Status of the CEDAR Upgrade Project

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with contributions from other members of the CEDAR project
Introduction / Remainder

• Purpose of the project:
  – Modify CEDARS to withstand higher rate ($\approx 10^8$ particles/s)

• Project scope:
  – Photomultipliers / voltage dividers / front-ends
  – Readout (funding to be clarified)
  – Thermal system
  – Monitoring of PMT gain stability

• Who is involved:
  – Warsaw University of Technology (WUT)
  – INFN Torino
  – Academia Sinica Taipei
  – CERN
PMT Status

**REQUIREMENTS:**
1. No pile-up
2. If it is not possible to avoid pile-up, then make it small enough so that we don’t lose too much data

**CURRENT STATUS:**
- Monte-Carlo done by Flavio revealed that light spot on the photocathode is small, centered at the PMT
- Can use smaller PMT
  - Less dark hits
  - Better timing
  - Can use HQE photocathode
- We selected Hamamatsu R11263-203
  - TTS = 390 ps (FWHM)
  - Pulse: $t_r = 1.1$ ns, FWHM < 2 ns
- Ordered 20 pcs, expected delivery in December 2017 (!!!).
  - Wen-Chen is negotiating with Hamamatsu to provide us with 1-2 units, so that we may perform characterization at WUT
Problem with R11265-203

- R11265 is a 4-channel PMT
- Given the shape of our light spot, we risk losing significant portion of photons at channel boundaries

Information obtained by Flavio from Hamamatsu
Advantage of R11265-203

- Advantages of Ultra-bialkali (UBA) photocathode (vs bialkali):
  - Much better quantum efficiency
  - ≈5% better at 250 nm, much better at visible spectrum

- From original CEDAR proposal we had the following information (Fig. 16 on page 21):

  We also knew from the proposal that CEDAR optics cuts anything below 240 nm
  So, we Wen-Chen made quick calculations to see what is the actual gain from switching to the UBA photocathode...
FINDINGS:

- Integrated photoelectron yield (A.U.)
  - EMI9820QB (current): 4.8
  - R3377 (new bialkali): 4.5
  - R11265 (new UBA): 7.1

- ≈50% more photoelectrons from UBA

But we still had the dip in the collection efficiency... which we don’t like, so...

Plots and numbers by Wen-Chen
Collection Efficiency - Potential Solution

From Flavio

- R11265 is a PMT with metal-channel dynode
- No big change of TTS wrt. to position on the photocathode

**Simple solution to the collection efficiency problem:**
- Blow up the light spot by putting PMT at different Z position (out-of-focus)
- Detailed Z position will be determined after X-Y scan of collection efficiency – WUT has setup for that
• Baseline design:
  – Discriminator (fixed threshold) + TDC

• Need to ensure the following functionality:
  – Particle tagging (pulse timing)
  – Gain monitoring (pulse amplitude/charge measurement)

• The former is easy with TDC/discriminator

• The latter can be accomplished with a time-over-threshold technique with multiple discriminators with different thresholds
  – This approach is successfully used by some neutrino/cosmic ray experiments
  – Papers are available
Readout 2/3

- Estimations of TDC specs (from Igor)
  - Possible to time both leading and trailing edge
  - Time bin \(\approx 250\) ps
  - Min. pulse width 4 ns
  - Not clear what is minimum pulse separation
- In any case, we can make system capable of >100M hit/s rate
- For gain monitoring, we need to shape the pulse (see next slide)
  - We may also sum all four channels, to save on TDC channels
• Estimations of TDC specs (from Igor)
  – Possible to time both leading and trailing edge
  – Time bin ≈ 250 ps
  – Min. pulse width 4 ns
  – Not clear what is minimum pulse separation
• Relatively inexpensive
  – ≈ 500 EUR/32 channels
• In any case, we can make system capable of >100M hit/s rate
• For gain monitoring, we need to shape pulse
  – We cannot artificially extend discriminator signal, as we want it’s length to be proportional to amplitude

The exact shaping times and number of threshold will be determined once PMT characterization is done in Warsaw
We will also check whether the ‘fast’ track for particle tagging should use all four channels or wire them together
PMT Gain Monitoring

• Measure PMT gain using light pulses of constant intensity, in off-spill time

• Components:
  – Pulsed light source – calibrated 470nm LED flasher, same as used in ECAL0
  – Multimode fiber splitter
  – Injection spacers for light delivery to PMTs (?)

• No update this time, but Robert will start working on the issue soon.

Contact: Robert Kurjata, WUT
## Funding Status

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### MEANING OF COLUMNS:
- **Needed** – estimated amount needed to complete the project
- **Available** – Funds already available, can be used now

*Exchange rates as of today (i.e. 2017-09-02)*
Summary 1/2

• PMTs ordered, will arrive sometime in October
  – Decided to use Hamamatsu R11265-203
  – Have problem of dip in collection efficiency, but possibly it can be solved by changing Z position

• Have clear picture of how the readout should look like
  – Will go with the TDC option
  – Need to determine if we want to use all four channels independently or to wire them together
  – Need to find optimum shaping for monitoring PMT gain, as well as number of needed discriminator+TDC channels
  – Already arranged for shipping precise Time-Interval-Counters from Japan (we used them in a different experiment) – will have 4 TDCs, 25 ps time resolution.

• Plan (incoming 2-4 weeks)
  – Prepare detailed schedule for the whole project, up to installation and commissioning
  – Decide if WUT can design/manufacture discriminators using NINO chip – decision within next 1-2 weeks.
  – Adjust setup for PMT testing, so that we can start immediately once the PMTs are available

• Will start work on concept of optical system for PMT gain monitoring this month
Summary 2/2

• Thermal system status (information from Johannes):
  – First calculations done, but need more input on plans as how to attach the PMT and the electronics to the vessel
  – CERN group reserved a designer for technical drawings
• CERN group has a dismounted CEDAR which we can use for tests and reverse-engineering
• Plan for an integration meeting with the CERN group (upon suggestion from Johannes):
  – Date to be decided, but sooner rather than later