# Radiation Hard Photodetectors

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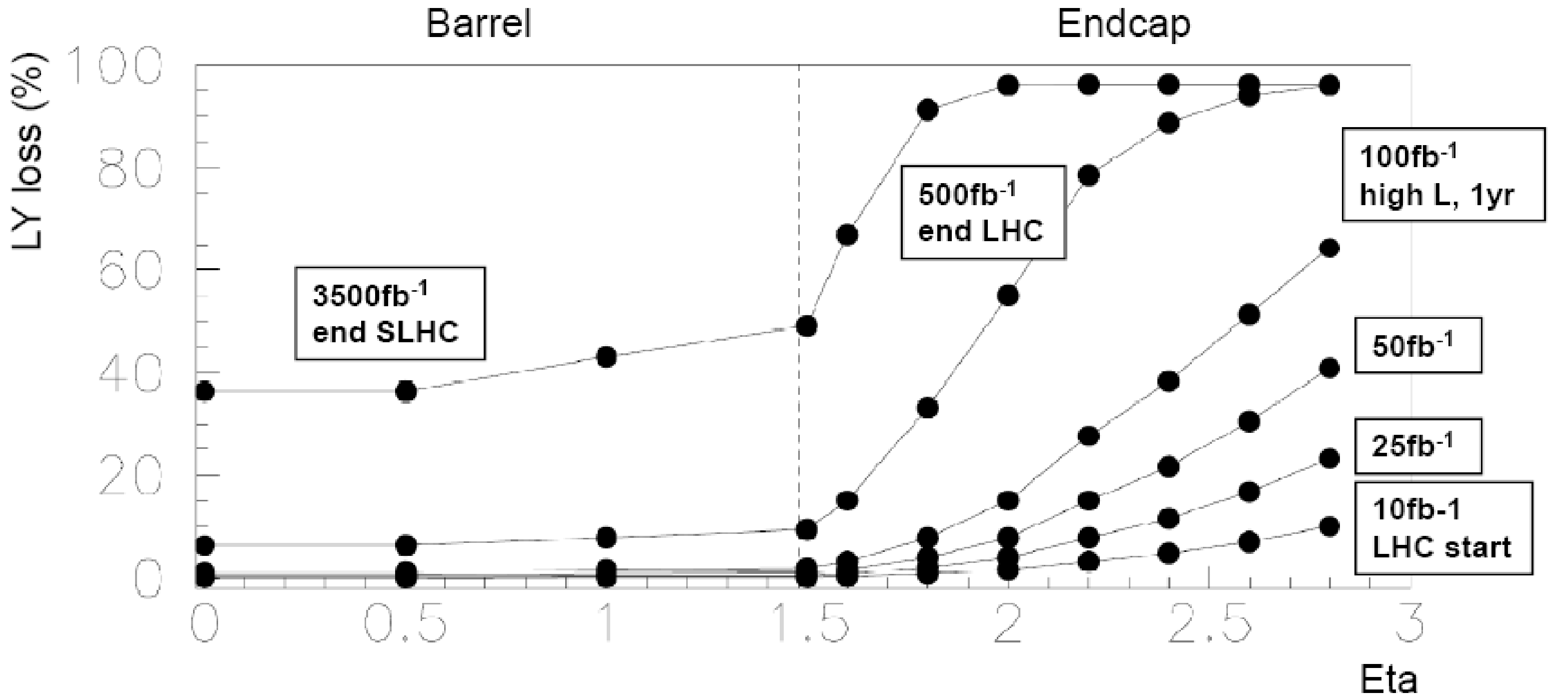
CMS SLHC Upgrade Workshop
29 October 2009

# Motivation

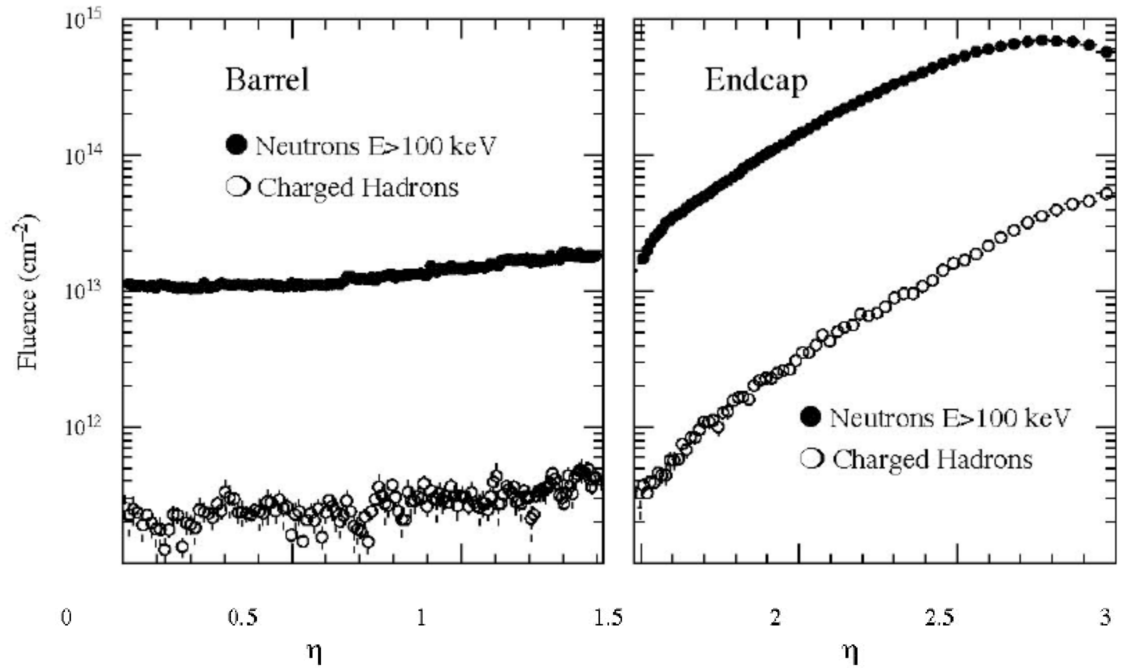
- **LHC era:**
  - $L_{inst}$ up to $10^{34}$ /cm²s, $L_{int}$ up to 500/fb
- **SLHC era:**
  - $L_{inst}$ up to $10^{35}$/cm²s, $L_{int}$ up to 3-6k/fb
  - Very challenging particle detection, acquisition and reconstruction environment
- **ECAL endcaps will need replacement for SLHC era:**
  - **At end of LHC era** >50% dark beyond |η|=2.0
  - New detection medium, new photodetectors, new front end, new geometry possibly

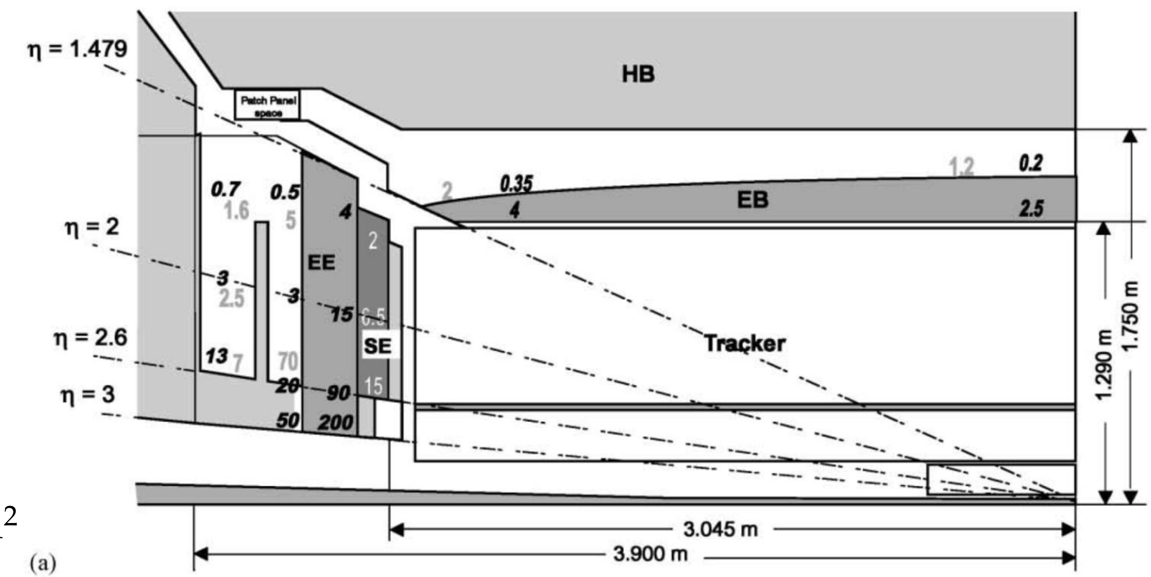


# Motivation

- The specifics of the new endcap not yet defined
- For nearly all options (new crystals, longitudinally segmented scintillator, hybrid, etc.) **a photodetection scheme will be needed**

- **Complicating things -** SLHC's high radiation environment:
  - Plots are for EE in LHC era:
    - 500 to 50k Grays
    - 5E13 to 7E14 100keV neutrons per $cm^2$
  - We assume that the dose and fluence values scale linearly with $L_{int}$
  - So then in the SLHC era (say SLHC is $L_{int}$=3000/fb):
    - 3k to 300k Grays
    - 3E14 to 4E15 neutrons /$cm^2$

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# Photodetector R&D Program at UVa: Goals

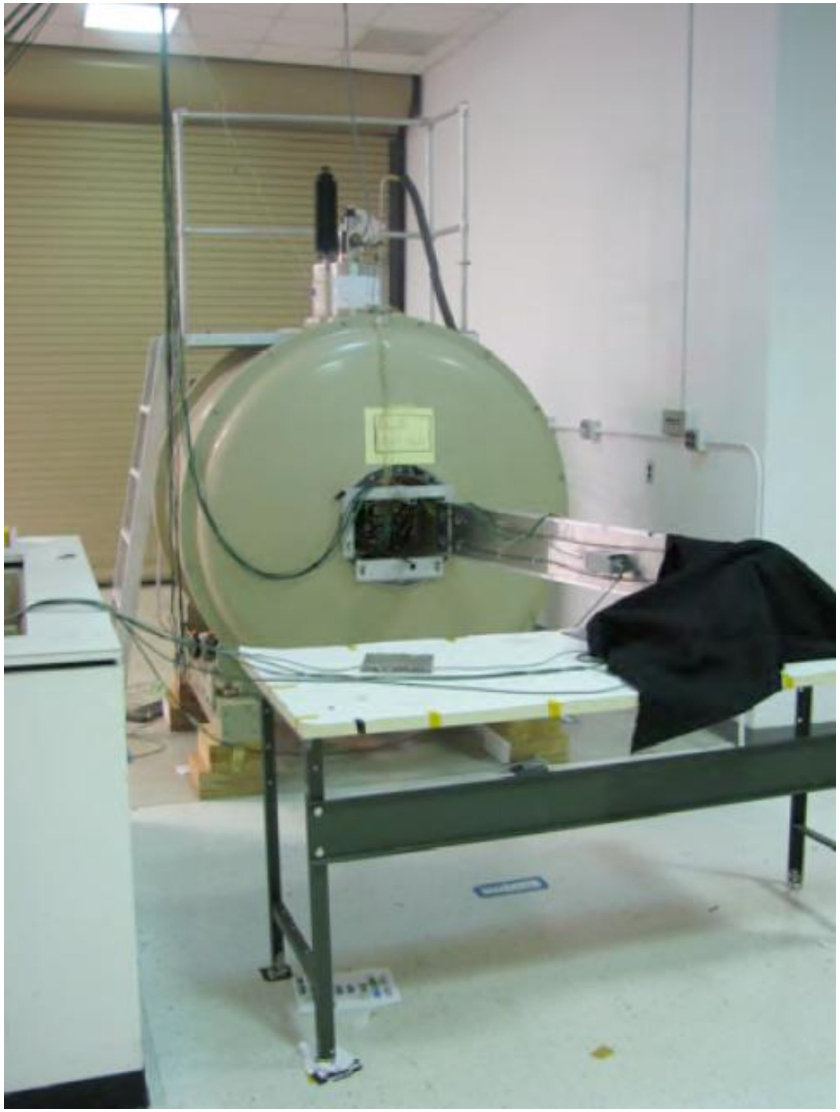
- Current photodetector options employed in ECAL (APDs, VPTs) are not candidates due to their **high susceptibility to radiation damage**
- In light of this we have undertaken a rad hard photodetector R&D program at UVa
- **Goals:**
  - **Identify** SLHC photodetector candidates
  - **Characterize** behavior of new devices under emulation of LHC and SLHC occupanices, compare nominal performance to current VPTs
  - **Irradiate the devices** using both EM and hadronic sources
  - **Evaluate** these new devices again after irradiation to gauge performance impact
- Complements current VPT characterization program ongoing at UVa
- Photodetector and crystal/scintillator choice are **completely correlated** but evaluation of all the above items are important in making decisions on both issues

# Photodetector R&D Program at UVa: Capabilities

- **UVa's magnetic field testbed**
  - Can study device behavior in magnetic field conditions up to 4.7T
  - Large bore (40 cm diameter) allows study of devices at angles up to ±27° wrt axial field
  - Lab temp stability to 0.5° C
  - Can emulate light occupancies expected in LHC, SLHC running via LEDs

- **New DAQ system** installed: National Instruments PXI platform Virtues:
  - maintainability
  - reduction in noise across components

- **Limitations** of test setup:
  - So far max frequency for load just 100 kHz (versus 40 MHz at CMS)
  - Not pursued emulation of high radiation environment – but can do this at other facilities



# Rad Hard Photodetectors: Devices

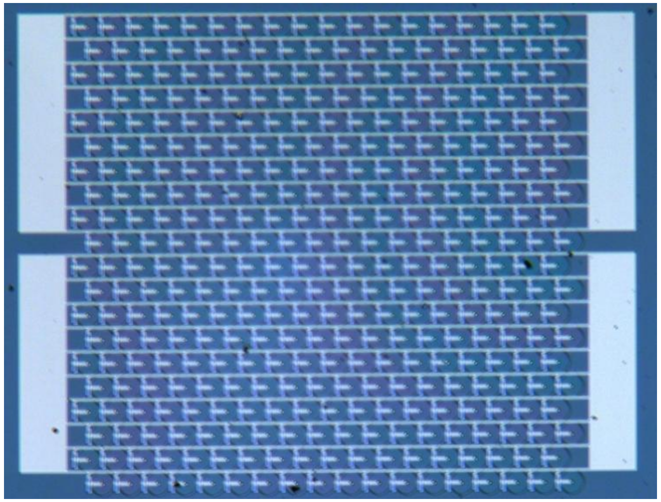
- Silicon APDs used in EB…not good for EE
  - Radiation dose introduces defects in the silicon material structure
  - This damage interferes with electron-hole pair creation
  - That spoils device operation when used to collect photons from crystals
- Coupled with dim PbWO4, use of silicon device in EE precluded

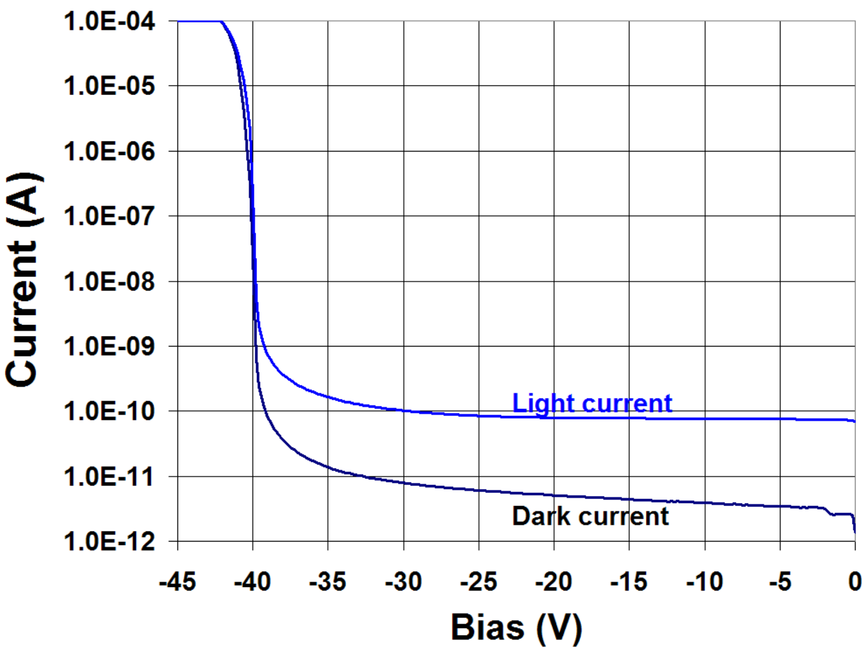
- But other solid state devices **could be possible**

- **LightSpin Technologies, Inc.**
  - US company based out of Maryland
  - Developer of "radiation hard photomultiplier chips" ™ made from GaAs, GaInP, others
  - GaInP & GaAs have proven track records of radiation-hardness.
    - Example: GaAs – not silicon – used in fabrication of microwave frequency ICs for use in satellites b/c of radiation tolerance

# Why GaX?

- GaAs, GaInP virtues:
  - Already defect rich.. so **less sensitive to radiation damage**
  - GaAs is more resistive than silicon, meaning less sensitivity to surface features, which implies **increased wafer-to-wafer consistency**
  - **Cost could be lower** than (already affordable) Si devices
- LightSpin has designed, built and tested 1 $mm^2$ devices
  - 10,000 to 400,000 channels per $cm^2$
  - Already quieter than silicon (dark current < 10 $pA/mm^2$)
  - Straightforward scaling to ~$in^2$ active areas with high yield
- Single-photon detection efficiency > 50%
- 10ps timing resolution possible





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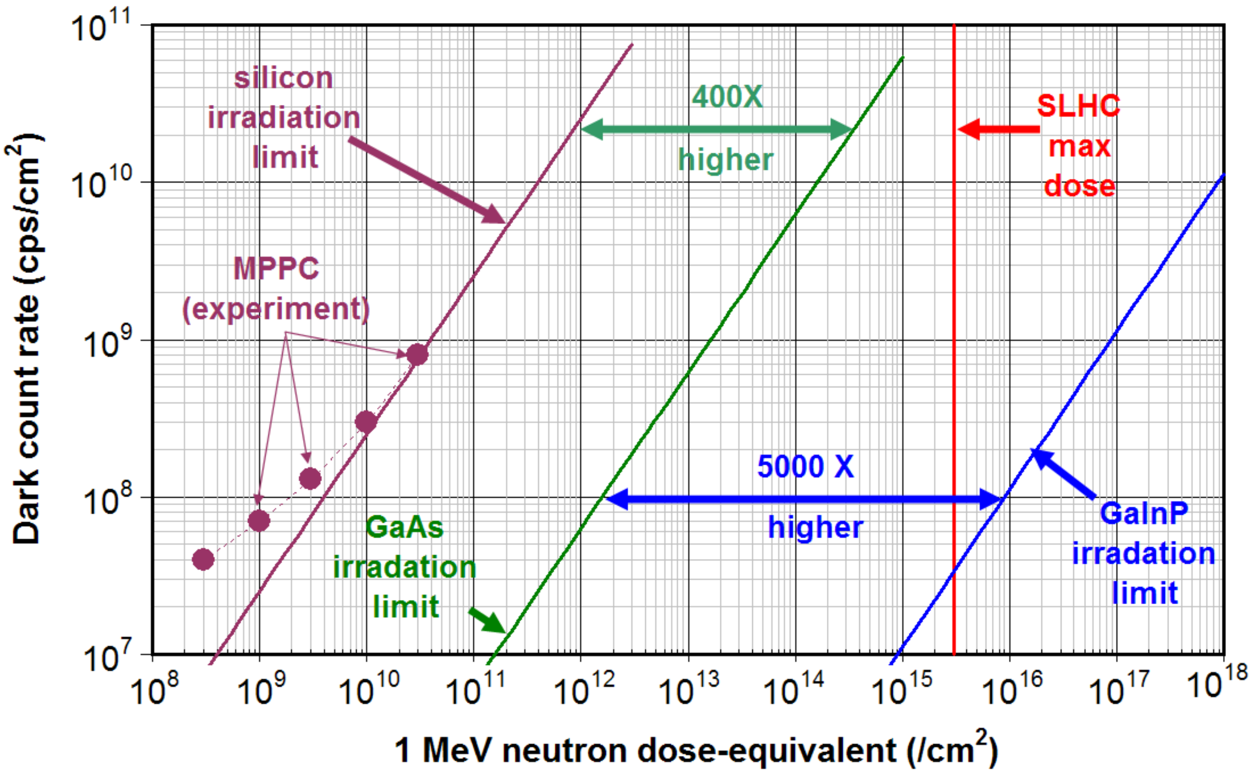


- **Reality:**
  - any device can be operated at high radiation exposure
  - penalty paid is in high dark currents, which manifest themselves as fake signals
- **Optimal:** high dose with low dark current
- Recall, SLHC neutron fluence of 3E14 to 4E15 100keV neutrons per $cm^2$
- Need to translate from 100keV to 1MeV neutron fluence but Lightspin estimates seem to indicate **GaInP might be the best candidate** for SLHC use.

# CMS Upgrade Proposal

- Made a **formal proposal to CMS** in August to pursue R&D for GaAs or GaInP photodetectors for SLHC endcap calorimeters
- **Joint venture between UVa and LightSpin, Inc.**
  - They provide us with a few of their 1 $mm^2$ GaAs photomultiplier chips mounted on readout boards with power connections
  - We evaluate them under SLHC occupancies before and after irradiation

- The proposed R&D program then would be the following:
  - Characterize baseline dark current levels and performance under load, including investigating sensitivity to temperature and magnetic field
  - Expose devices to EM radiation at UVa using a moderate local $\beta$ source; re-evaluate performance
  - Further push EM exposure through use of strong EM source, possibly through UVa hospital, to emulate actual SLHC; re-evaluate performance
  - Expose additional devices to hadronic radiation at to-be-determined facility; re-evaluate performance

- Activity ready to begin once funding arrives

- 2010 will be GaAs, future is more radiation tolerant GaInP

# Summary and Plan

- Radiation hard photodetectors will play a role in an upgraded endcap calorimetry.
- UVa has initiated an R&D program to look into specific photodetector devices and evaluate their performance and the impact of radiation damage
- Formal proposal submitted to CMS in August for 2010 studies on GaAs devices
- Work plan in place, we are ready to get underway

# Backup