VPTs for the CMS experiment

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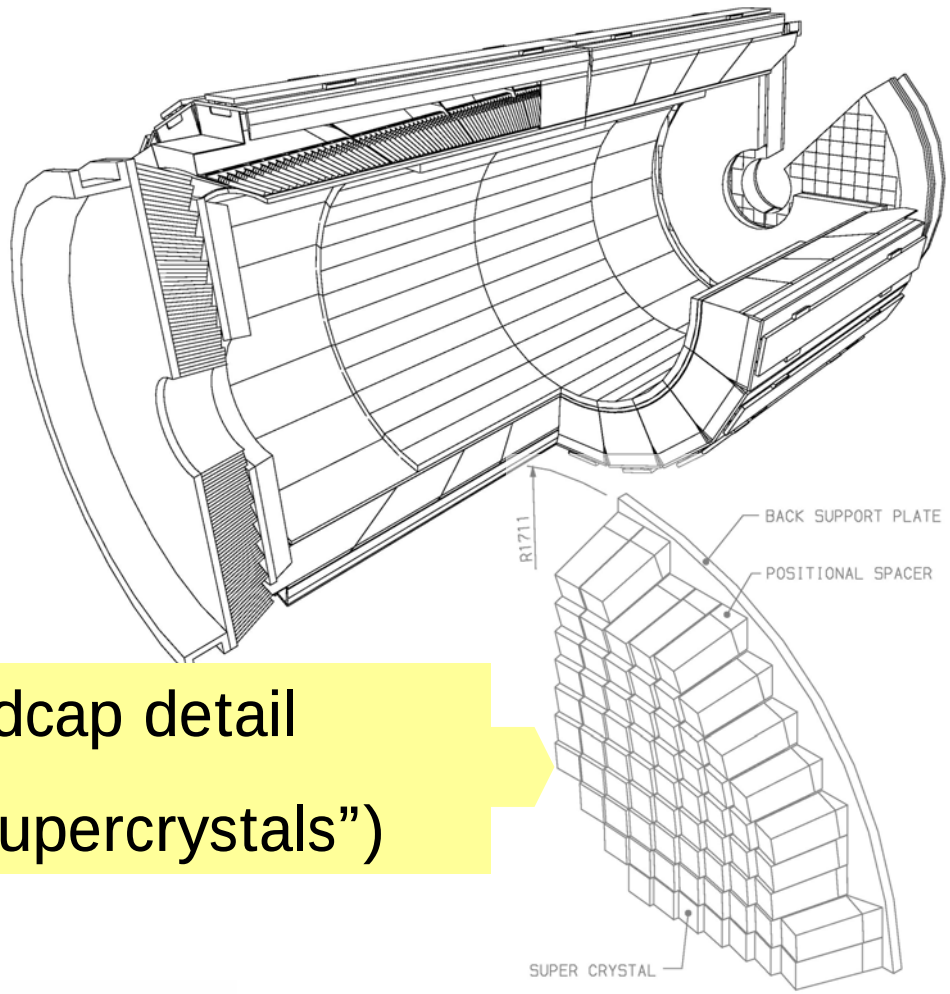
Outline of talk

1. Description of CMS Electromagnetic Calorimeter
2. Experimental conditions and challenges
3. Selection of Vacuum PhotoTriodes (VPTs)
4. Experience with VPTs from RIE
5. Conclusion

The CMS Electromagnetic calorimeter



Endcap detail

("supercrystals")

$PbWO_4$ crystals

~61000 in barrel
~15000 in endcaps

Pointing geometry

Length: 6m

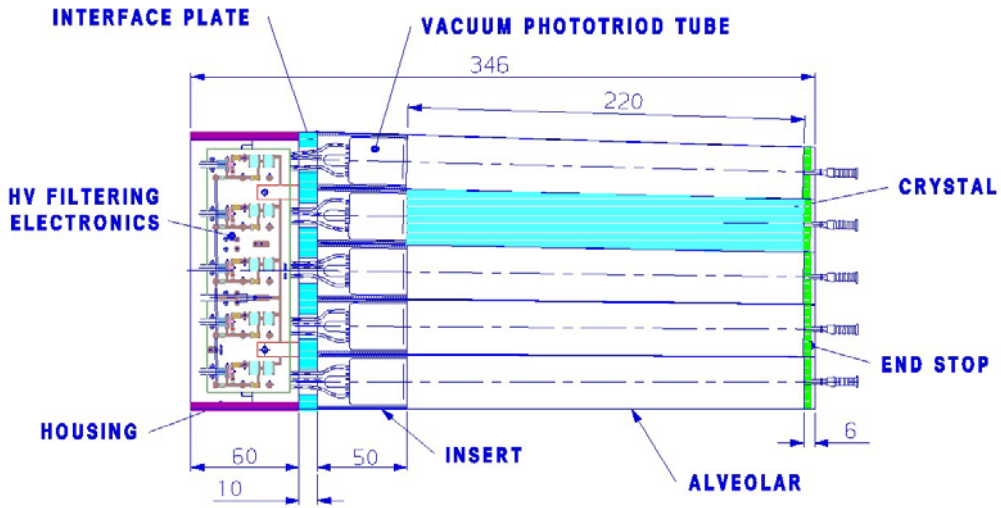
Radius: 1.75m

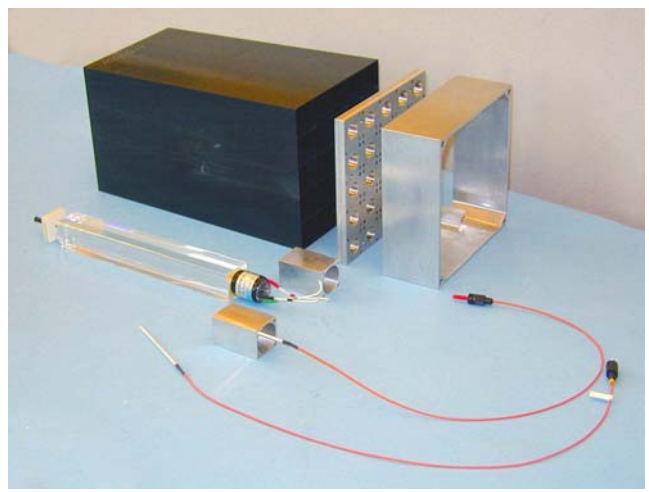
Depth: 24-25 X_0

Target energy resolution:
<1% at E = 100 GeV

Details of the SuperCrystal

- Basic unit –Supercrystal
  - 5×5 array of crystals
  - Carbon-fibre alveolar
- $PbWO_4$ crystals
  - Radiation hard
  - X_0 = 8.9 mm
  - Fast scintillation
    - 90% light in 100ns
  - Mechanically fragile
  - Low light yield
    - ~50 γ/MeV





Challenges for ECAL photodetector

High radiation environment

- Dose is strong function of angle to proton beams
- Barrel: Up to 4 kGy in 10 years of LHC running
- Endcap: 4-200 kGy in 10 years

Fast response required

- Interval between LHC beam crossings is only 25ns

Low light yield from $PbWO_4$

- Approximately 50 photons/MeV $\Rightarrow$ need device with gain

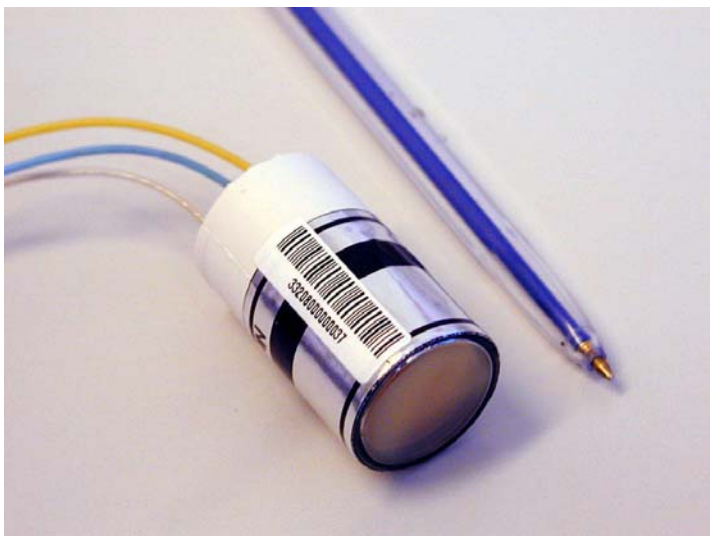
CMS choices

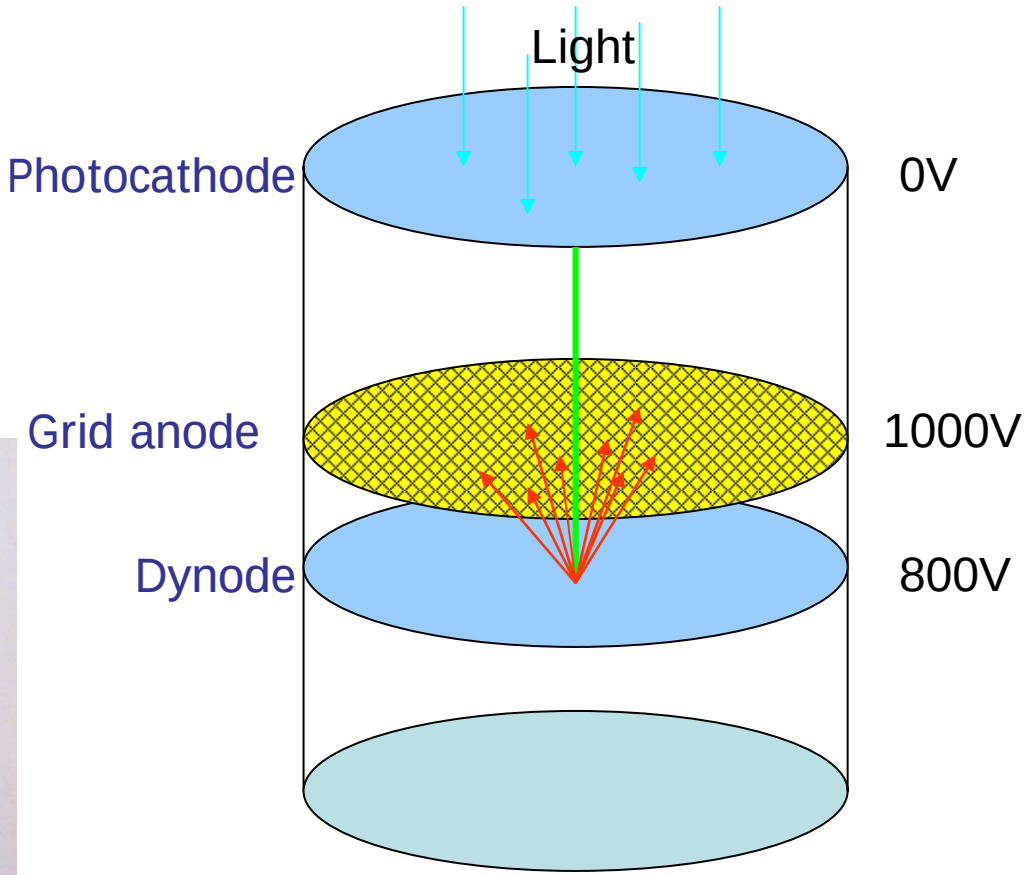
- Barrel – Avalanche PhotoDiodes
- Endcap – Vacuum PhotoTriodes (VPTs)

Structure of Vacuum PhotoTriode

Single-stage photomultiplier

Gain ~ 10





Specification for CMS VPTs

Radiation tolerance

Less than 10% loss in output after 20 kGy

Quantum efficiency p

$p \geq 15\%$ for light of wavelength 420nm

Gain g at zero magnetic field

$g \geq 7$

Magnetic field response

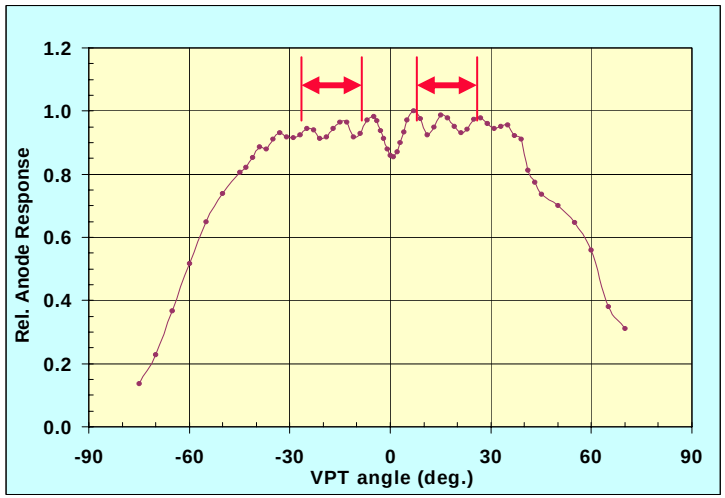
Loss in yield at 4T < 15% with respect to 0T

Stable ($\pm 10\%$) at angles up to 26° to magnetic field

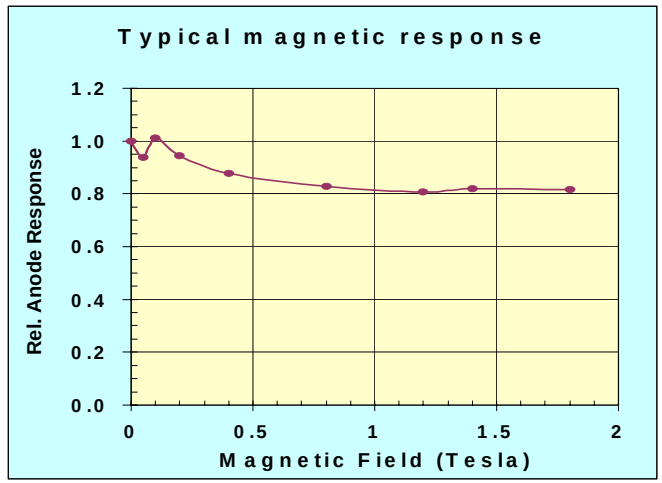
Selection of VPTs

- Prototypes supplied by several manufacturers
  - Electron Tubes
  - Hamamatsu
  - Meltz
  - Photonis
  - Research Institute Electron
- Testing and evaluation up to 1999
  - Most manufacturers were able to meet specifications
- Tendering for contract in 1999
  - Successful tender from RIE to supply 15500 VPTs

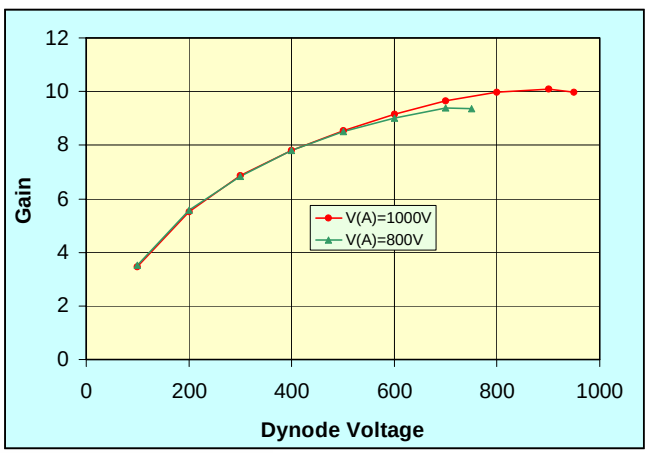
Typical response of prototype VPTs



VPT response vs angle in 1.8T magnetic field



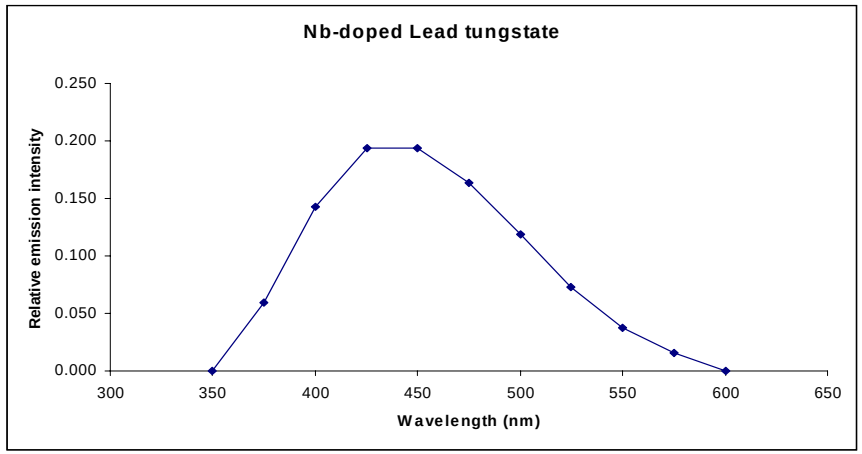
VPT response vs field at 15°

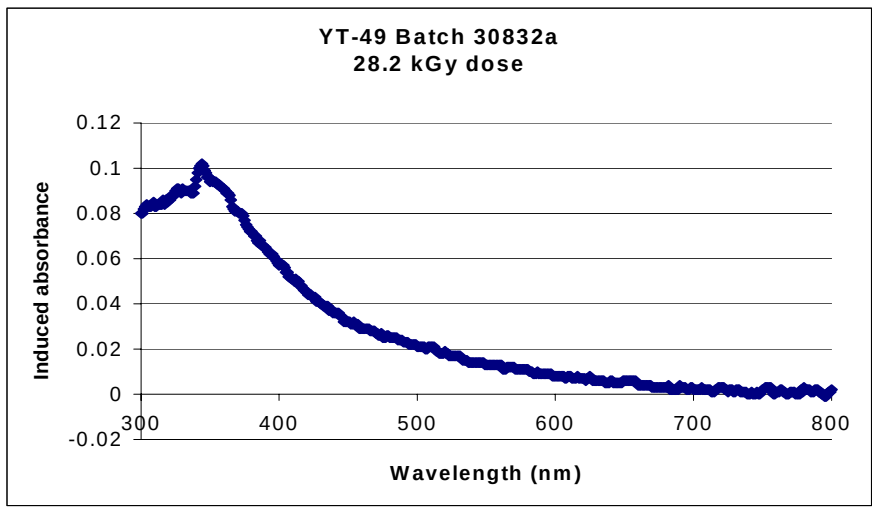


Variation of gain
with applied voltage

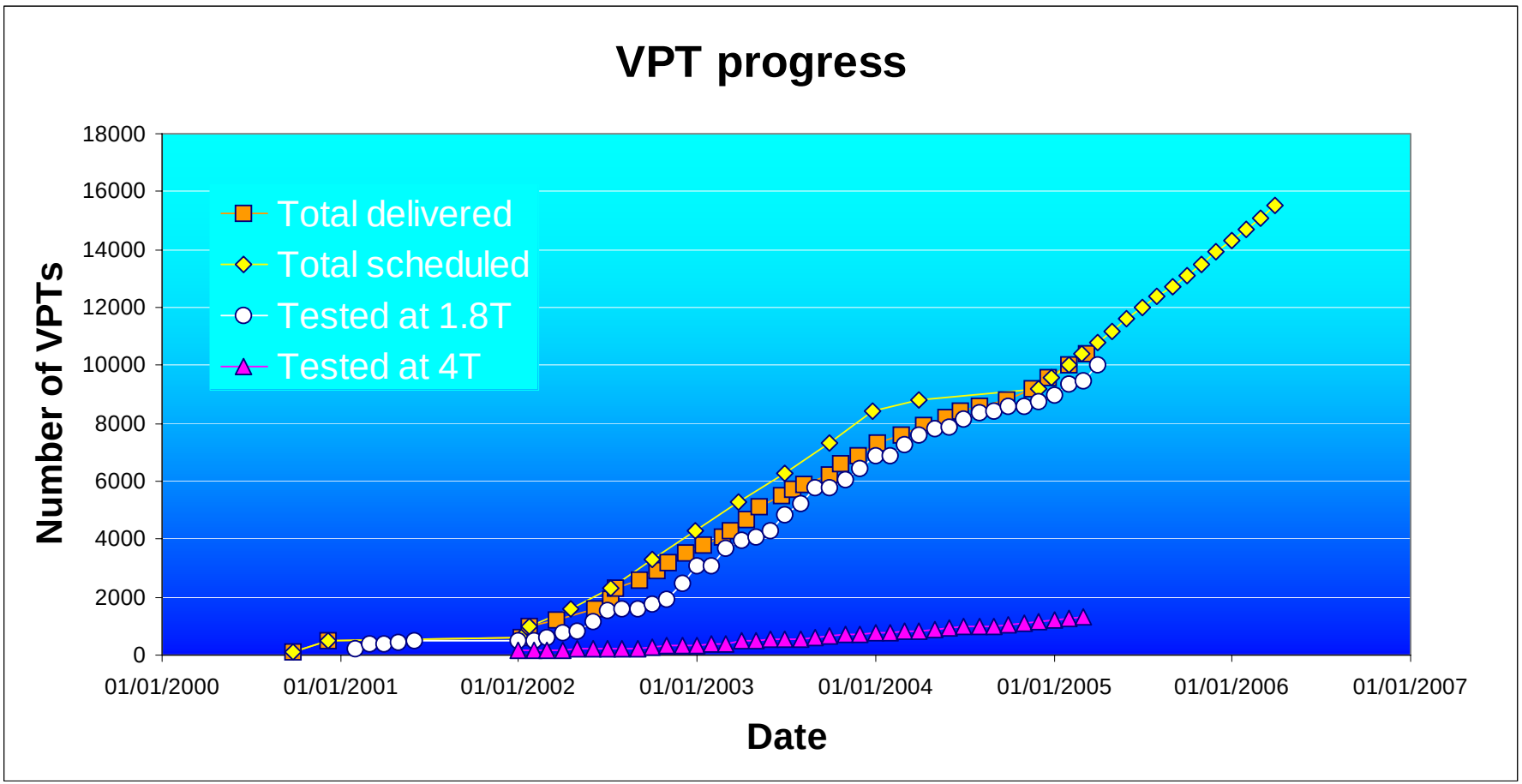
Radiation tolerance of faceplate glass

- γ dose varies strongly with angle.
- All VPT faceplate glass tested to 20 kGy at Brunel University.
- Glass batch accepted if <10% transmission loss (convoluted over $PbWO_4$ spectrum) after 20kGy.





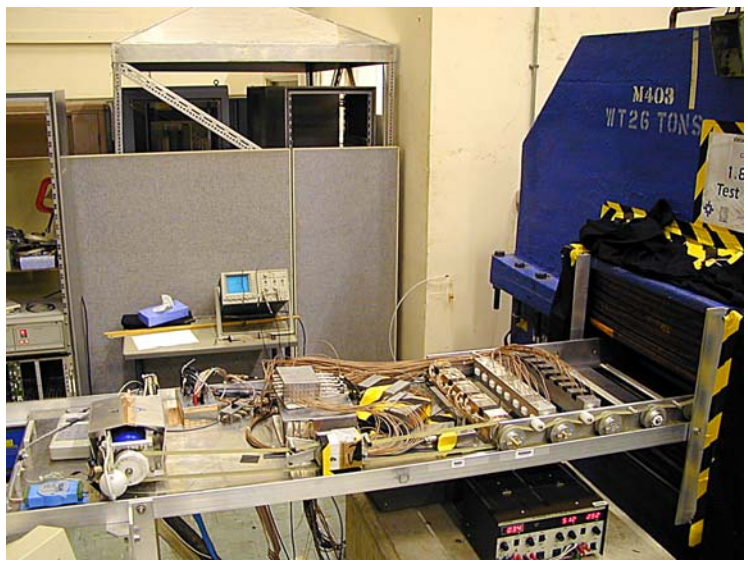
Delivery of VPTs



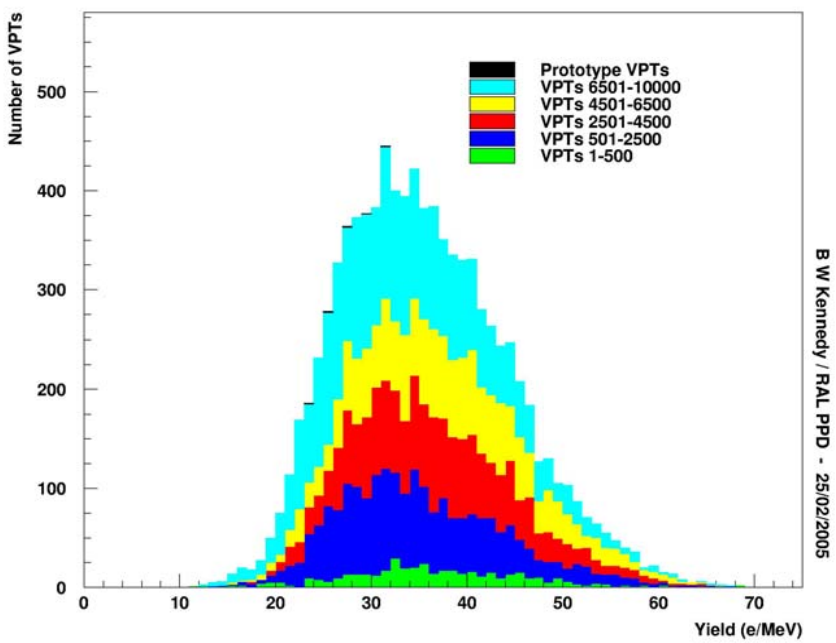
VPT testing procedure

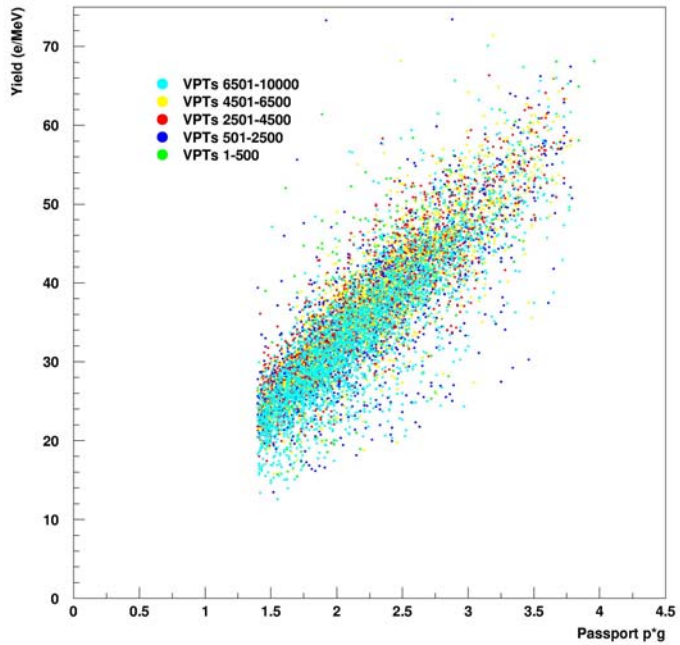
Two UK testing facilities

- Up to 1.8T at RAL
  - All VPTs, variable angle
- 4T system at Brunel University
  - Sample testing (10%), fixed angle



Measurements on 10000 VPTs





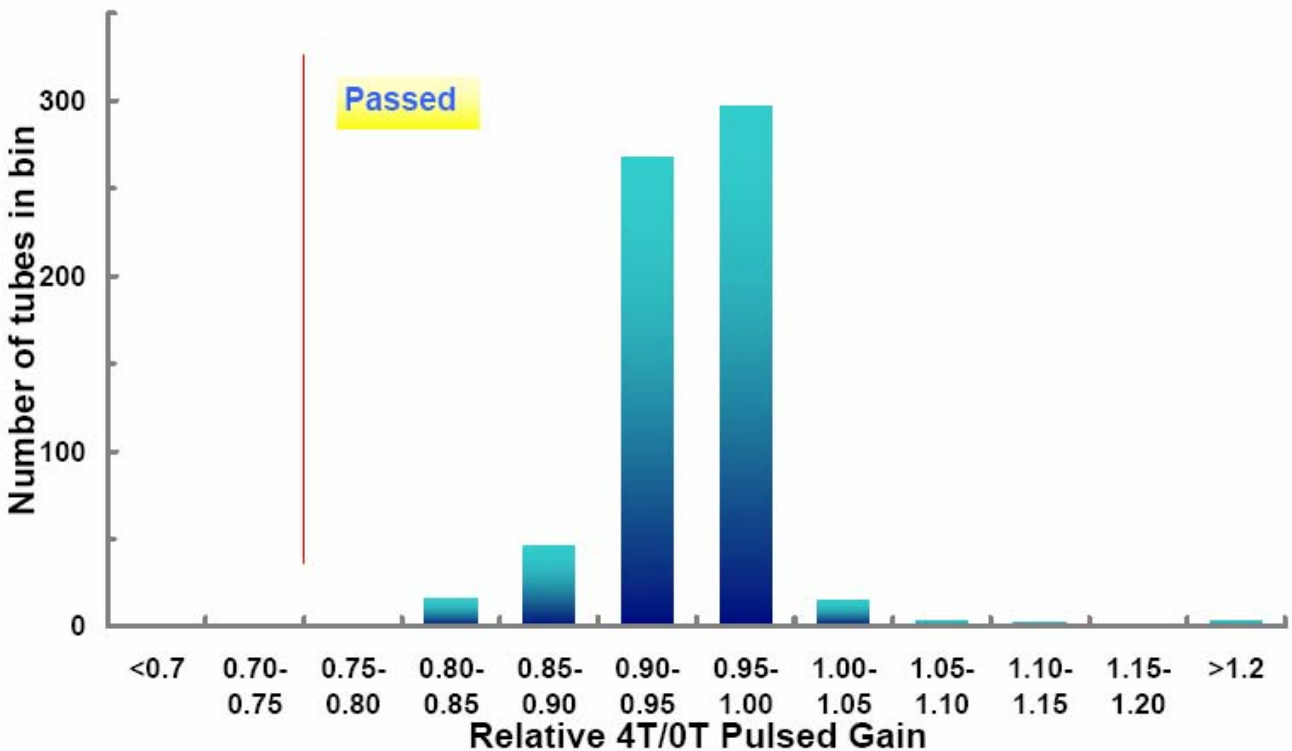
Response measured at RAL in 1.8T magnetic field.

Consistent VPT response from batch to batch.

Correlation between 0T measurements at RIE and 1.8T measurements at RAL

4T to 0T relative response

Measured at Brunel University.
VPT at 15° to magnetic field.

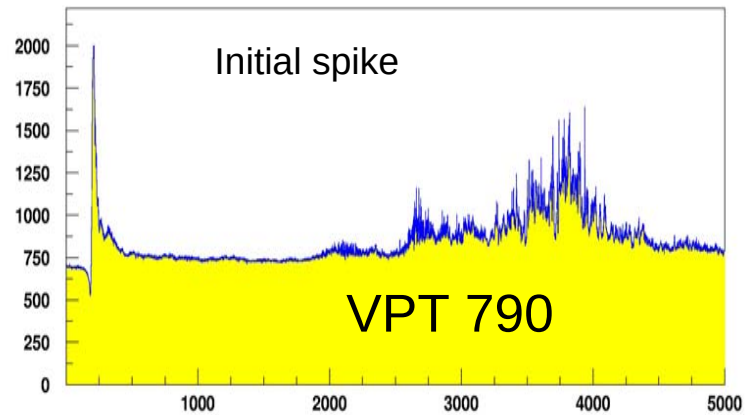


Resolution of problems

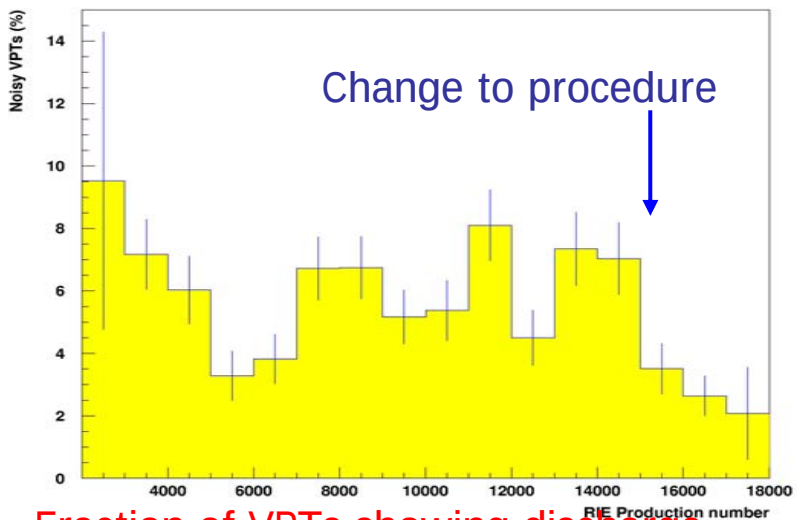
Regular meetings between RIE and CMS groups at CERN, RAL, RIE.

Some problems inevitable in long production run.

- Most significant – discharges seen in small fraction VPTs.
- Exchange of information between CMS groups and RIE, and careful investigation by RIE experts
- ⇒ improvement in manufacturing procedure to reduce number of VPTs with discharges.



Example of discharge in VPT response



Fraction of VPTs showing discharge

Conclusions

- VPTs supplied by RIE meet needs of the CMS experiment.
- Delivery of VPTs is on schedule.
- Regular and open meetings between CMS and RIE enable problems to be solved.
- We look forward to the successful conclusion of the contract in February 2006.