Status of the CEDAR Upgrade Project

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with contributions from other members of the CEDAR project

COMPASS TB meeting, 2017-09-04

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

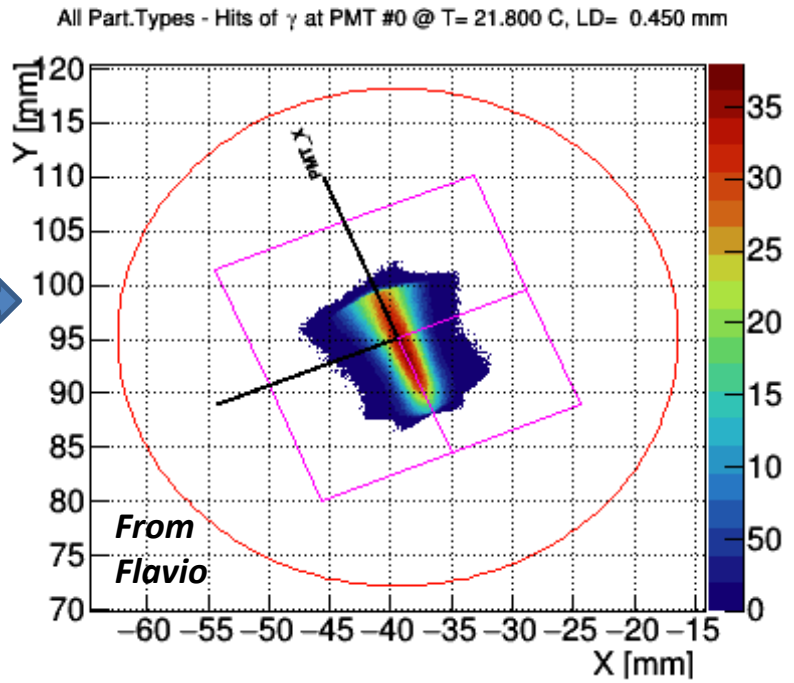
PMT Status

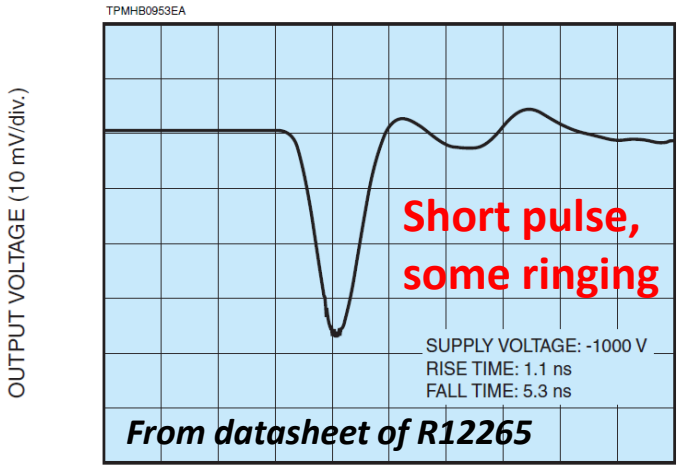
REQUIREMENTS:

1. No pile-up
2. If it is not possible to avoid pile-up, then make is small enough so that we don't loose too much data

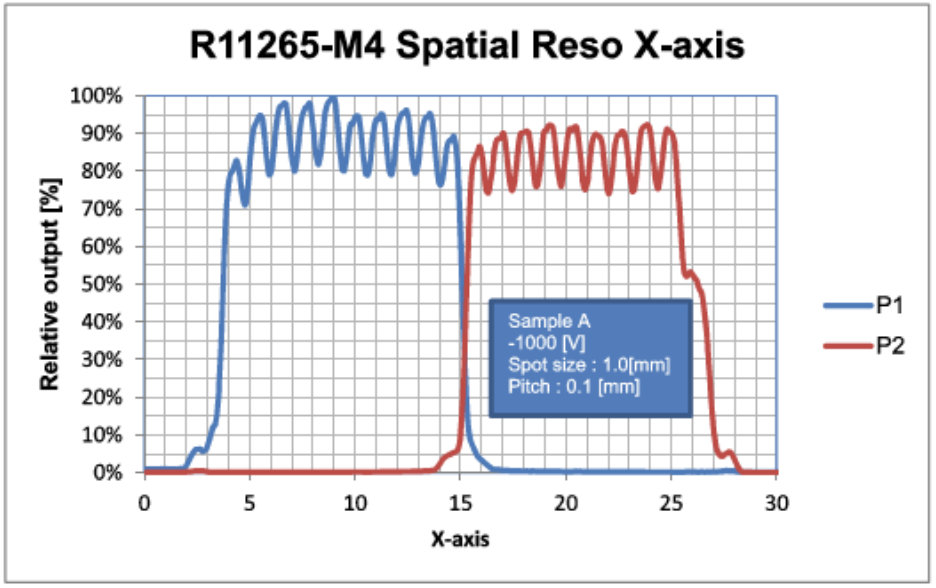
CURRENT STATUS:

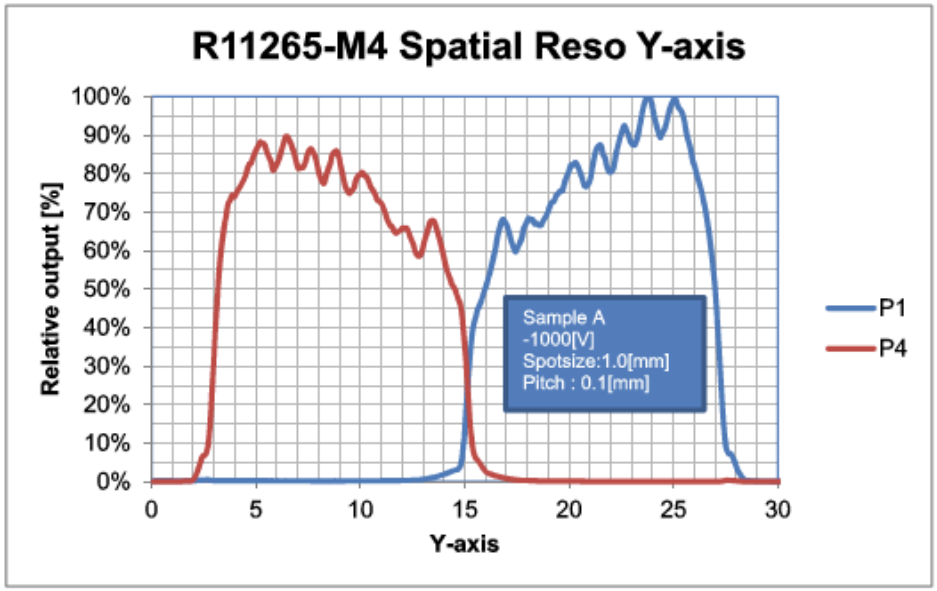
- Monte-Carlo done by Flavio revealed that light spot on the photocathode is small, centered at the PMT
- Can use smaller PMT
  - Less dark hits
  - Better timing
  - Can use HQE photocathode
- We selected Hamamatsu R11263-203
  - TTS = 390 ps (FWHM)
  - Pulse: t_r = 1.1 ns, FWHM < 2 ns
- Ordered 20 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

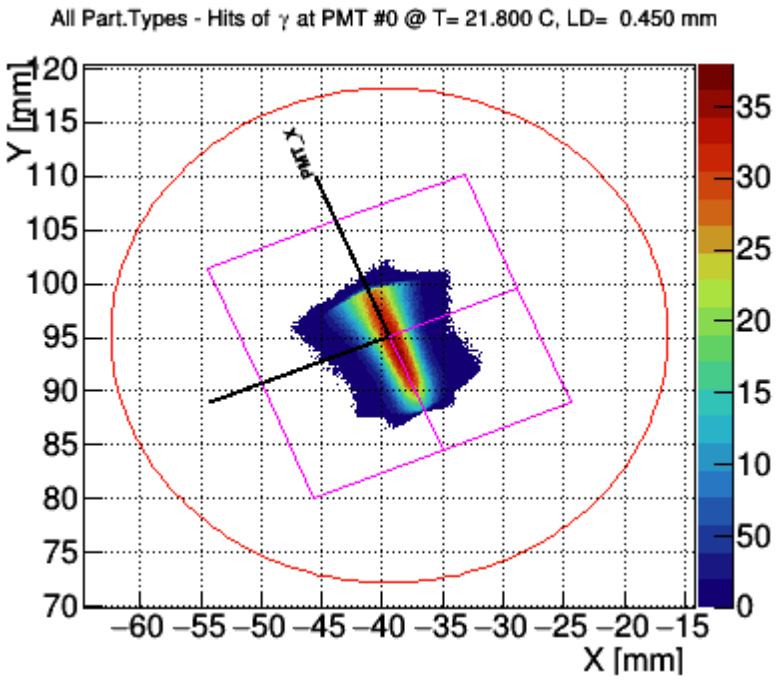




Problem with R11265-203





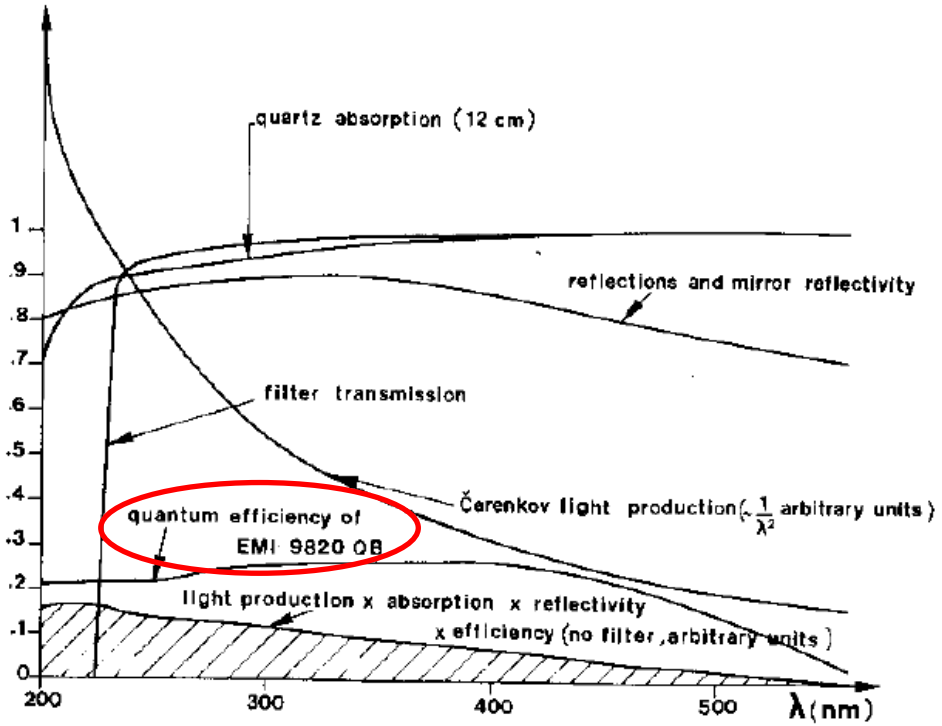


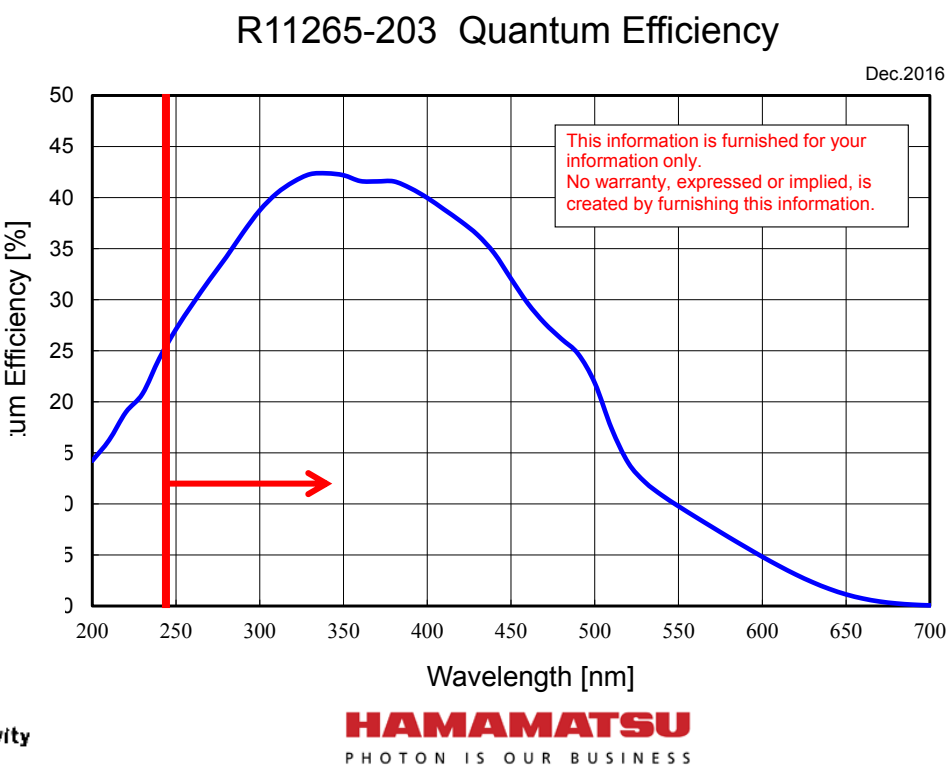
- R11265 is a 4-channel PMT
- Given the shape of our light spot, we risk loosing significant portion of photons at channel boundaries

Information obtained by Flavio from Hamamatsu

Advantage of R11265-203

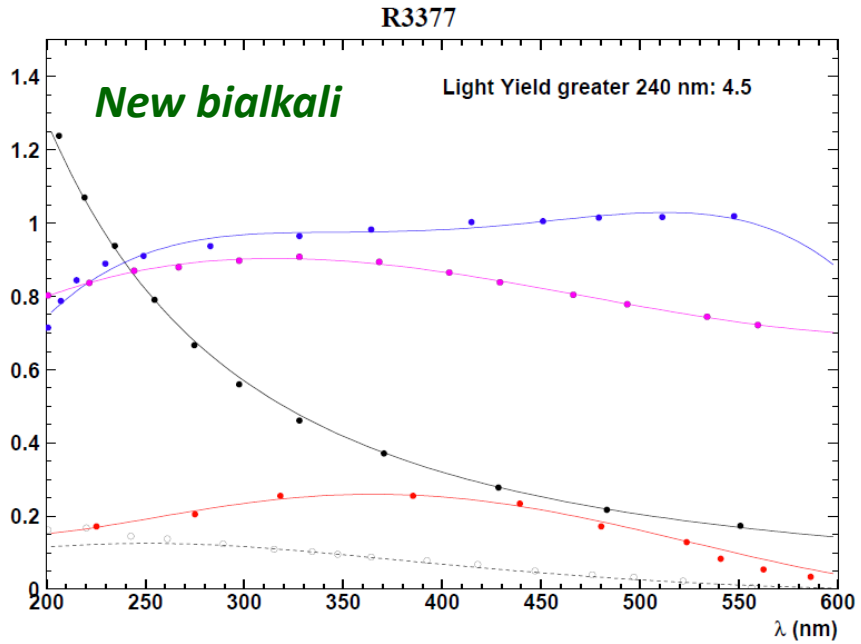
- Advantages of Ultra-bialkali (UBA) photocathode (vs bialkali):
  - Much better quantum efficiency
  - ≈5% better at 250 nm, much better at visible spectrum
- From original CEDAR proposal we had the following information (Fig. 16 on page 21):

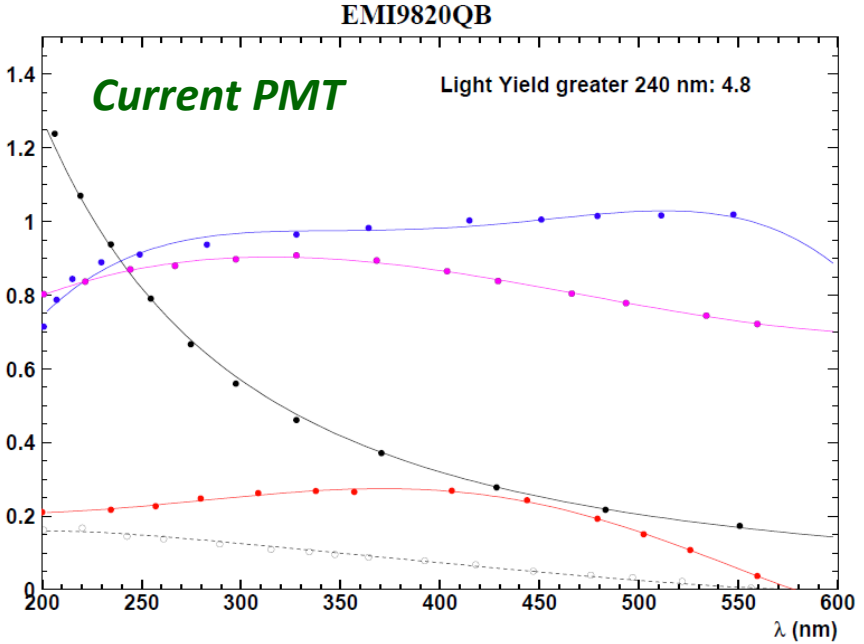


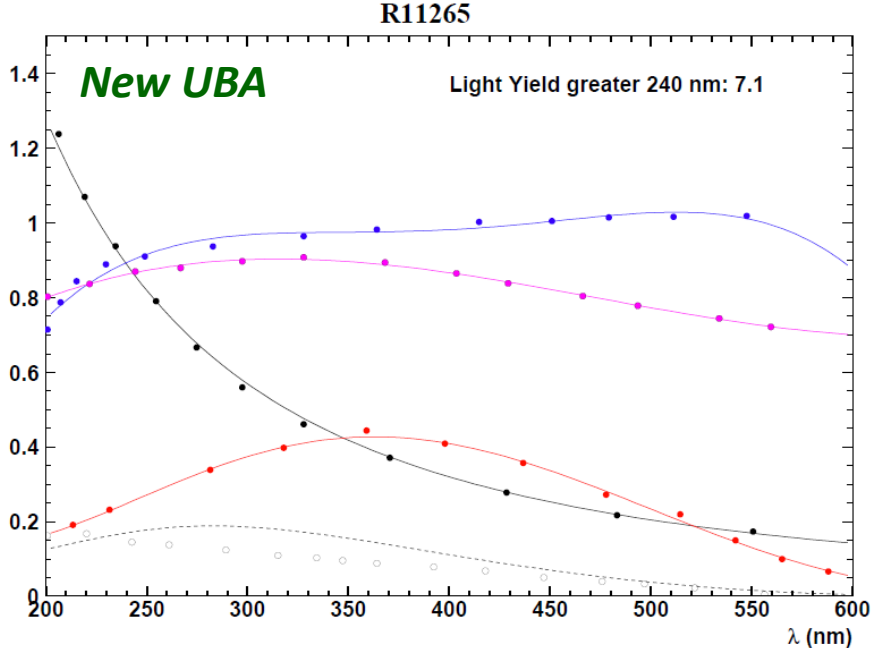


- We also knew from the proposal that CEDAR optics cuts anything below 240 nm
- So, we Wen-Chen made quick calculations to see what is the actual gain from switching to the UBA photocathode…

PMT Status







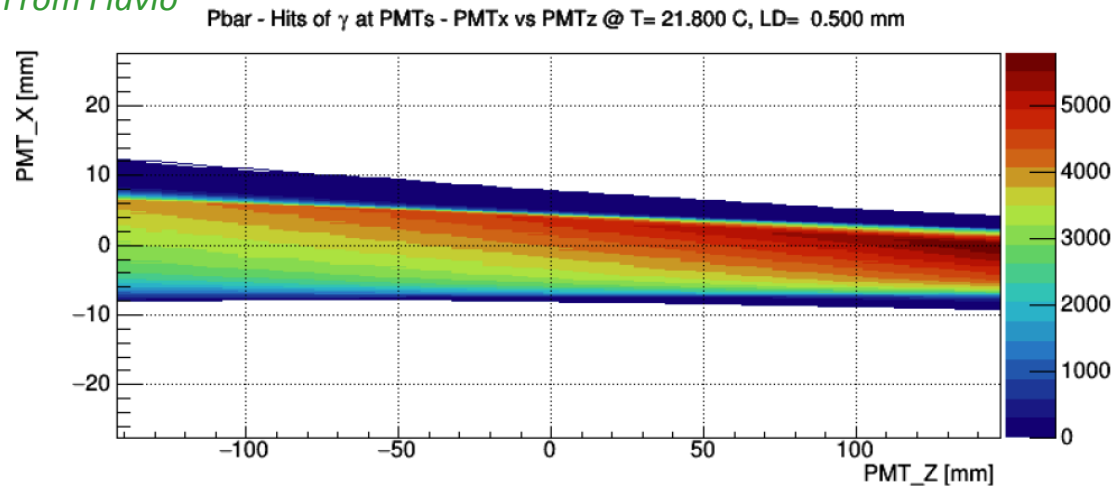
FINDINGS:

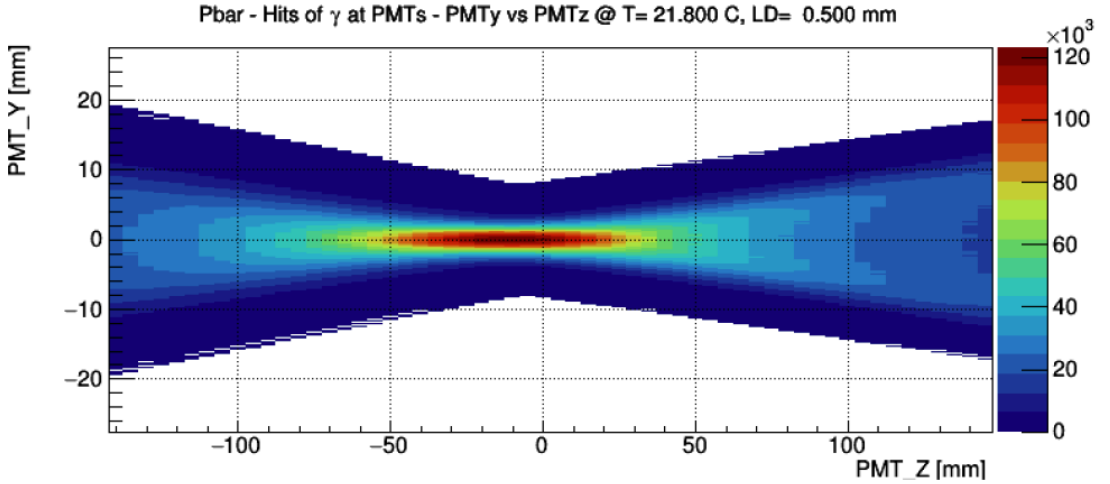
- Integrated photoelectron yield (A.U.)
  - EMI9820QB (current): 4.8
  - R3377 (new bialkali): 4.5
  - R11265 (new UBA): 7.1
- **≈50% more photoelectrons from UBA**
- But we still had the dip in the collection efficiency… which we don't like, so…

Plots and numbers by Wen-Chen

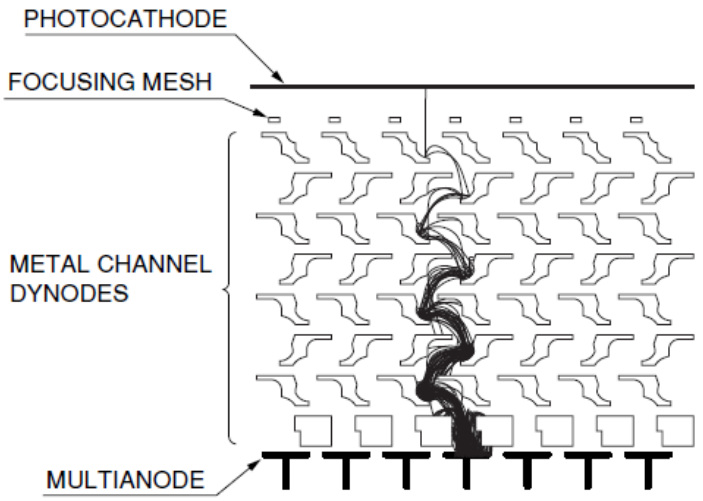
Collection Efficiency - Potential Solution

From Flavio





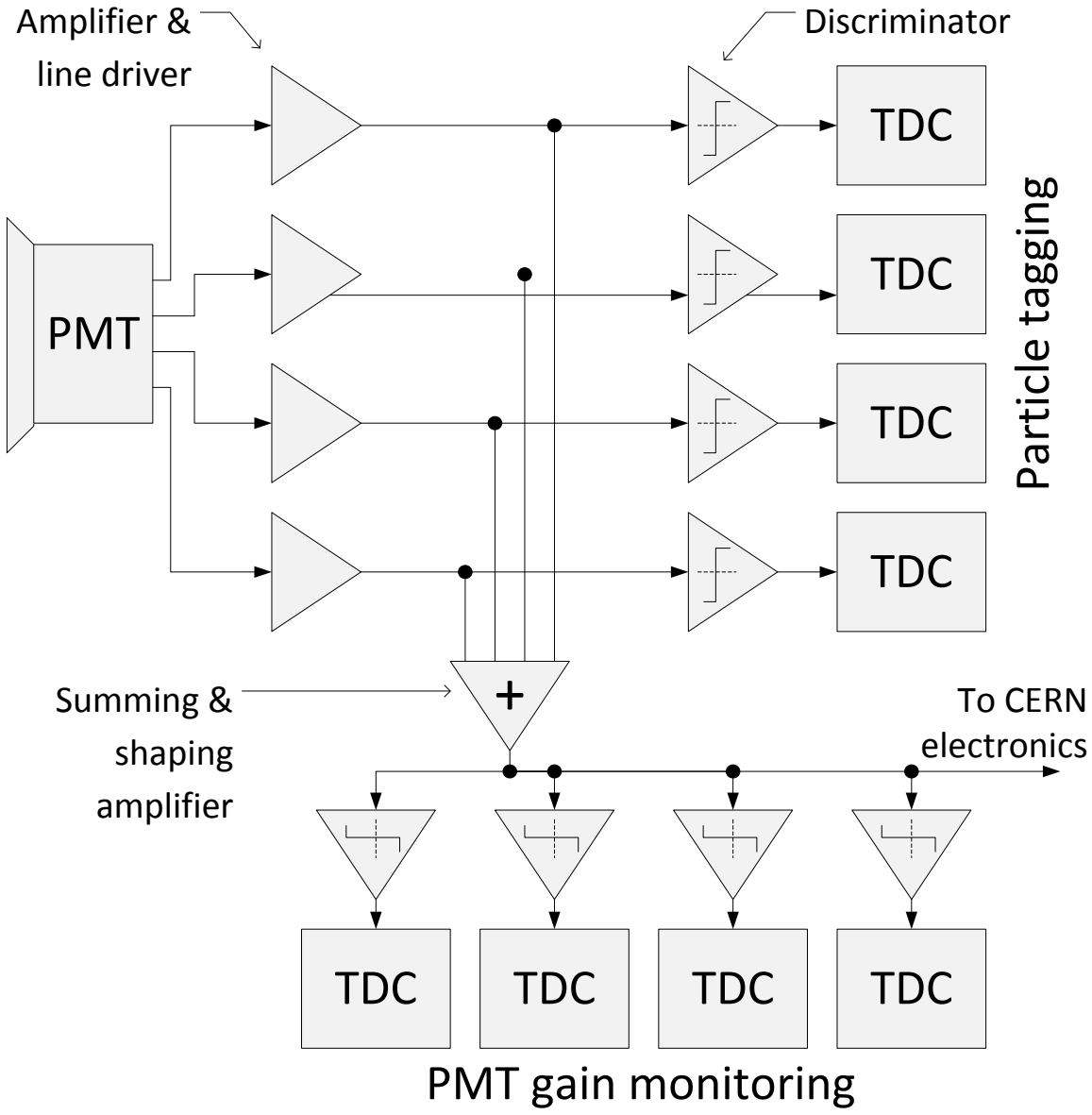
- R11265 is a PMT with metal-channel dynode
- No big change of TTS wrt. to position on the photocathode



From Hamamatsu PMT Handbook

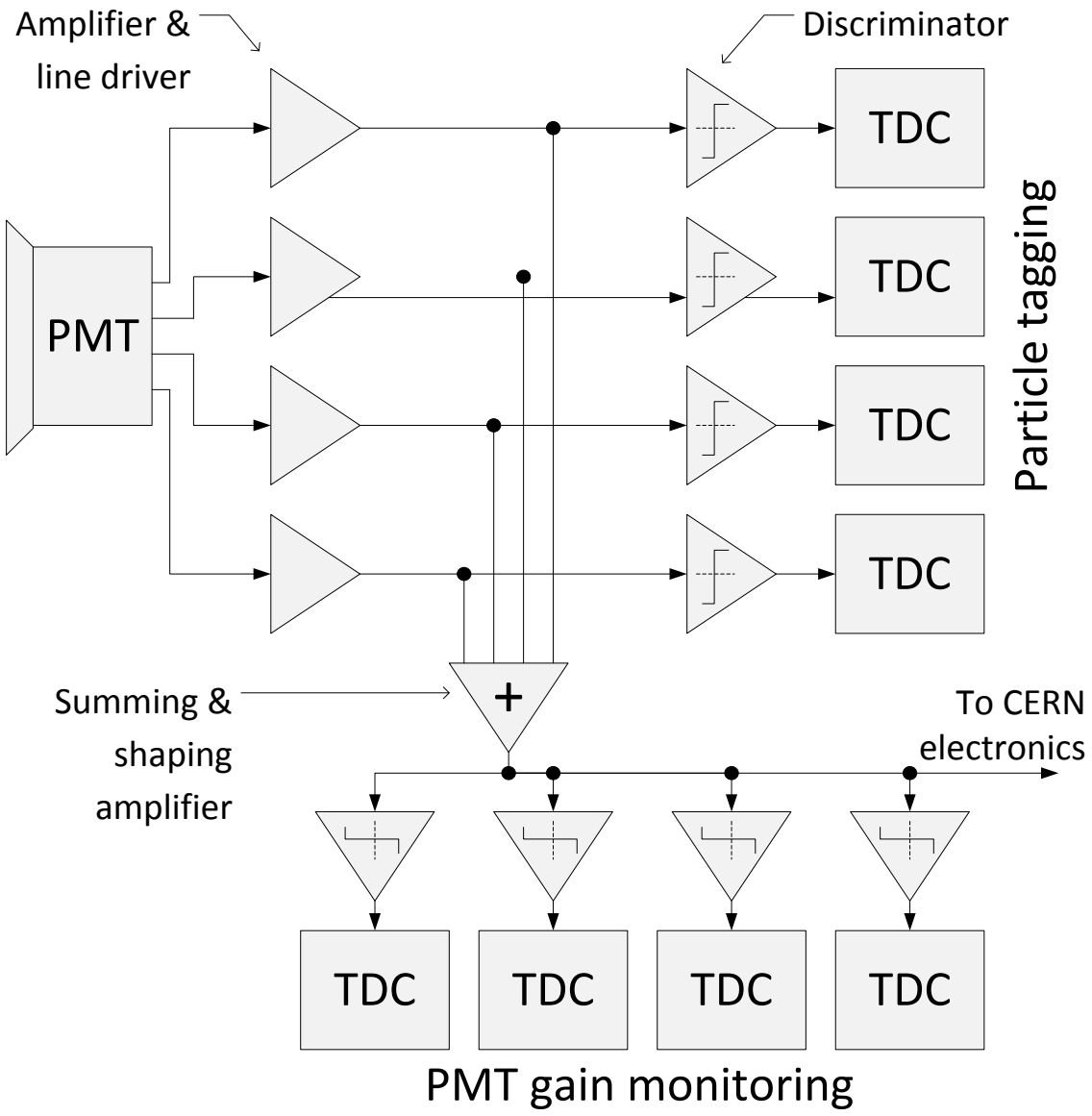
- Simple solution to the collection efficiency problem:
  - Blow up the light spot by putting PMT at different Z position (out-of-focus)
  - Detailed Z position will be determined after X-Y scan of collection efficiency – WUT has setup for that

Readout 1/3



- 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

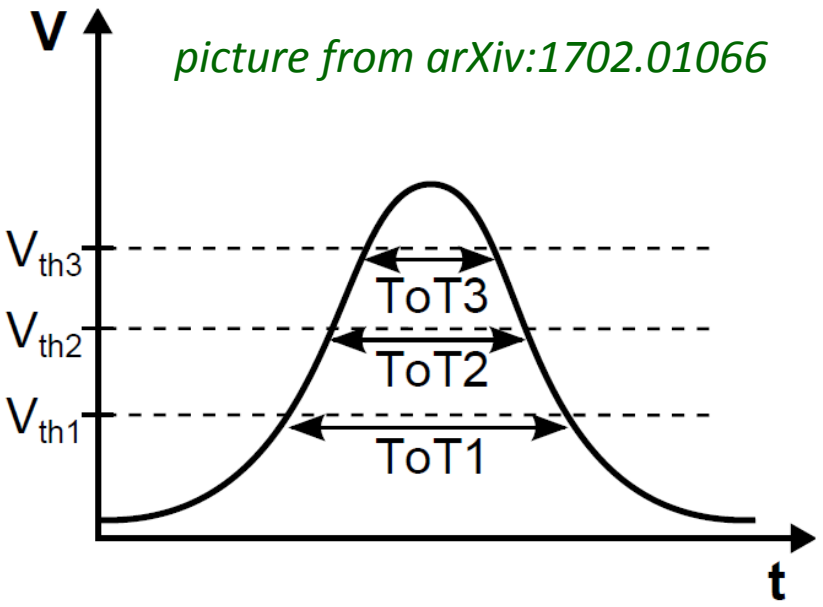
Readout 2/3



- Estimations of TDC specs (from Igor)
  - Possible to time both leading and trailing edge
  - Time bin ≈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

Readout 3/3

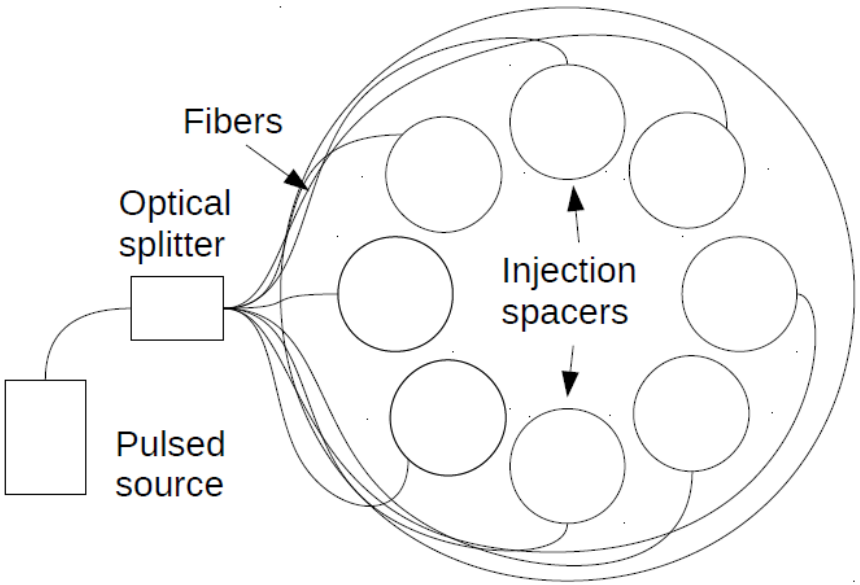
PRINCIPLE

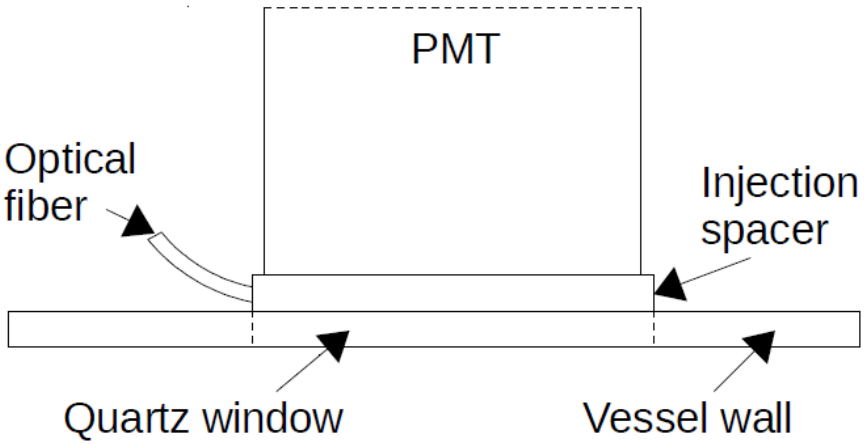


- The exact shaping times and number of threshold will be determined once PMT characterization is done in Warsaw
- We will also check whether the 'fast' track for particle tagging should use all four channels or wire them together

- 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

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

Task	Responsible	Funding	
		Needed	Available
New PMTs	Academia Sinica	**Ordered**	
Installation/commissioning	Academia Sinica		
Thermal system	WUT/CERN	18 811,78 EUR	18 811,78 EUR
Gain monitoring	WUT	11 051,92 EUR	11 051,92 EUR
Front-ends	WUT	7 759,86 EUR	7 759,86 EUR
Installation/commissioning	WUT	26 595,15 EUR	26 595,15 EUR
Installation/commissioning	INFN		
Readout	AC/WUT/Munich/INFN (?)	???	13 998,00 EUR
Total		64 218,70 EUR	78 216,70 EUR

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