LENA
Electronics Requirements

LENA – PMm2 Meeting
LAL Orsay, 04/06/09

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Outline

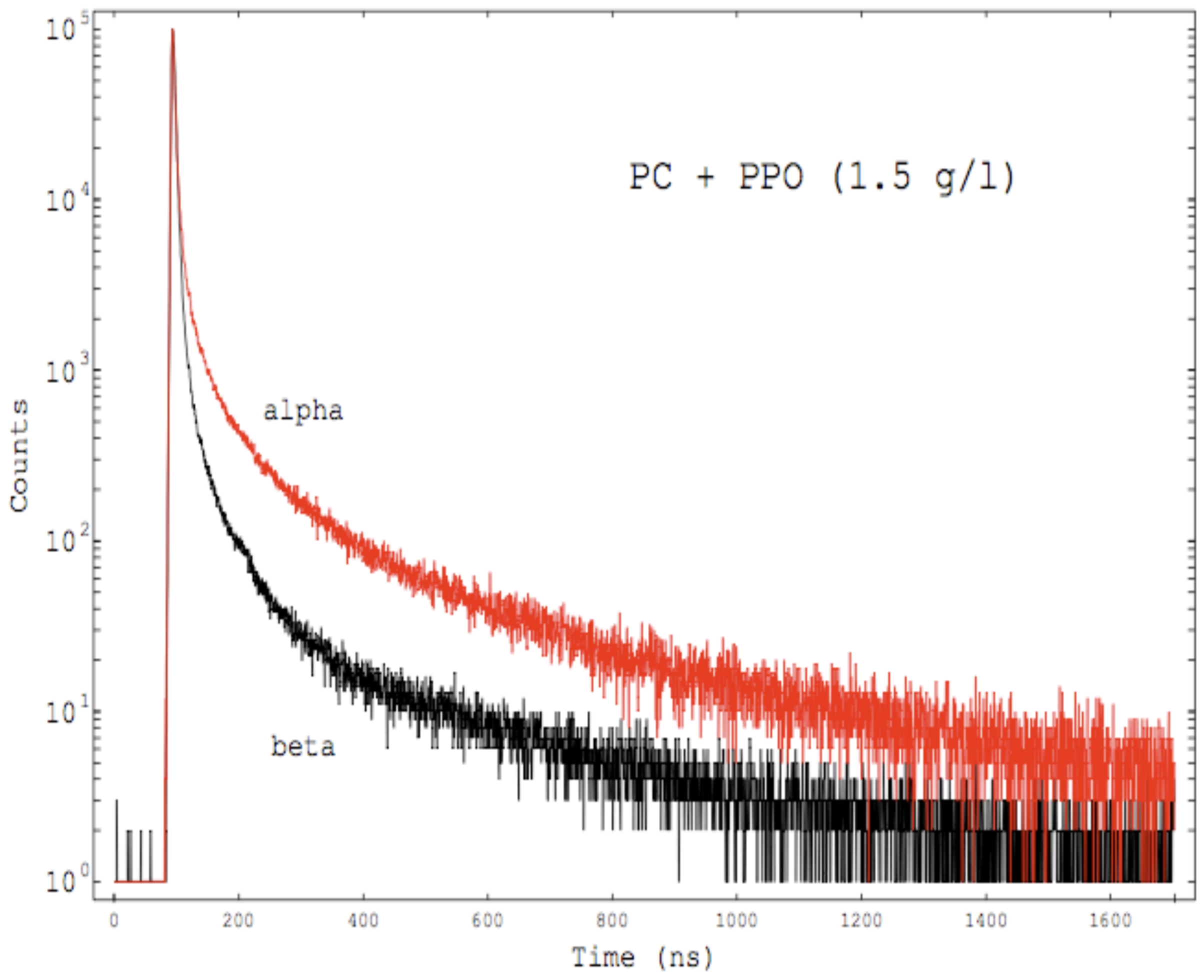
Scintillation Signal

Photomultipliers

Dynamic Range, Timing & Rates

Data Acquistion

Scintillation Signal



Event Energy
Number of Photons

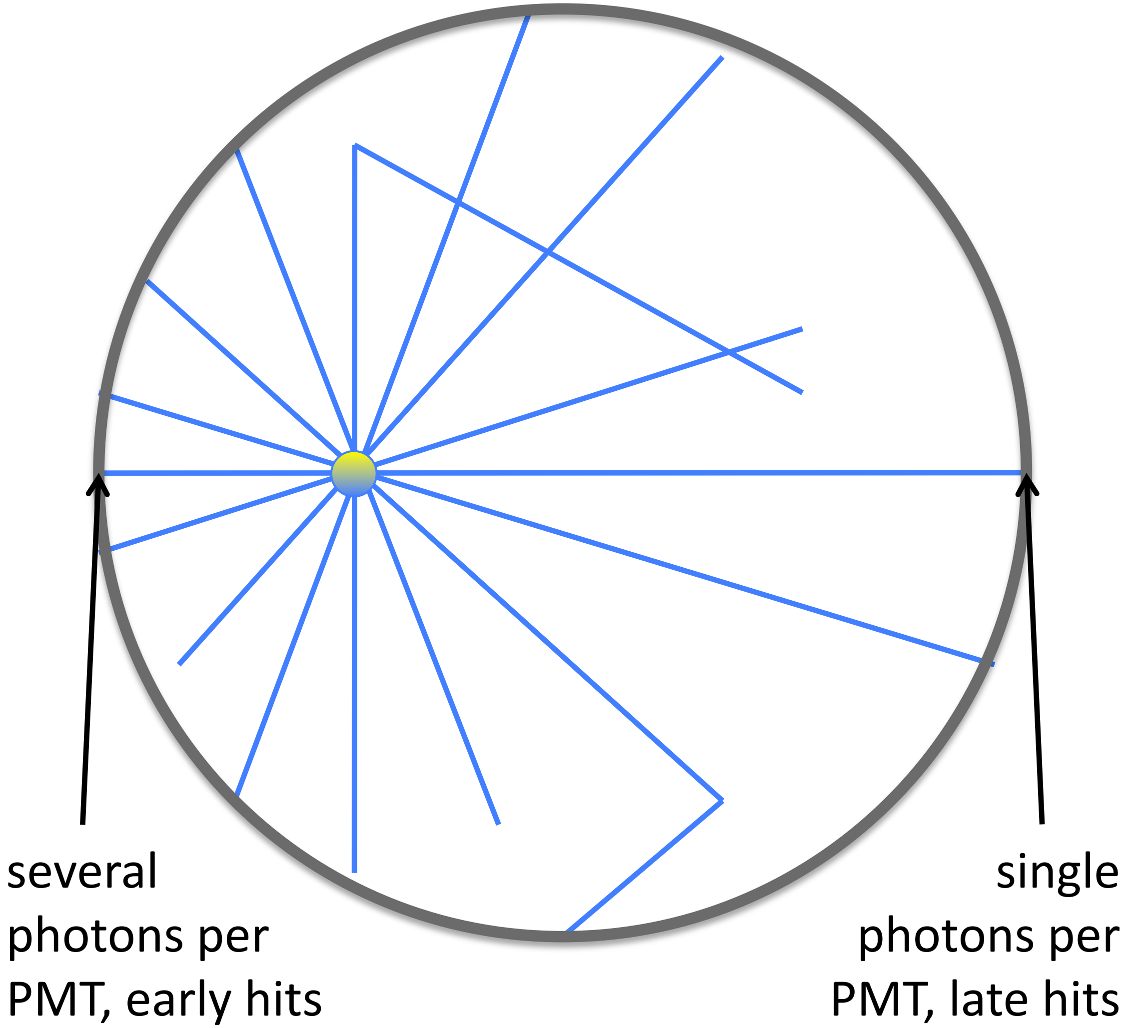
Light Yield (electrons)
10,000 photons per MeV
emitted isotropically

Timing
signal decays exponentially
2 (or more) components

fast component: 3-7 ns
slow component(s): >20 ns

Particle Identification
relative ratio of the
decay components

Detector Signal



Event Energy

Light Yield (/MeV): 10^4

Photoactive Coverage: 30%

PMT Photoefficiency: 20%

+ Light Absorption/Scattering

Photoelectrons/MeV <600

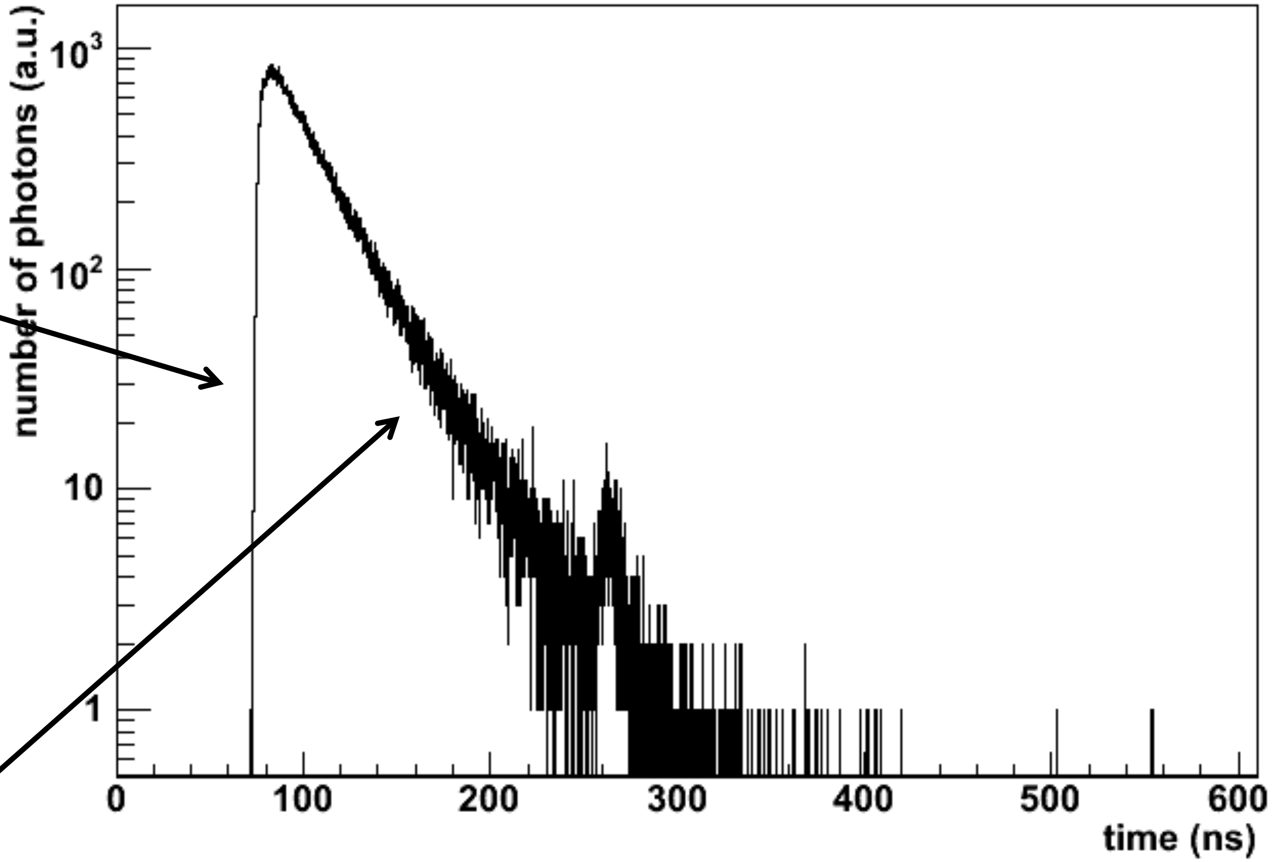
Vertex Reconstruction

uses hit pattern of PMTs (PMT position, Number of Hits per PMT, photon arrival time) to determine barycenter

Integral Pulse Shape

Time Resolution
governed mainly by
rise time (5-10 ns)

rise time is
determined by:
- fluorescence time
- light scattering
- PMT time jitter
- electronics

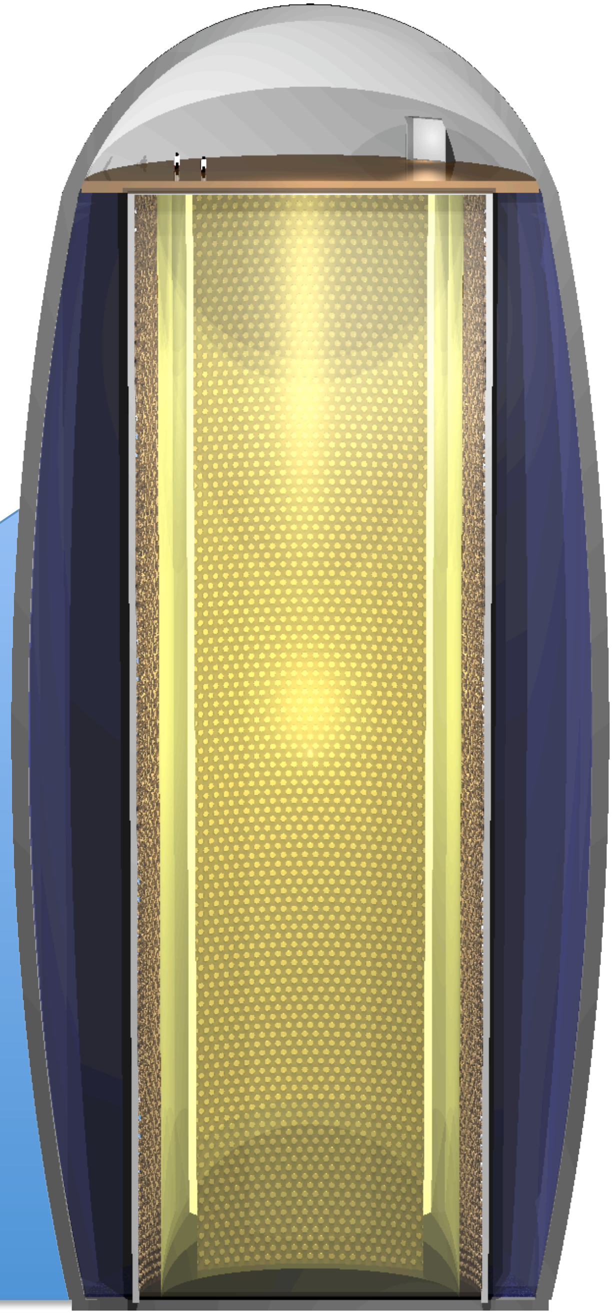


Particle Discrimination
governed by **signal decay**

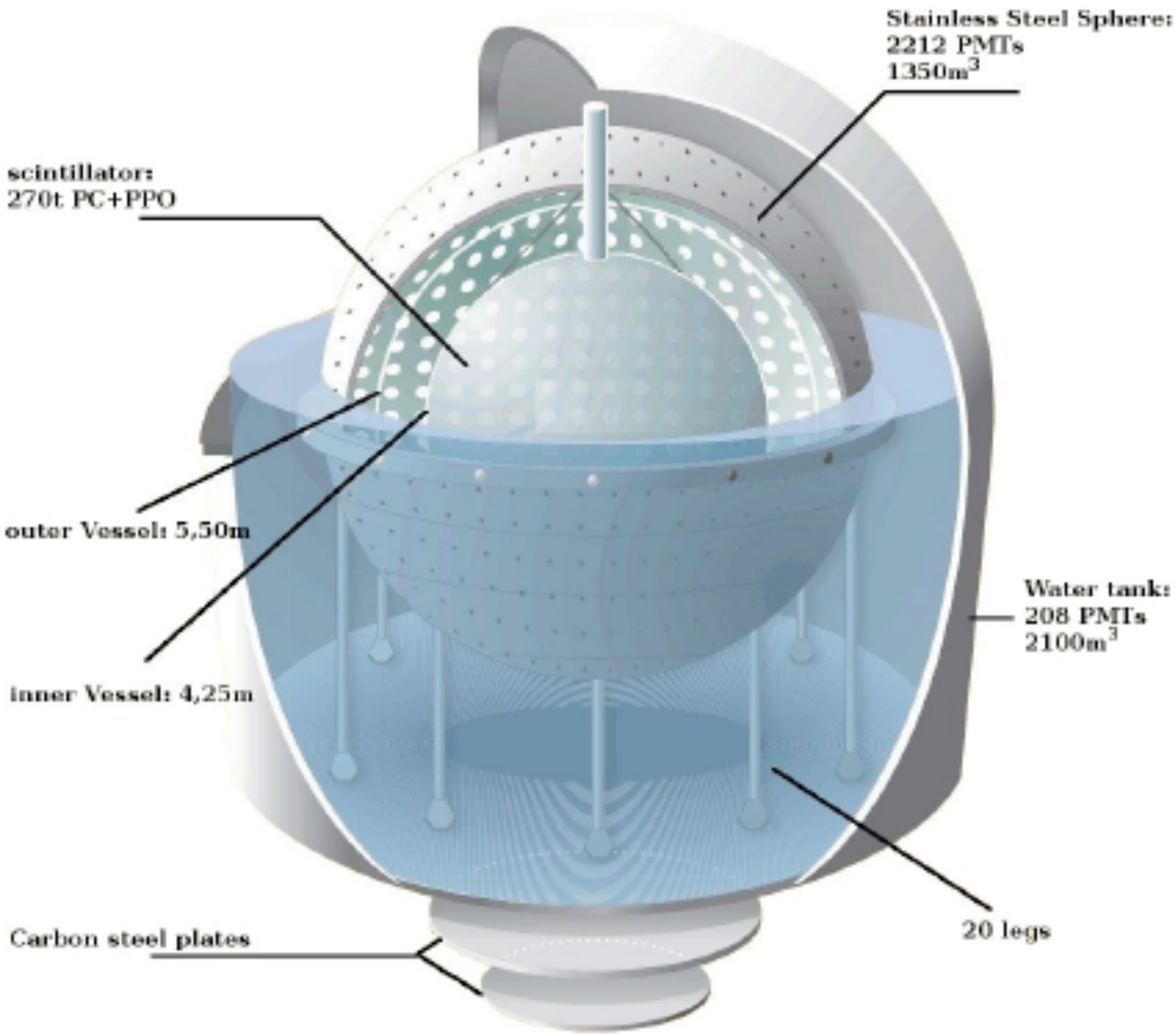
What can we learn from BOREXINO?

Liquid-scintillator detector
Total: 1kt of organic liquid
270 tons of LS target
2200 PMTs

optimized for the detection of low energy solar neutrinos (E<1MeV)



BOREXINO Detector Layout

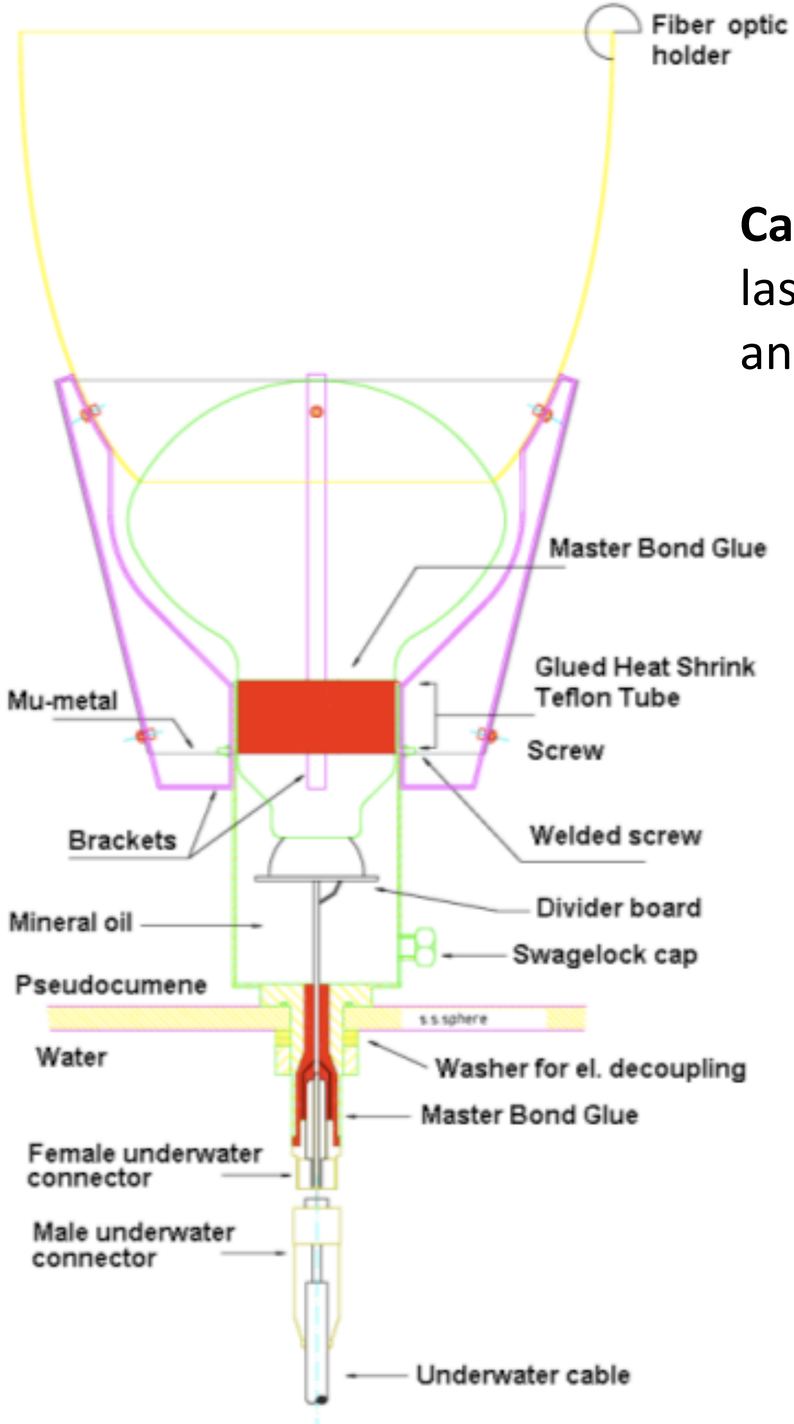


BOREXINO PMTs
ETL 9351 (8“)

Voltage for gain 10^7	1650 V	typ.
Maximum voltage	2200 V	max
Maximum cathode-first anode ΔV .	900 V	max
Rise time	4/6 ns	typ.
FWHM	7/10 ns	typ.
Fall time	8/12 ns	typ.
Linearity peak current at gain 10^6	8 mA	typ.
Linearity peak current at gain 10^7	10 mA	typ.
Linearity integ.charge at gain 10^6 ..	80/120 pC	typ.
Linearity integ.charge at gain 10^7 ..	100/150 pC	typ.
SPE Peak-to-Valley ratio	2.5	typ.
Photocathode sensitivity at 420nm	26.5 %	typ.
Transit time spread fwhm	2.8 ns	typ.
Pre-pulsing ($2\sigma - 20\sigma$)	3/6 %	max
After-pulsing ($0.05 \div 12.4$ μs)	2.5	typ.
Dark current at gain 10^7	25 nA	typ.
Dark counts at gain 10^7	3000	typ.

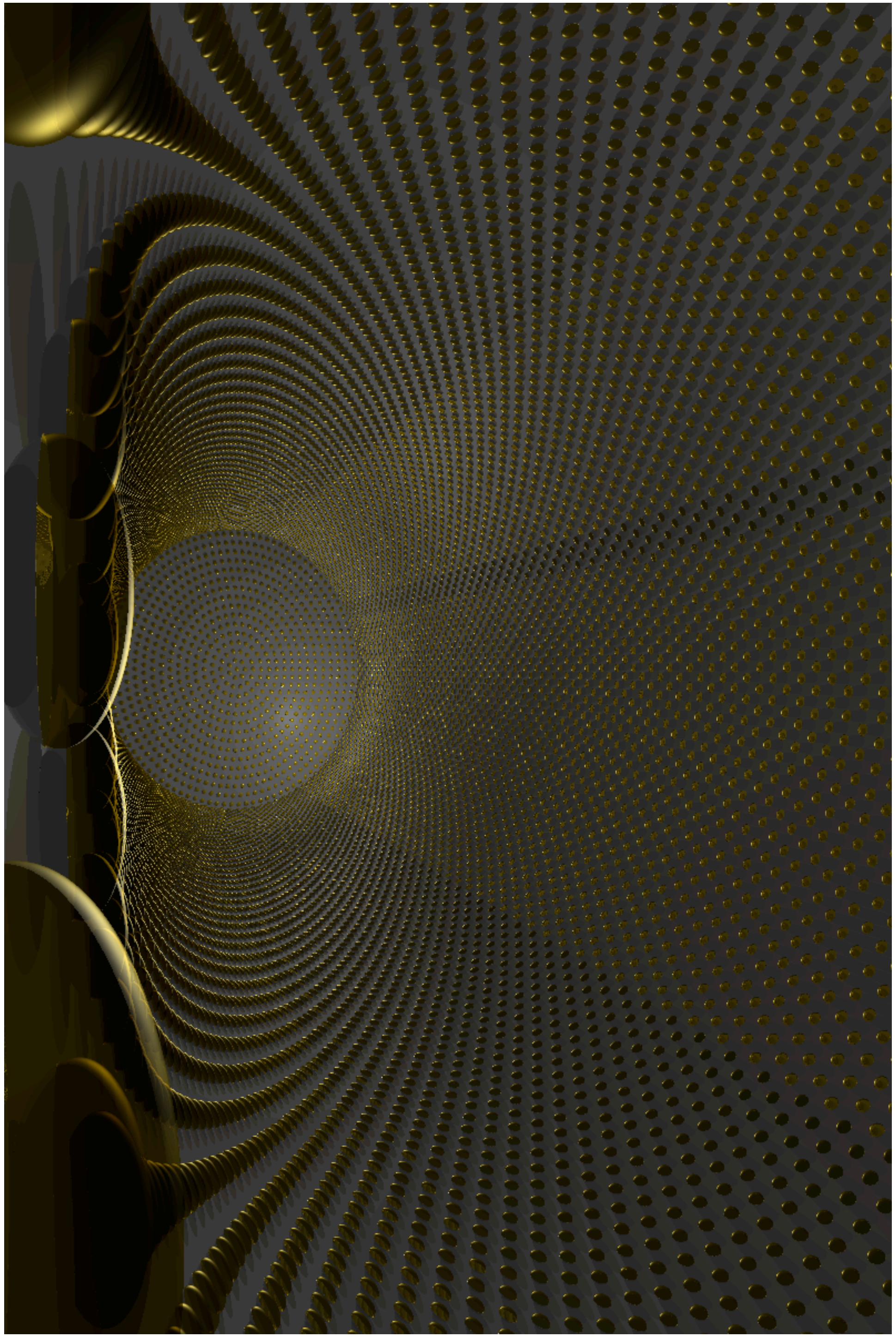
High Priority Parameters	
Photocathod quantum efficiency	$> 21\%$
After pulses	$< 5\%$
Single p.e. transit time spread	< 1.3 ns
Late-pulsing	$< 4\%$
Dark count rate	< 20 kHz
Single p.e. peak to valley ratio	> 1.5

BOREXINO PMTs



Calibration using LEDs/ lasers for SPE charge and relative timing

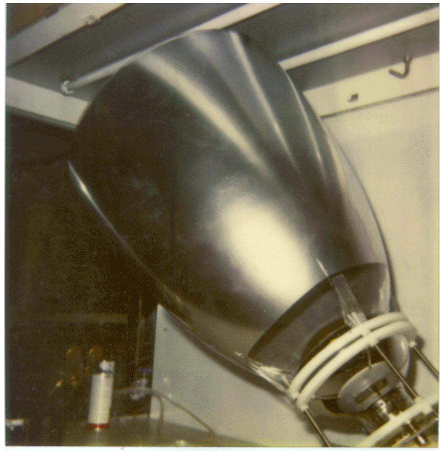
Light cones focusing field of view on the active detection volume, double effective optical coverage



LENA PMTs

Default Configuration
13,500 PMTs of 20‘‘ cathode diameter
optical coverage: 30%

Usage of Light Cones
8‘‘ phototubes or larger coverage
in the cylindrical geometry,
light cones can be larger than in Bx



Light cone used in the Borexino prototype CTF

Cabling could be run inside the tank

Pressure resistance/encapsulation is needed for bottom PMTs (10 bar)

Dynamic Range

BOREXINO

Energy Range
Several 100 keV to 20 MeV
(solar neutrino spectrum)

Light Yield
500 pe/MeV

Overall Photoelectron Signal
50 to 10,000 pe

(almost) evenly distributed over all PMTs due to spheric geometry

Photons per PMT
0.025 to 8

LENA

Energy Range
Several 100 keV to 1 GeV (20 GeV)
(solar neutrinos to proton decay)

Light Yield
150-250 pe/MeV

Overall Photoelectron Signal
50 to more than 200,000 pe

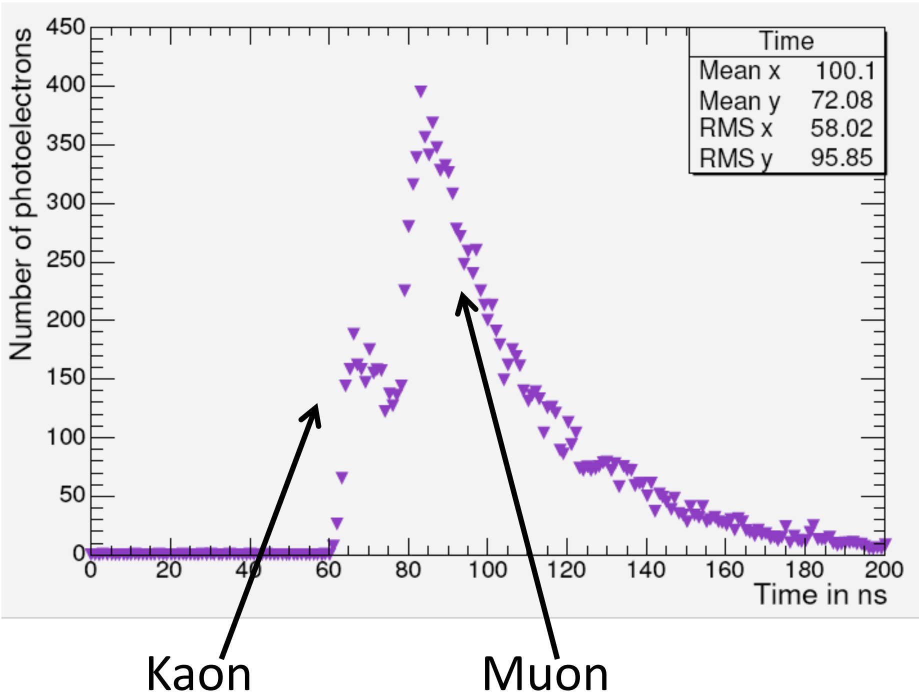
light is concentrated on several rings of PMTs along the cylinder mantle

Photons per PMT
0.025 to more than 100

Timing Capabilities

$$p \rightarrow K^+ + \bar{\nu}$$

$$K^+ \rightarrow \mu^+ \nu_\mu$$

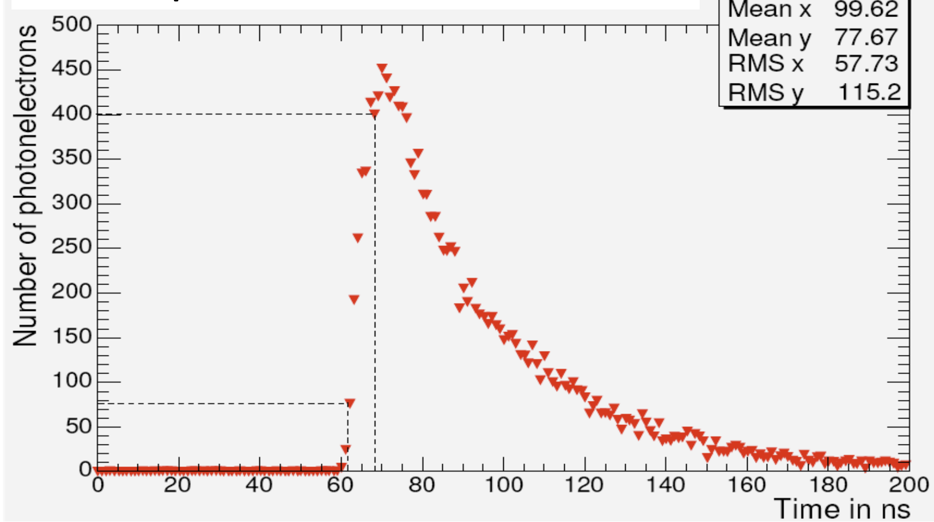


Efficiency ranges from 56% to 69% for typical rise times of 7 to 10 ns

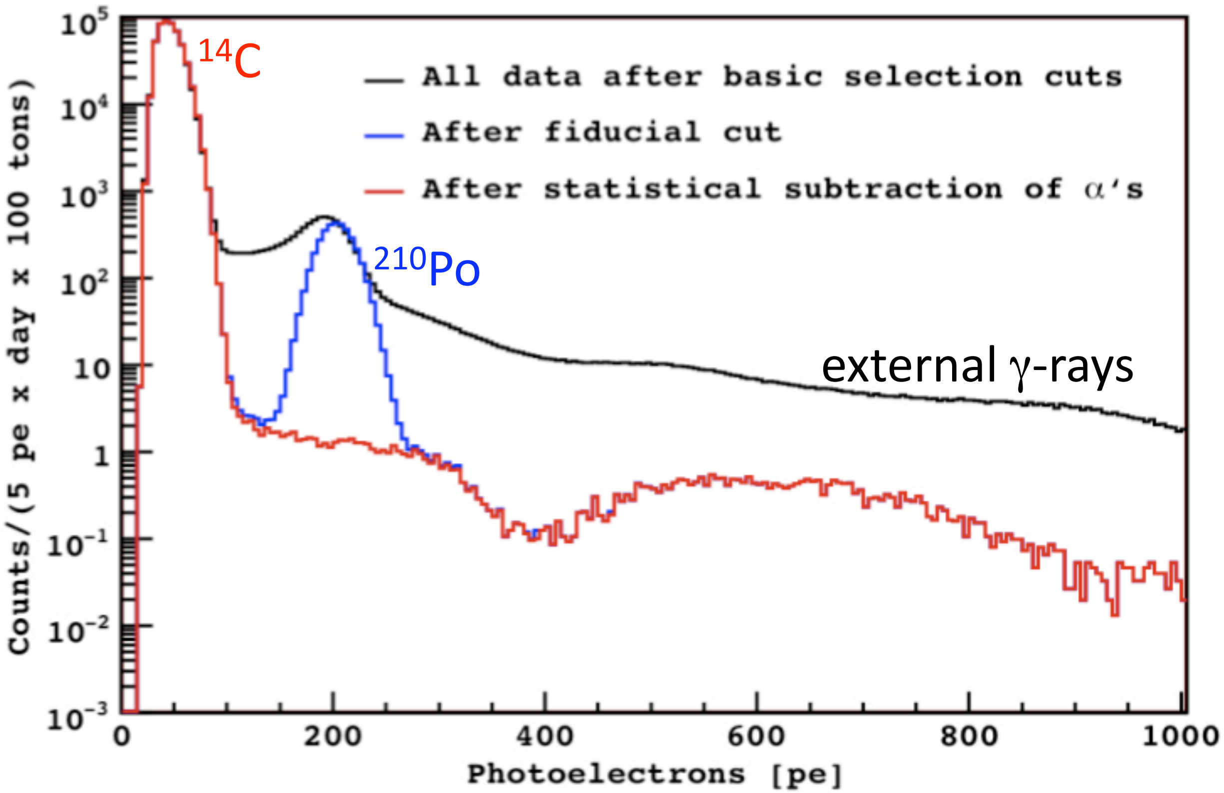
Large impact on proton decay (into $K^+\nu$) detection efficiency:

Signal of kaon (τ=13ns) and of its decay products (mostly muons) must be separated by rise time analysis

Background Source:
Atmospheric Muon-Neutrinos

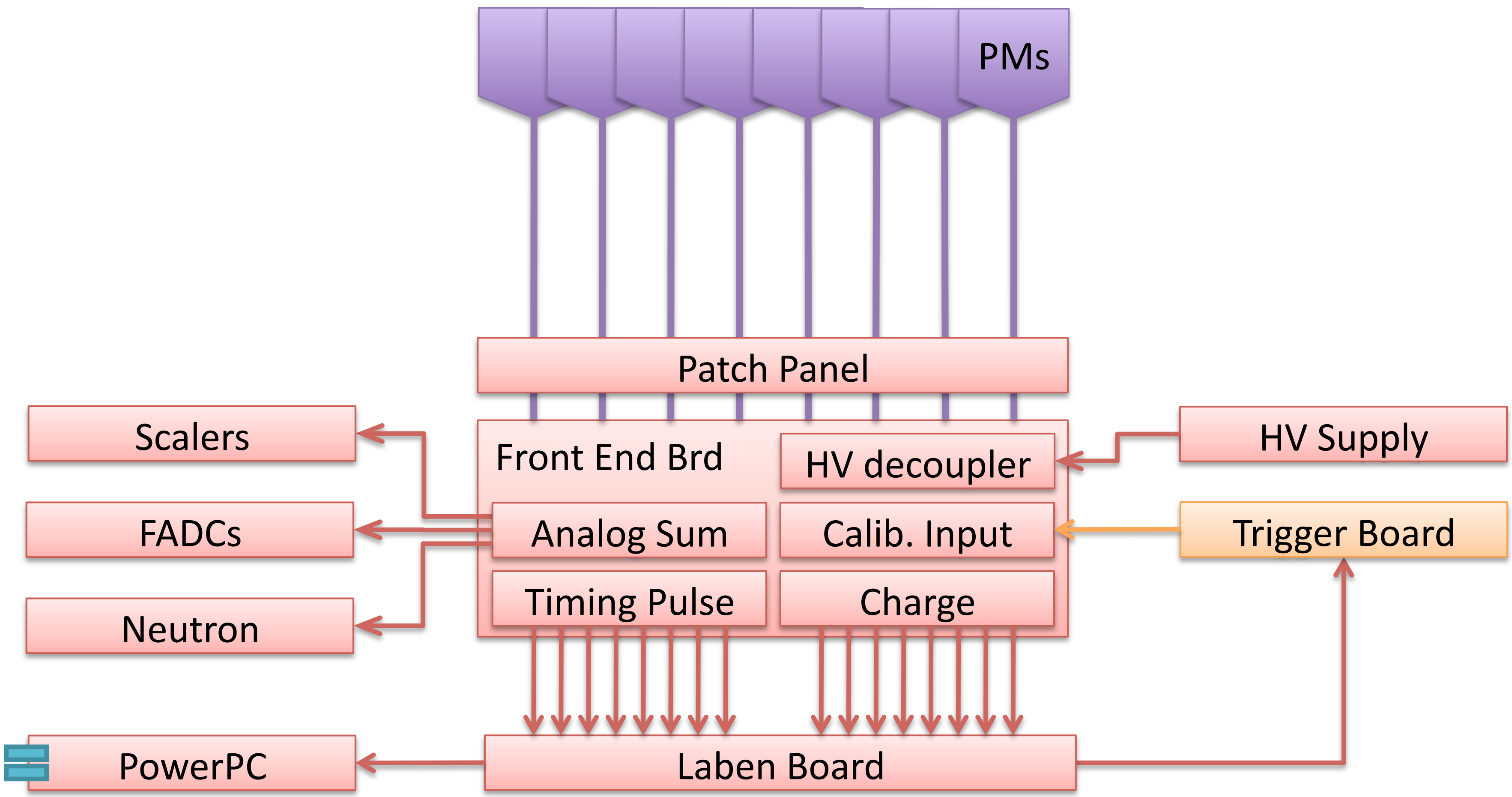


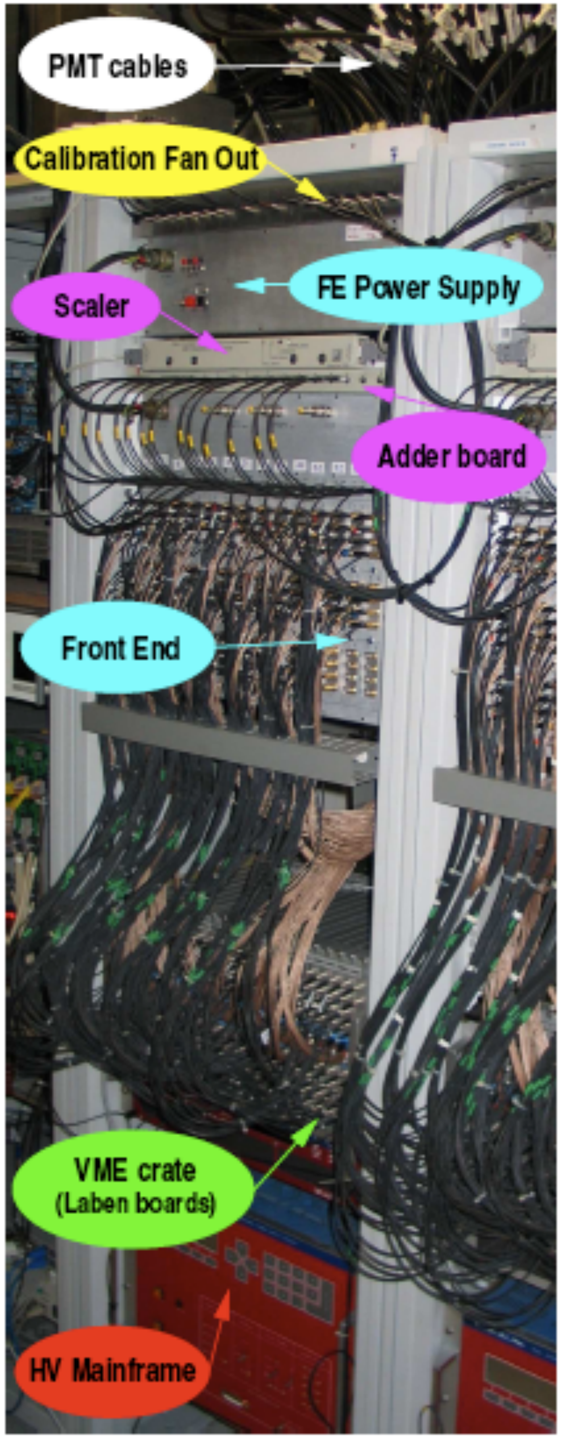
Trigger Threshold and Rate



BOREXINO (270 t)	instrumental threshold:	25 pe (50 keV)	rate: 30 Hz
	physics threshold:	100 pe (200 keV)	rate: 1 Hz
LENA (50,000 t)	excluding C14 events:	50 pe (200 keV)	rate: 200 Hz

BOREXINO: DAQ Layout





Main DAQ System

In case of a trigger (of either Inner or Outer Detector), all PM hits in a time gate of 16 μs are recorded.

Each individual hit provides two signals:

TDC: photon arrival time is recorded at a 100 ps accuracy relative to the trigger

ADC: charge of all photons arriving in the next 80 ns is integrated

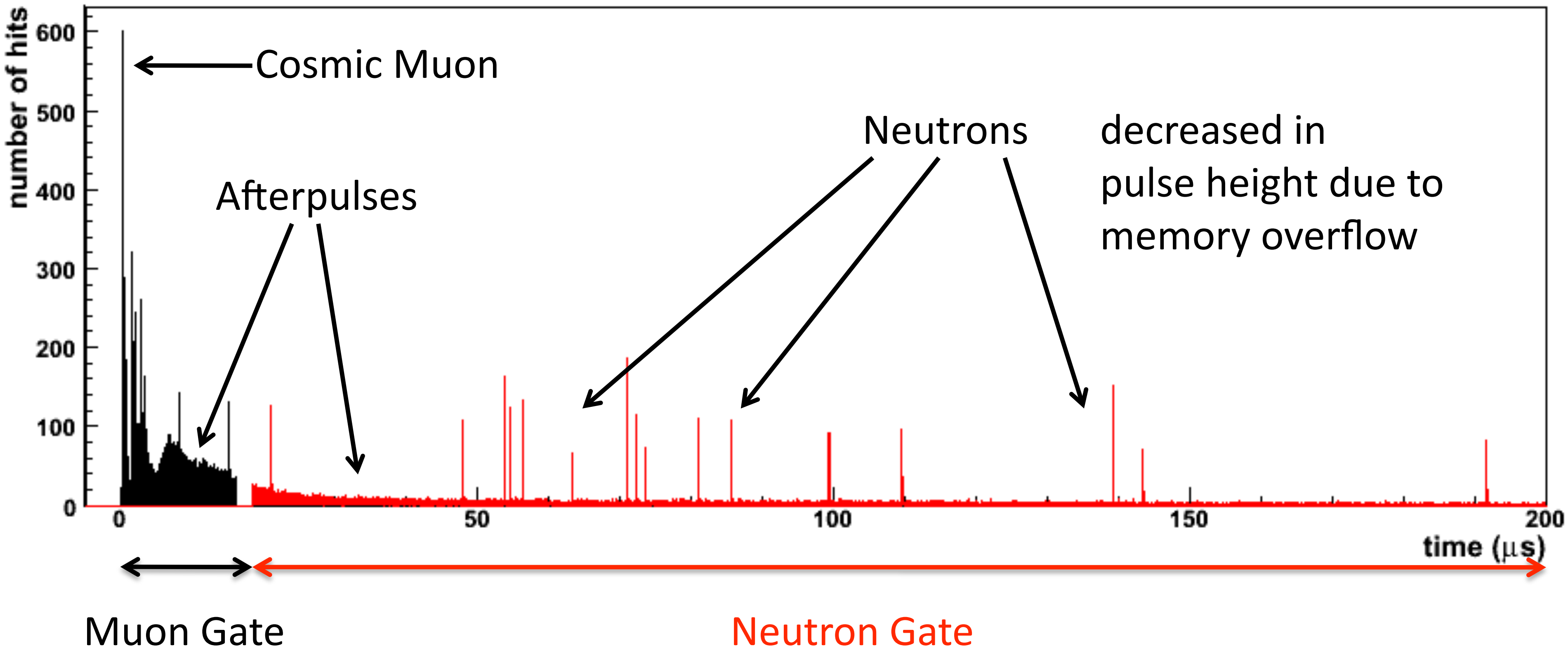
Only the arrival time of the first photon in the integrating time gate is available.

Deadtime

of each individual channel: 150 ns

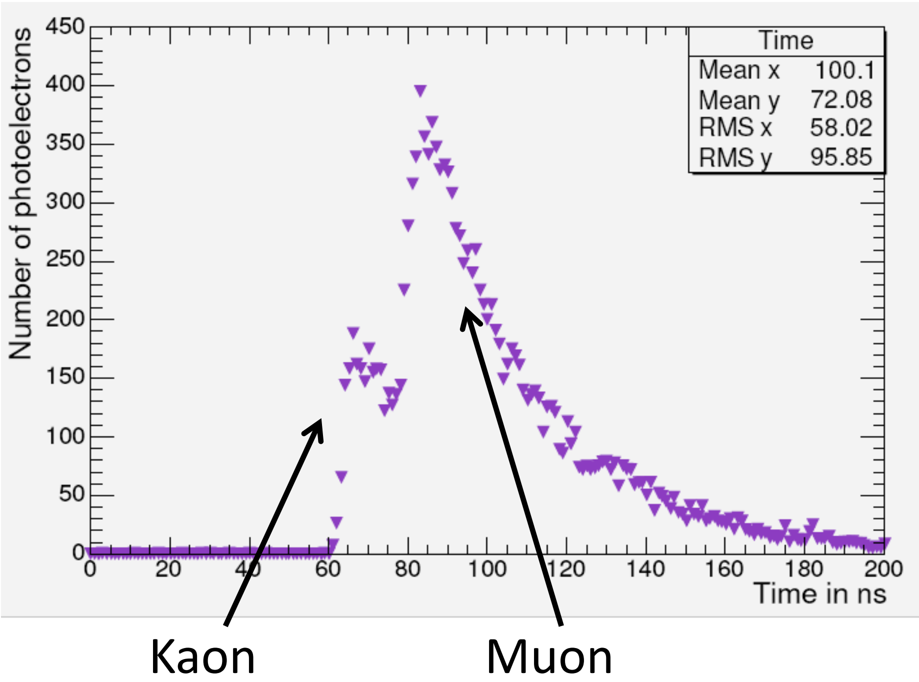
after gate is closed: <2 μs

High-Energetic Events in BOREXINO



detector blinded for several μs after each muon due to afterpulses
very luminous muons decrease the effective pulse height of neutrons
... decrease in neutron detection efficiency
and cosmogenic background rejection

Requirements in LENA



PMTs (20‘‘ or 8‘‘+light cones)
time jitter: <2ns, efficiency: >20%
dynamic range: spe to 100 pe
time and charge calibration

Main DAQ system as in BOREXINO (TDC+ADC signal for each PMT) are sufficient for low-energetic events.

For cosmogenics, suppression of after pulses and improved trigger and DAQ capabilities are necessary.

For proton decay, analog sum of groups of channels (or all channels) is needed to allow for pulse shape analysis on short time scales.

Scalers monitoring groups of channels for control of PM performance.