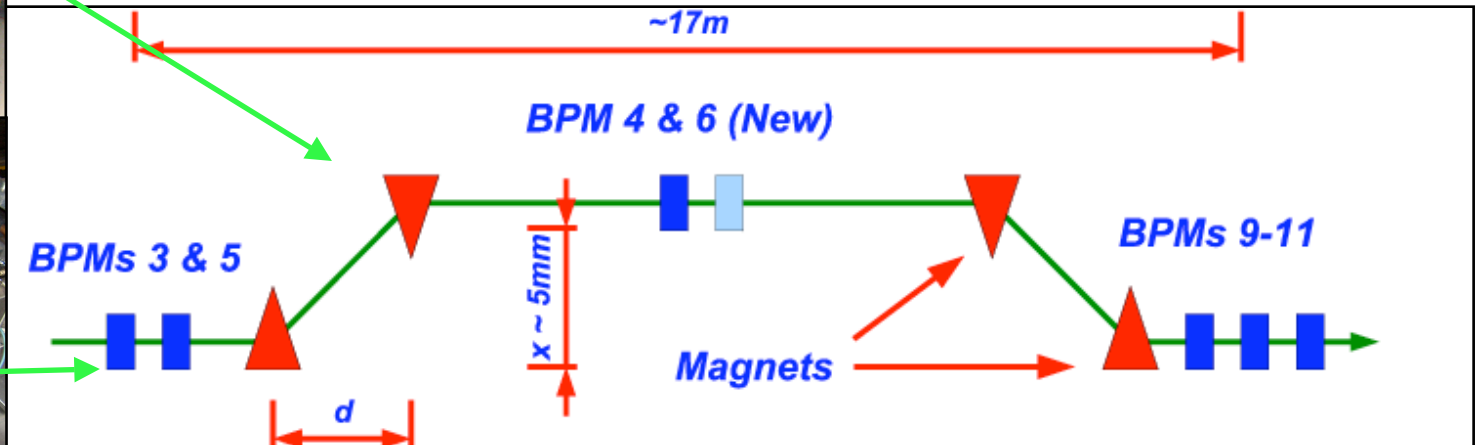
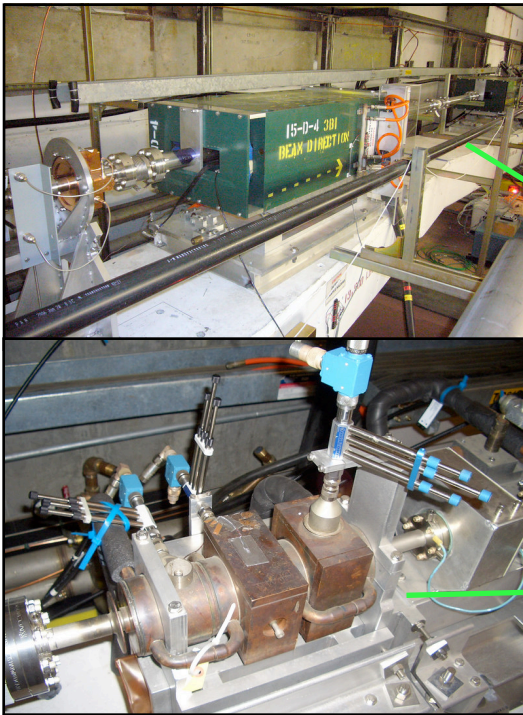
- Post-IP diagnostics disfavoured (cost drivers)

# Introduction

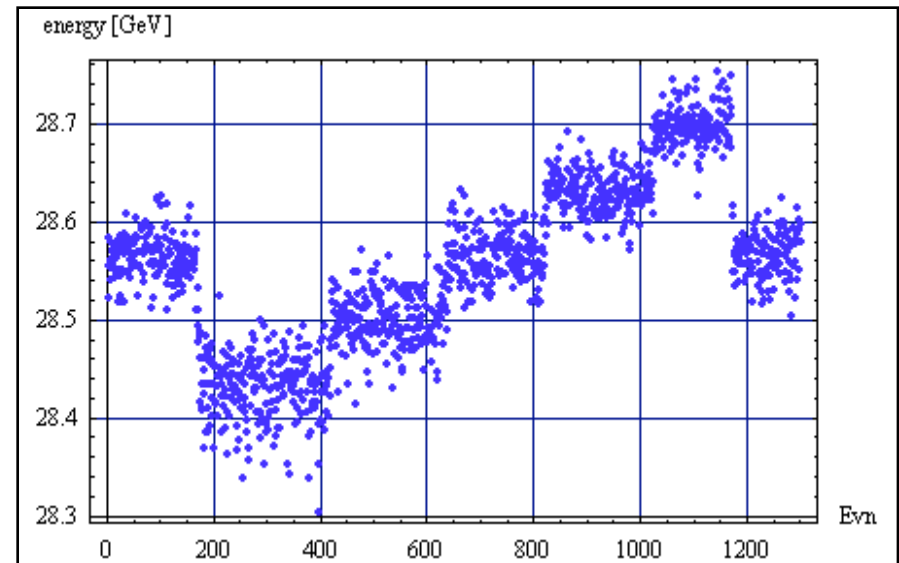
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- Tool development for BPM and spectrometer design
  - Geant4 simulation toolkit of spectrometer
  - BDSIM simulation of transport from spectrometer to IP
  - RF simulation of BPM system
  - Cavity BPM processing algorithm library
- Two main R&D threads
  - ATF1&2
    - Stability essential for goals of ATF2
  - ESA (T474 collaboration)
    - Full spectrometer prototype system

# End station A (ESA) T474



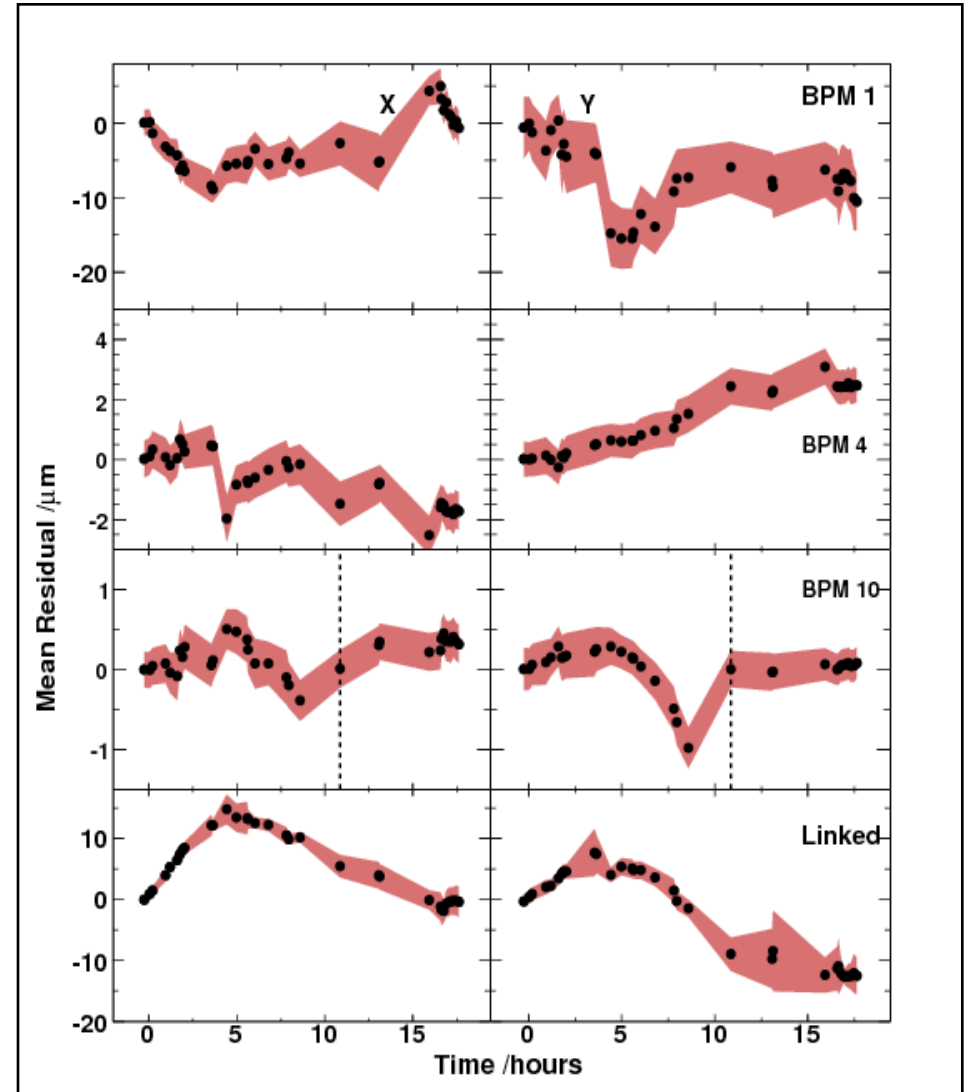
- Complete spectrometer test-beam
- 4 chicane magnets
- >2 BPMs at each location



Complete spectrometer run analysis for publication  
EUROTeV/NIM-A paper or PRSTAB

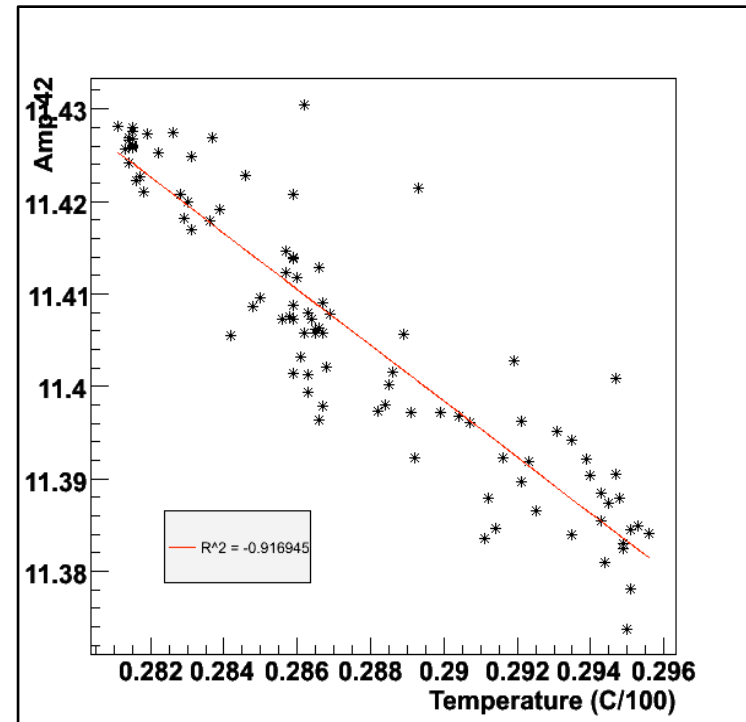
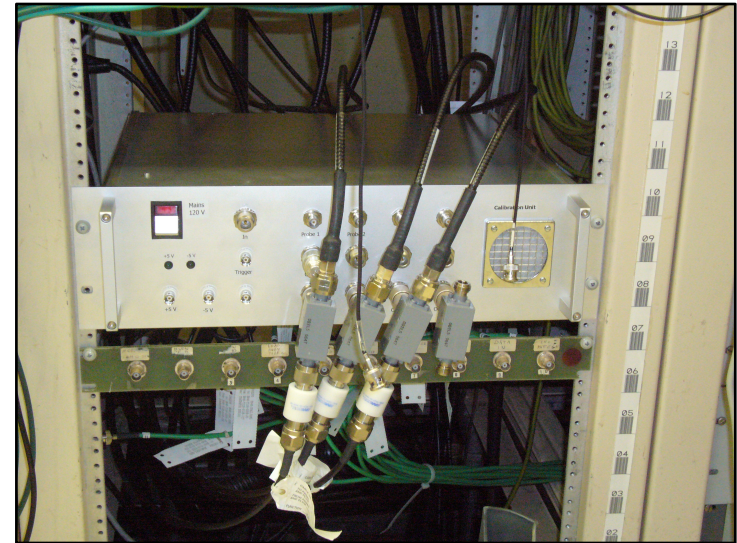
# ESA-T474

- Basic cavity operation/  
performance complete
- EUROTev-  
Report-2007-059  
(published in NIM-A)
- Resolution targets met  
few 100nm
- Drifts over time scales  
of 1 day
- Effect attributed to  
electronics gain variation  
with temperature
- Implications for ESPEC  
and ATF2



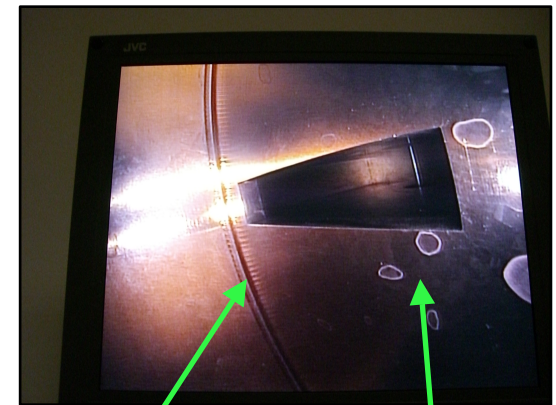
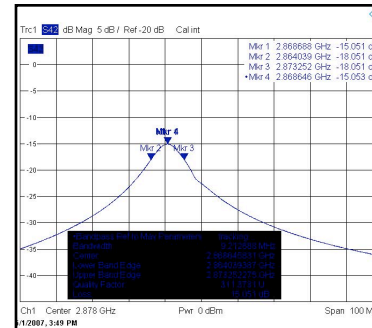
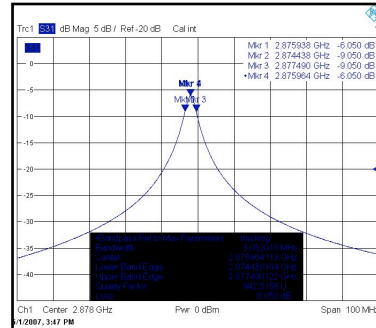
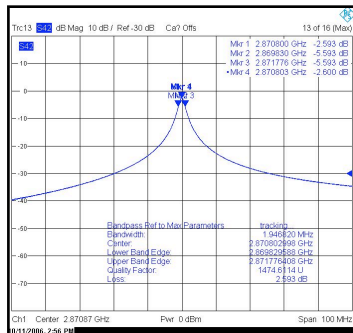
# Electronics monitoring

- CW tone injection system
  - Essential for subtraction of drifts
  - Split CW-RF into reference and dipole processing electronics
  - Ratio dependent on temperature
  - Subtract gain variations online



# Spectrometer BPM results

- S-Band cavity
- Aperture for spectrometer and FF
- Fabricated within LCABD and EUROTeV



■ Al prototype transmission:  
 $Q_L = 1470$

■ Cu prototype, "good" channel transmission:  
 $Q_L = 950$

■ Cu prototype, "bad" channel transmission:  
 $Q_L = 300$

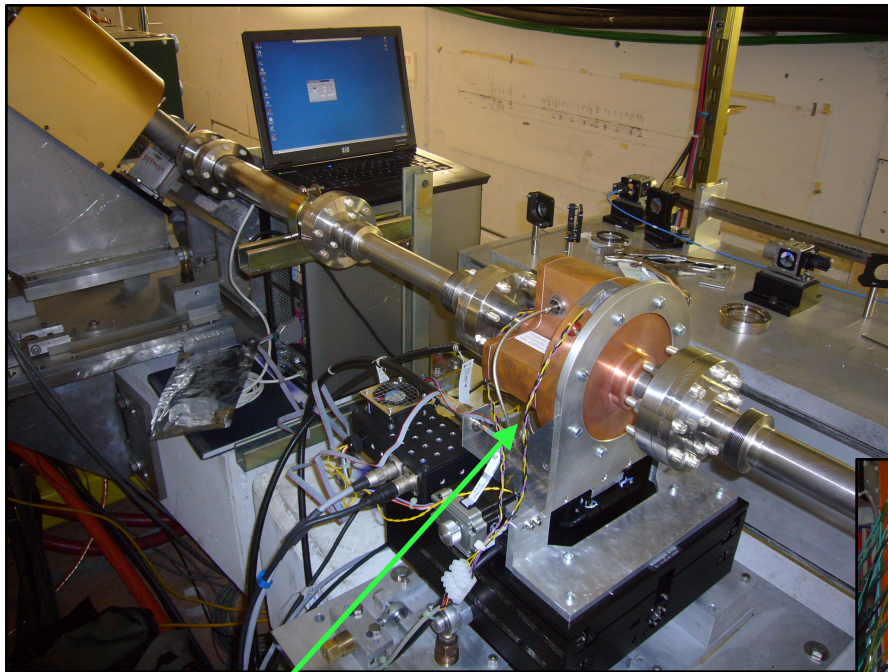
Gaps between brazed parts

stains



# Spectrometer/Final focus BPM

S-band Position cavity



2D robust mover system

S-band Reference cavity



Electronics racks

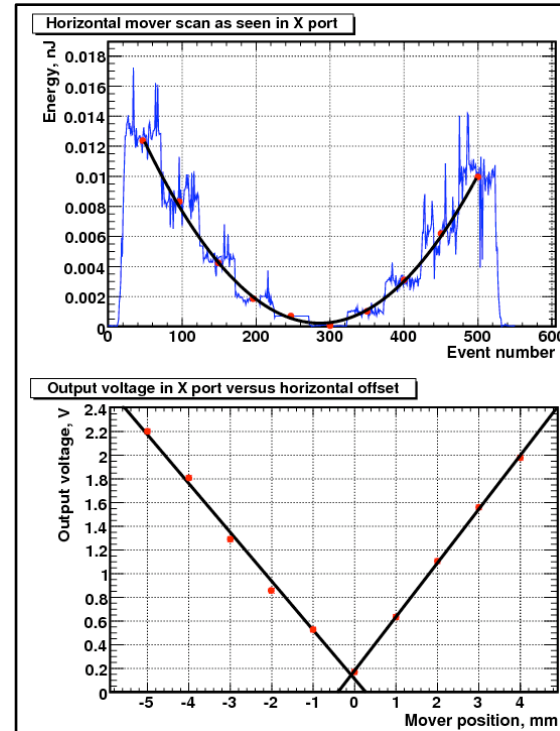


Movers controller

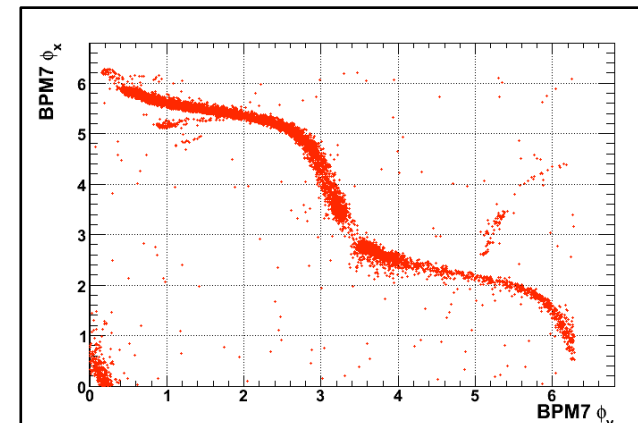
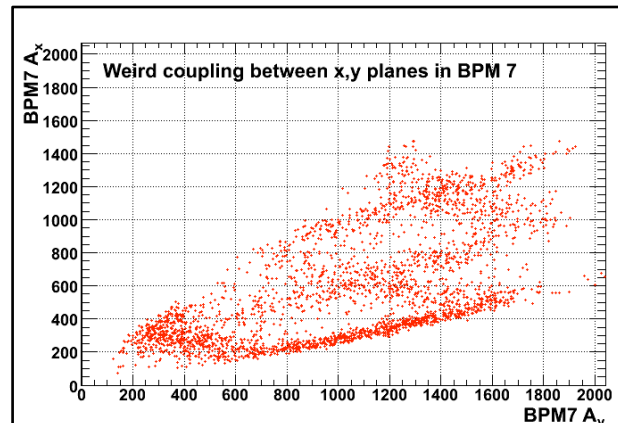
PC for remote control

# ESPEC-BPM test beam results

- Coupling as expected
  - $M : \sim 0.45 \text{ V/mm/nC}$
  - $S : \sim 0.70 \text{ V/mm/nC}$
- Strange x-y cross coupling
  - Modes not orthogonal



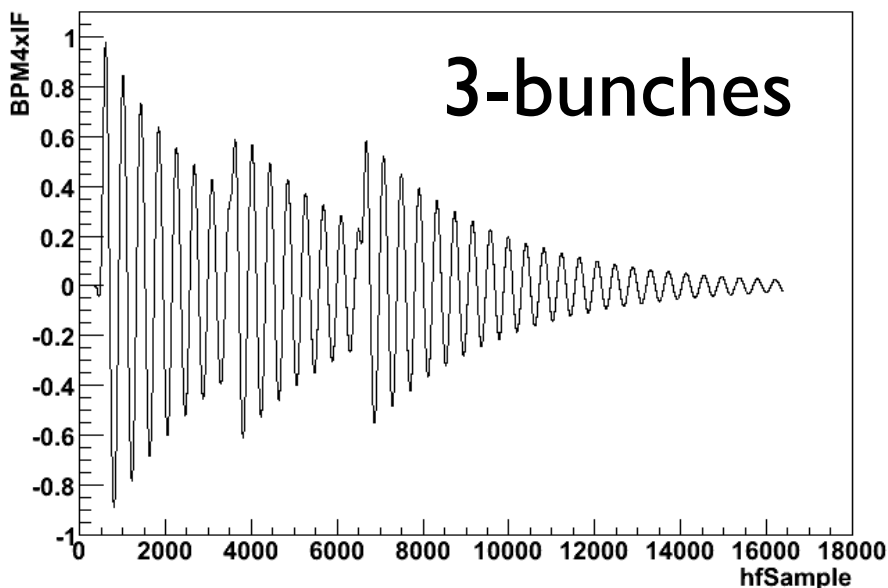
Will complete fabrication write up as EUROTeV note



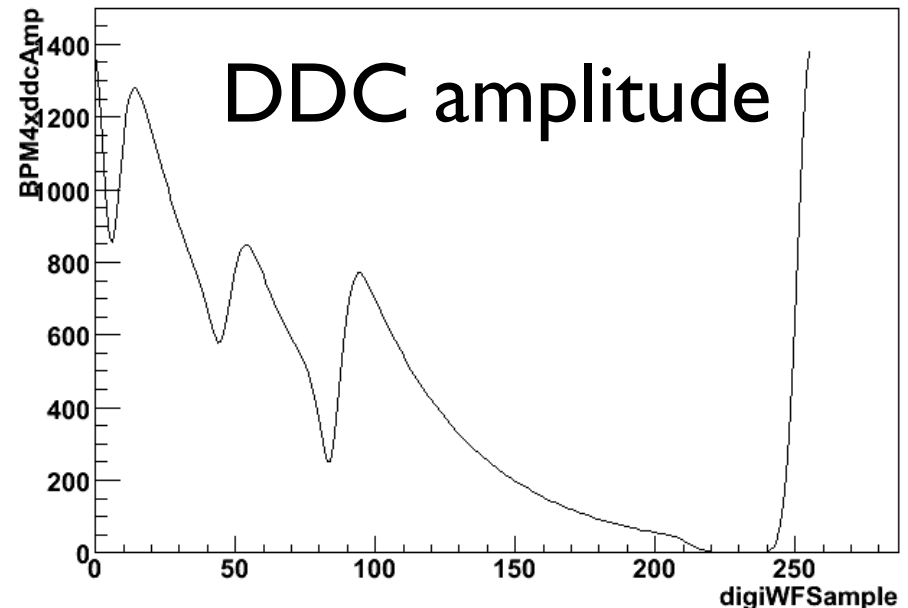
# BPM simulation

- Full set of RF components, manipulations
  - Mixing, time domain filters, digitisation, amplifiers, noise sources
  - Cavity is simulated as delta function and then filtered with cavity filter (Q, frequency etc)
  - Prototype electronics before fabrication

BPM4xIF:hfSample {evtnum==1}



BPM4xddcAmp:digiWFSample {evtnum==1}



# BPM signal processing

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- Library of BPM processing algorithms
  - Complete set of algorithms used at NanoBPM and ESA-T474
    - Digital down conversion
    - Signal fitting, exponential decays
    - Calibration and correction
    - SVD of orbit measured from BPMs
- Use at ATF2...

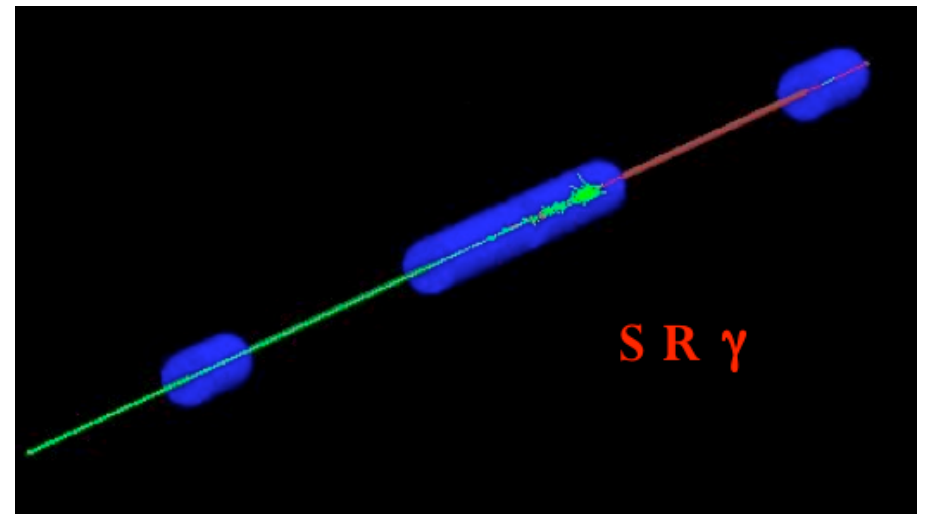
# Spectrometer simulation

- Geant4 simulation complete
- XML geometry description
- Sensitive layers as BPMs
- Use to reconstruct beam energy
- Study
  - Charge centroid
  - Halo/ISR
  - Magnet specs
  - BDS, collimation

## XML description

```
<!-- The 3B1 magnet -->  
<dipole name="3B1" zpos="32.912" fieldtype="map">  
  <map file="../fieldmaps/15-D-4.RUN5.HALL.MAP"  
    scale="-1." />  
</dipole>
```

```
<!-- the central BPM -->  
<bpm name="BPM4" zpos="38.189" xres="0.00053"  
  yres="0.00046" />
```



# ATF BPM systems

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- NanoBPM collaboration
  - Verified  $\sim 15\text{nm}$  operation for short time periods
- C-band systems (EUROTeV-Report-2007-037, NIM-A)
  - Proof of principle for ATF2 cavity system
  - ATF2 C-band system is derivative of NanoBPM system
    - Electronics, processing, calibration
    - Temperature and gain monitoring system as with ESA systems

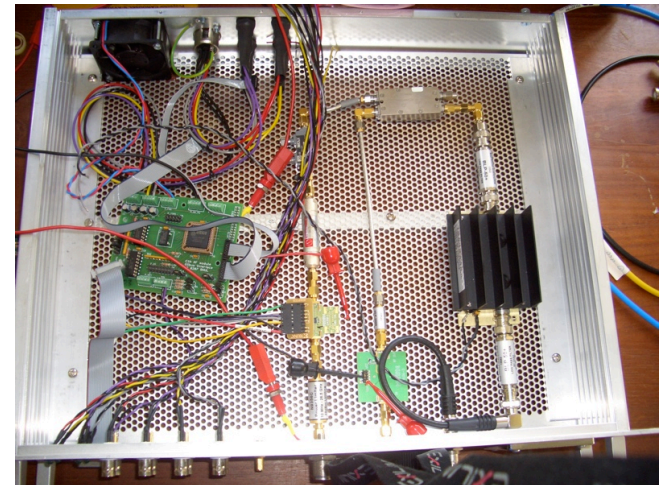
# ATF2 C and S-band BPM systems

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- EUROTeV has enabled involvement in ATF2 C and S-band BPM systems
  - Electromagnetic design
  - S-band mix down electronics
  - S and C band processing algorithms and control systems
  - ATF2 beam line commissioning
    - Starts in the next few months (Supported by EU)



S-band  
mixer  
system



# Summary

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- Upstream spectrometer deliverables near complete
  - Work needed for the simulation
  - Tools in place, need to complete study and write up
- Downstream diagnostics part of EUROTeV deliverables
  - Some work exists but disfavoured as solution
- EUROTeV very successful for cavity BPM work
  - High degree of involvement in ATF1 & 2
  - Stable operation of high resolution dipole cavities for whole LC