3rd Roma International Conference on Astro-particle Physics

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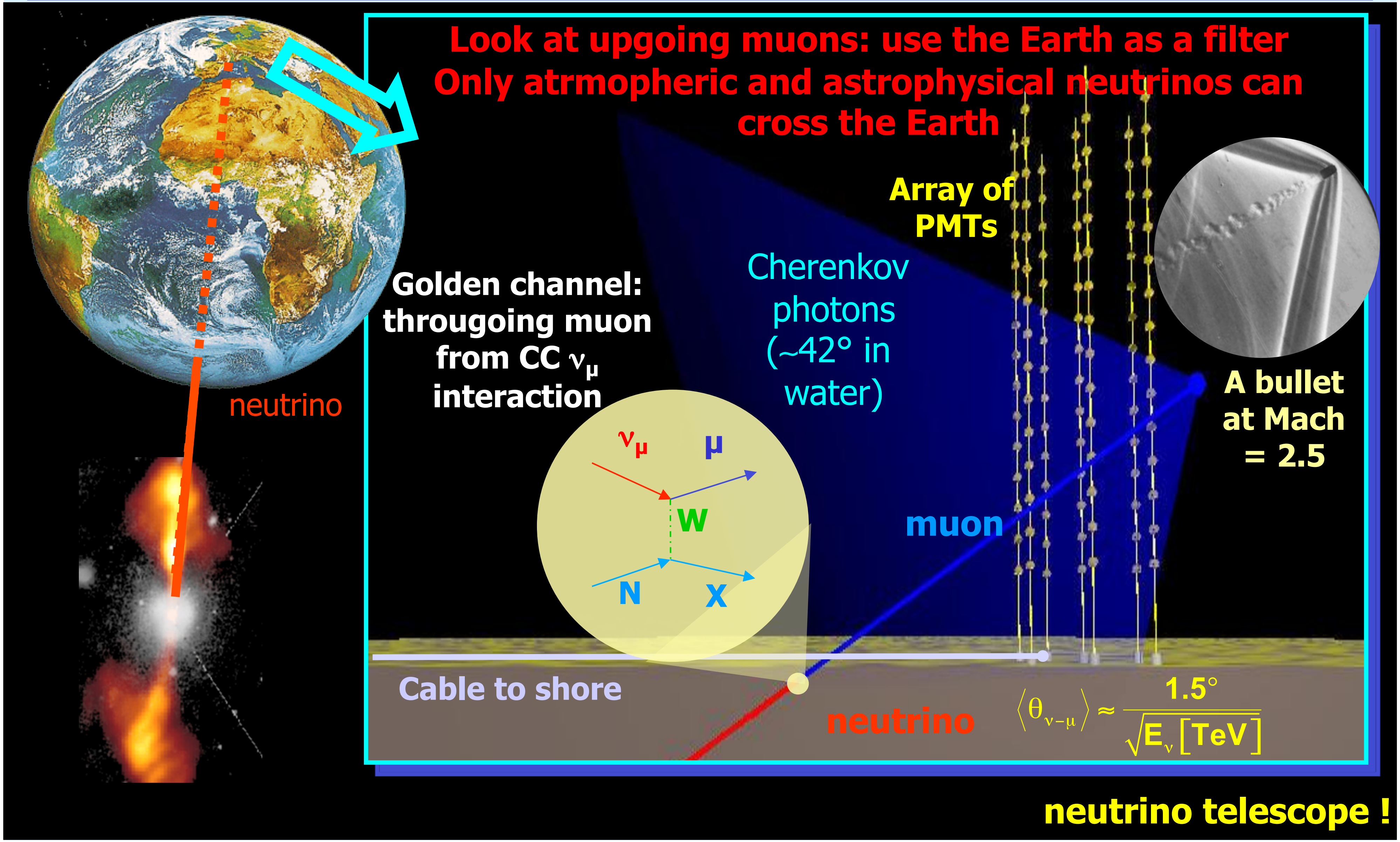
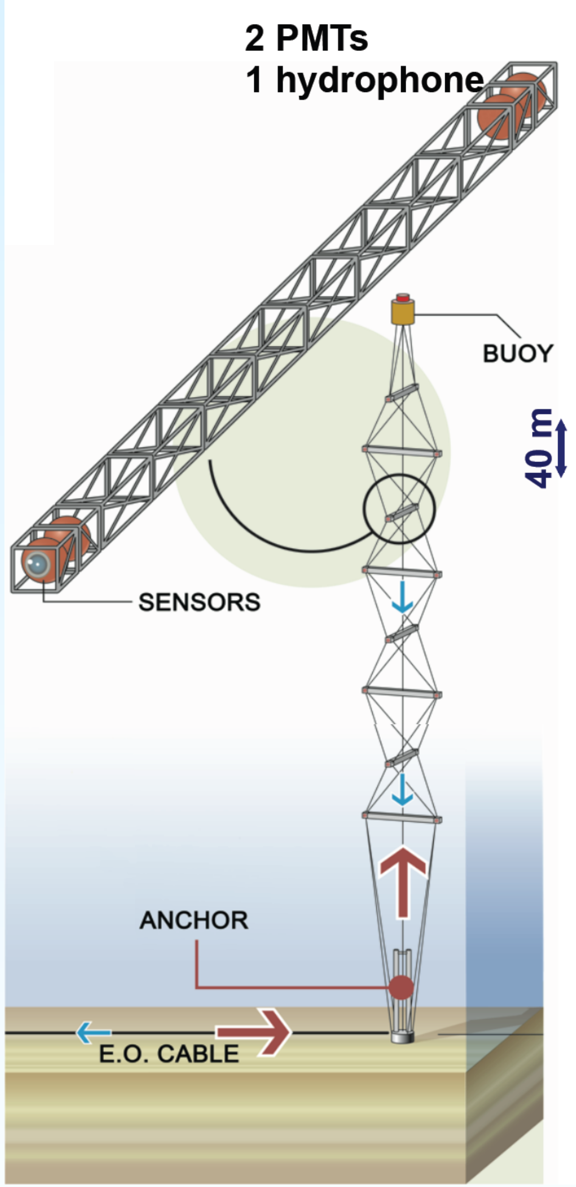
The data acquisition and transport design for NEMO phase 2

F. Simeone on behalf of the NEMO Collaboration

Underwater Cherenkov neutrino detectors



NEMO Experiment



NEMO is an underwater neutrino telescope experiment

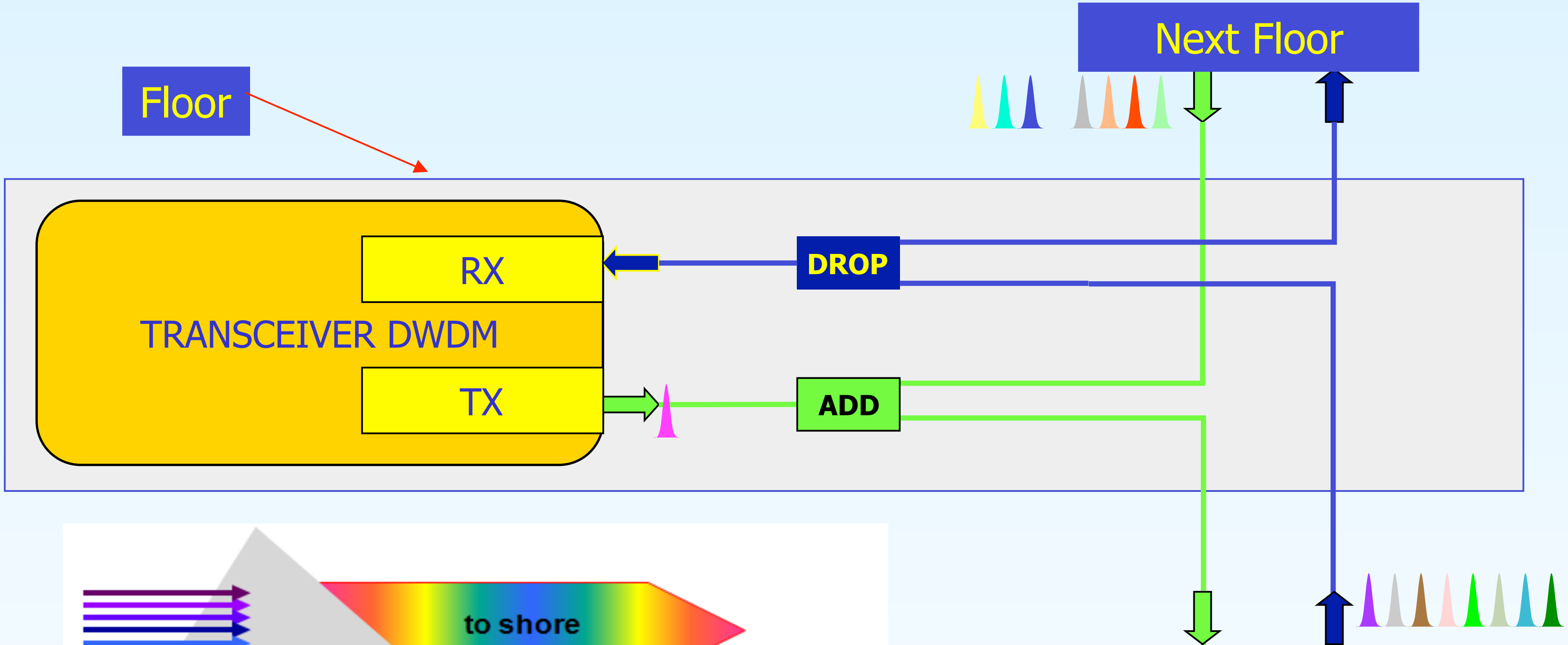
- Events reconstructed with Čerenkov photon detection
- Photo-Multipliers (PMT) are used as sensors
- Background rate (due to ^{40}K) ~70kHz
- PMT Signal Bandwidth <100MHz
- PMT full hit length ~70ns
- Timing coherency on the apparatus scale for hit "time stamping"

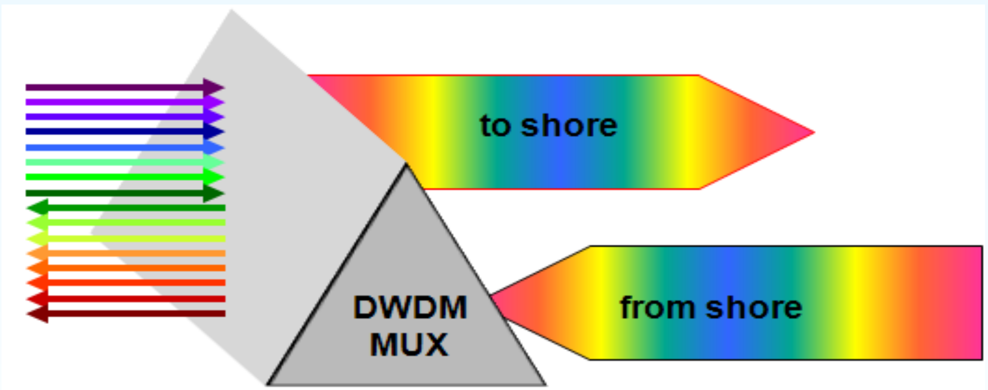
Design Choices

- Optical Signal digitization: sampling 200MHz@8bit
  - ➔Background bit rate per PMT is about 10Mbps
  - ➔4 OMs produce about 40Mbps per floor
- Acoustic Signal digitization: sampling 192Hz@24bit
  - ➔bit rate per hydrophone is about 6Mbps
  - ➔2 hydrophones produce about 12Mbps per floor
- Communication Synchronous Protocol
  - Clock and bit stream on same transport medium
  - Compliant with DWDM standards
  - Reduced number of fibers

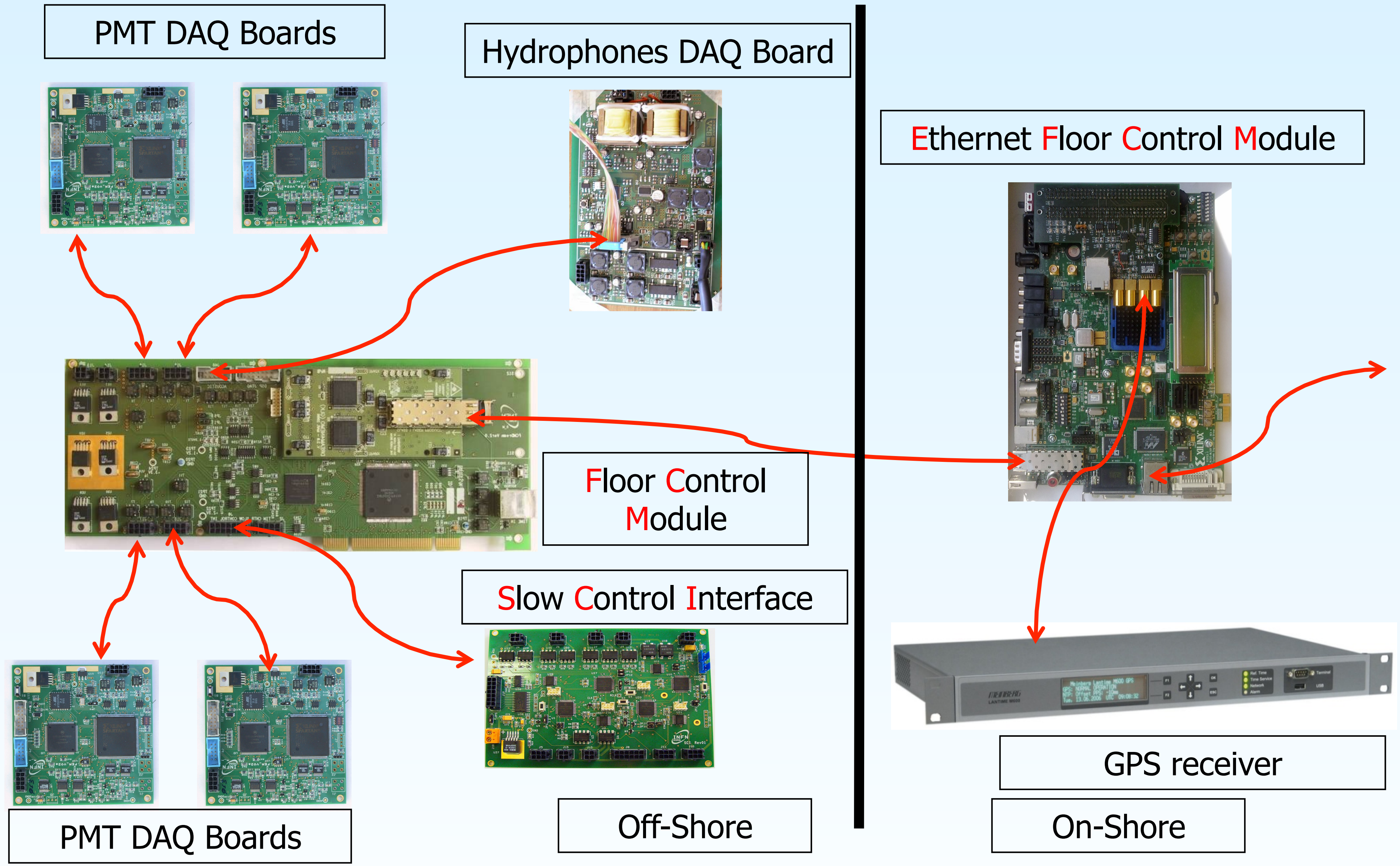
DWDM

Each floor has a point to point communication link





Floor scheme



Floor Control Module Board

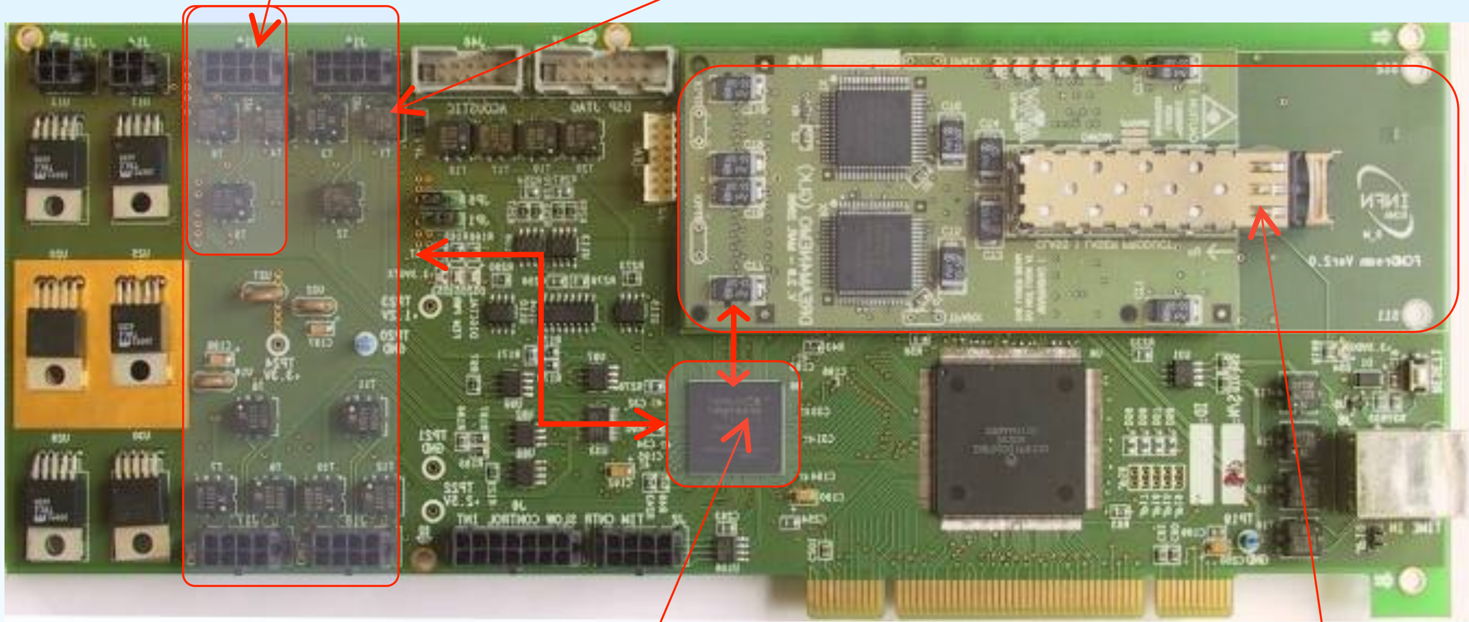
- Off-Shore - On-Shore link
  - Fiber optic interface (DWDM transceiver)
  - FEM Interface (proprietary protocol)
  - Acoustic Interface (AES3 standard protocol)
  - Slow Control Board (SPI standard protocol)

- Communication with other electronics:
  - Slow Control Board
  - Acoustic Board
  - Time Calibration Board
- Safe reconfiguration from remote
- Used on-shore for bidirectional data communication

FCM part I

3 Differential Lines:
- Tx Clock line (5 MHz)
- Tx Data line (5 Mbps)
- Rx Data line (20 Mbps)

Electrical Interfaces for 4 Optical Modules



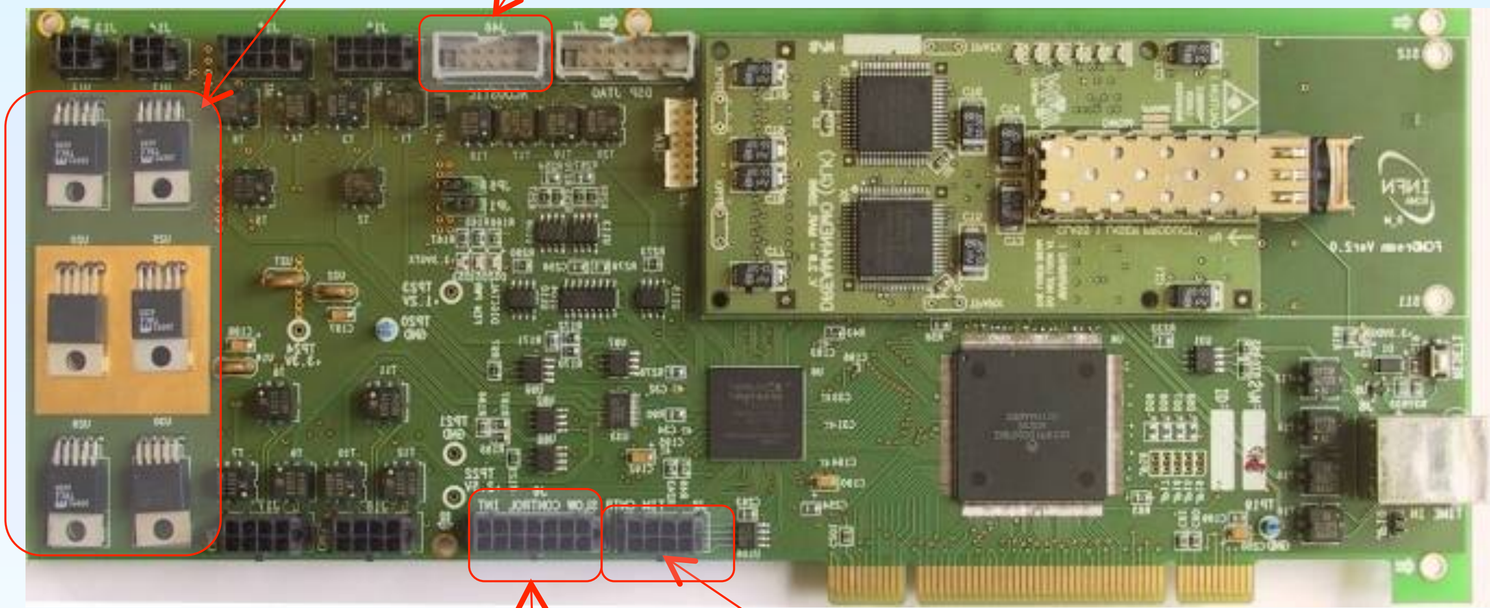
Spartan-3 FPGA
Manage the communication and the interfaces with the other boards

Electro-Optical Interface:
Ser-Des (up to 1.4 Gbps) + DWDM compliant Transceiver

FCM part II

Power Area: linear regulators to minimize noise.

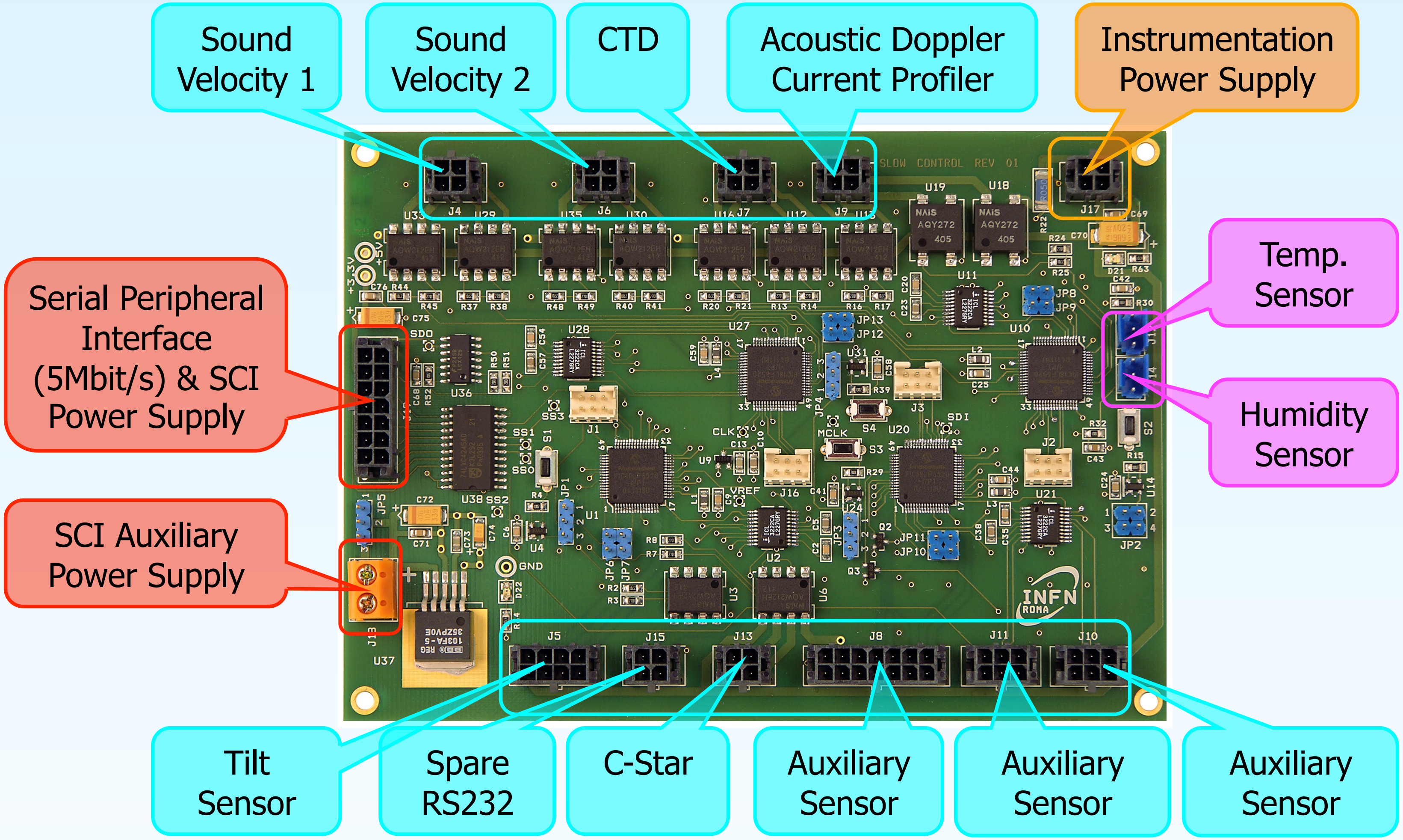
Acoustic Board link (AE3 standard)



Slow Control board connector: electrical link with SPI interface

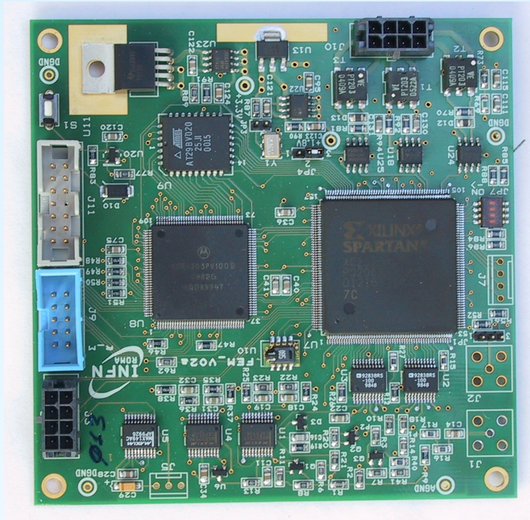
Time calibration connector: send trigger signal synchronous with the master clock.

Slow Control Interface



Front End Module Board

- Signal sampling: two 100 MHz 8bit-ADCs
- Analog conditioning:
  - quasi-logarithmic compander => 13 bit
  - on-board calibration circuit
  - ADCs pedestal adjustment
- PMT HV management
- Low Power: 0.3A @ 3.3V
- Safe reconfiguration from remote



FEM Board: interface

Local sensors (temperature, humidity) and front-end setup

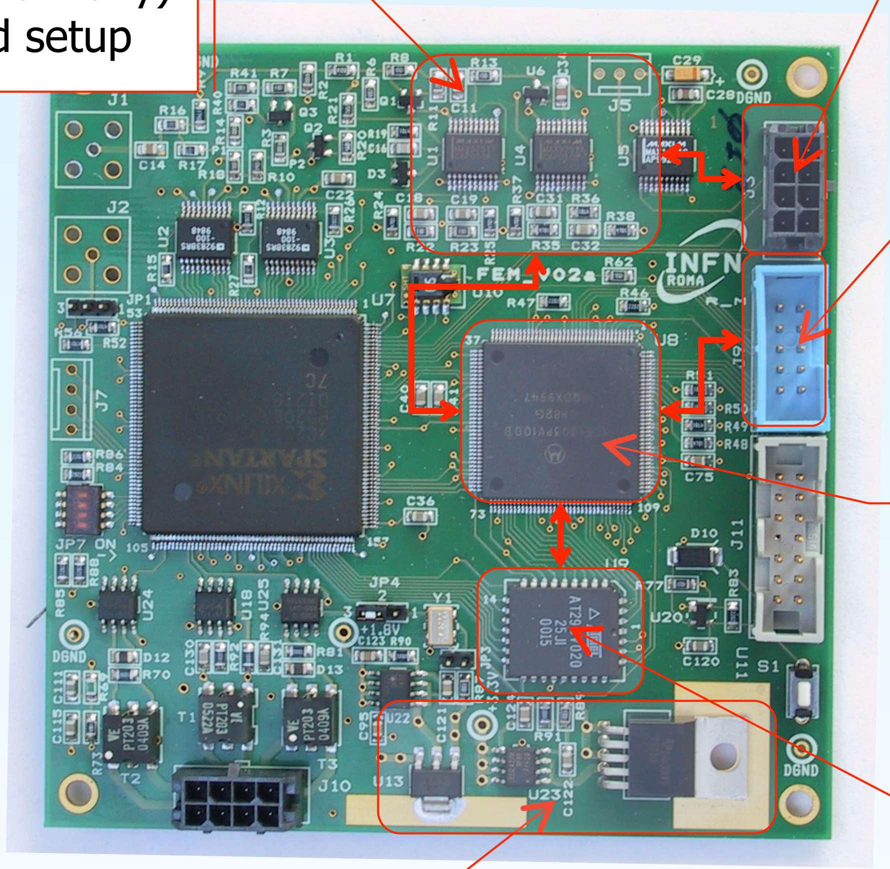
PMT electrical interface

Serial interface for test, debug and stand-alone operations

Local processor for start-up, debug and board monitoring

Flash EEPROM (remotely reprogrammable)

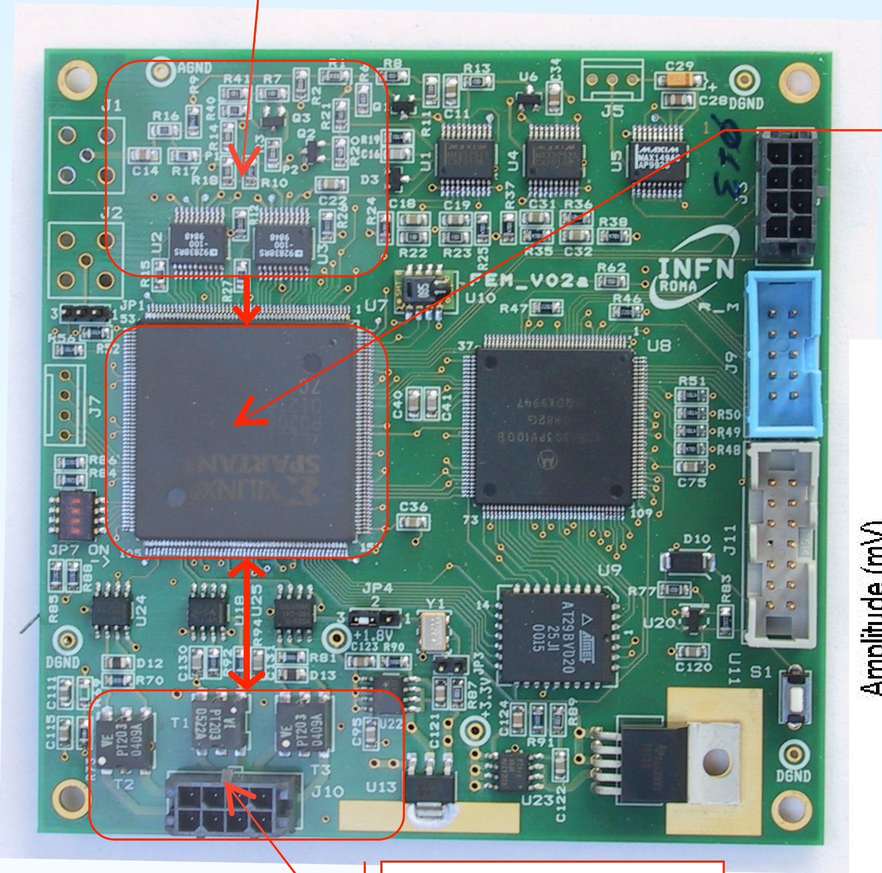
On-board power regulators

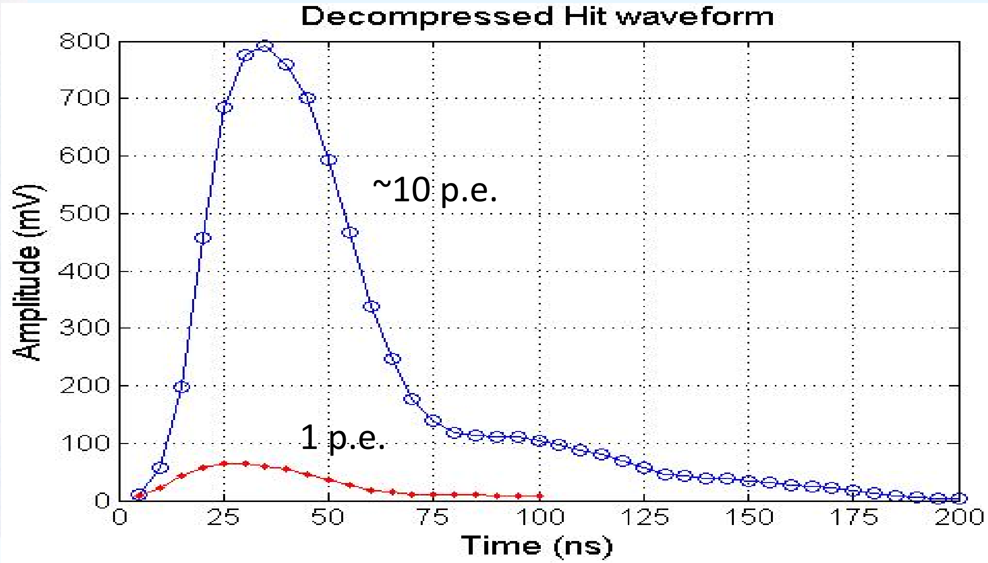


FEM Board: PMT signal

Analog conditioning and digital sampling of PMT signal

Spartan IIE FPGA:
L0 trigger, FIFO, data coding and line interface



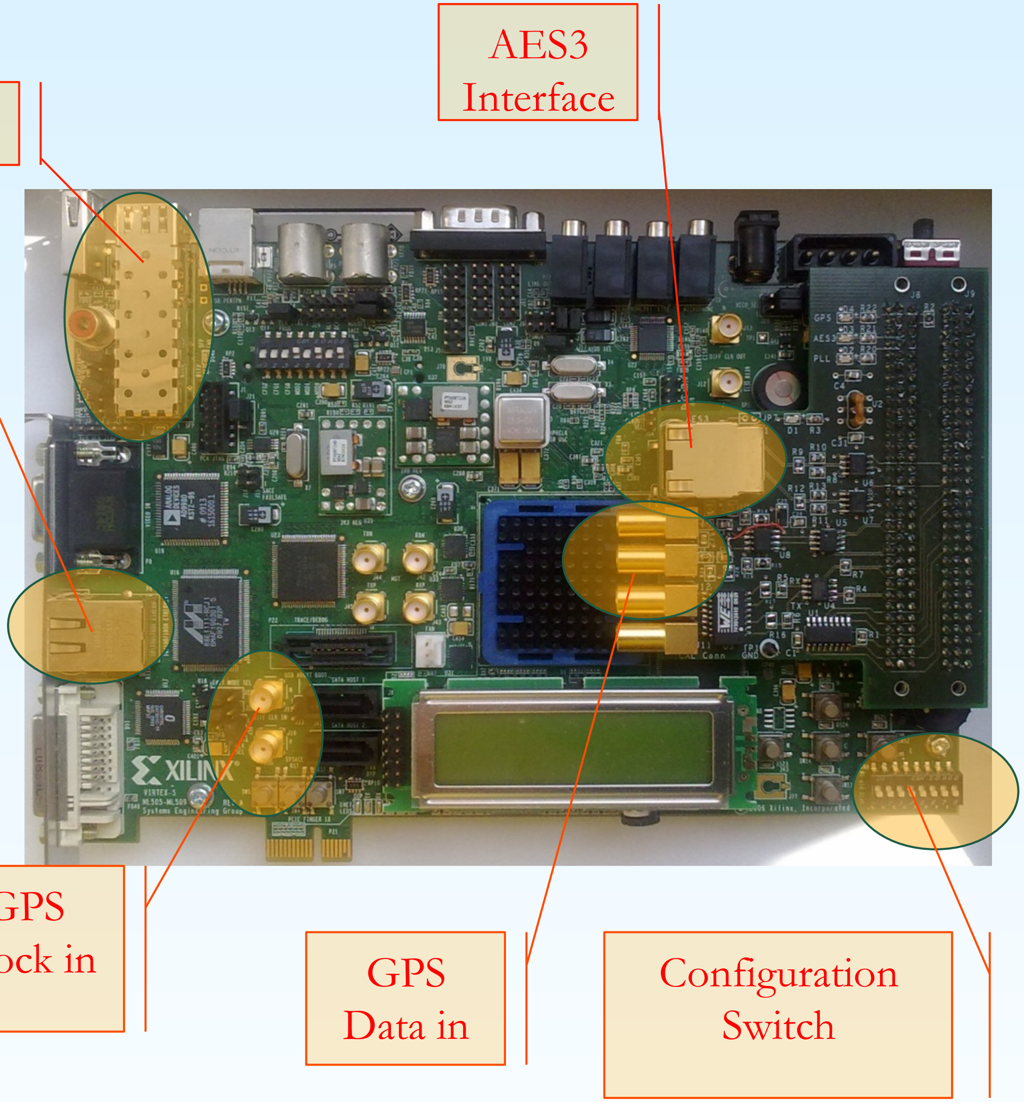


FCM – FEM Interface

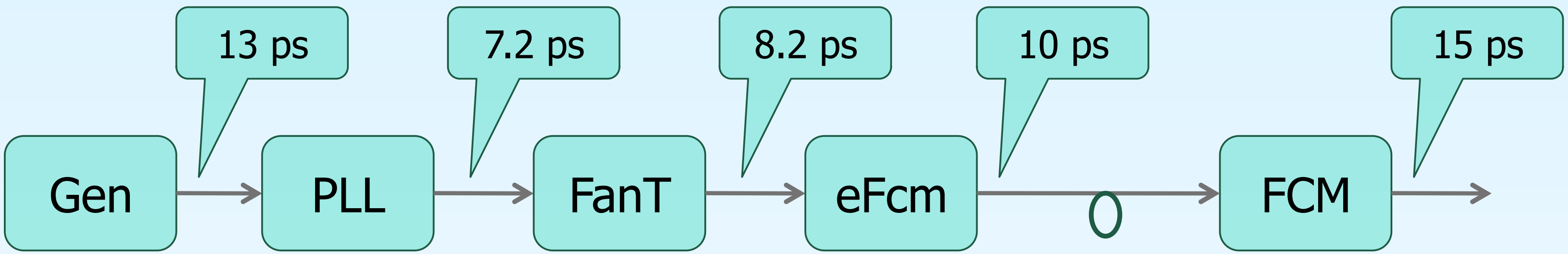
eFCM Board

Xilinx Virtex5 development board:

- •Embedded PowerPC
- •Embedded uBlaze
- •Receive and distribute underwater the GPS clock
- •Manage the optical communication with the underwater floor
- •Extract the acoustic signals and distribute them over a dedicated physical link
- •Extract the PMT signals and distribute them over a gigabit ethernet
- •Manage the point-to-point connection with the remote instruments



Jitter measurement



Board	Jitter$_{RMS}$ [ps]
Generator	13
PLL	7.2
FantimeV1	8.2
eFcm	10
FCM	15

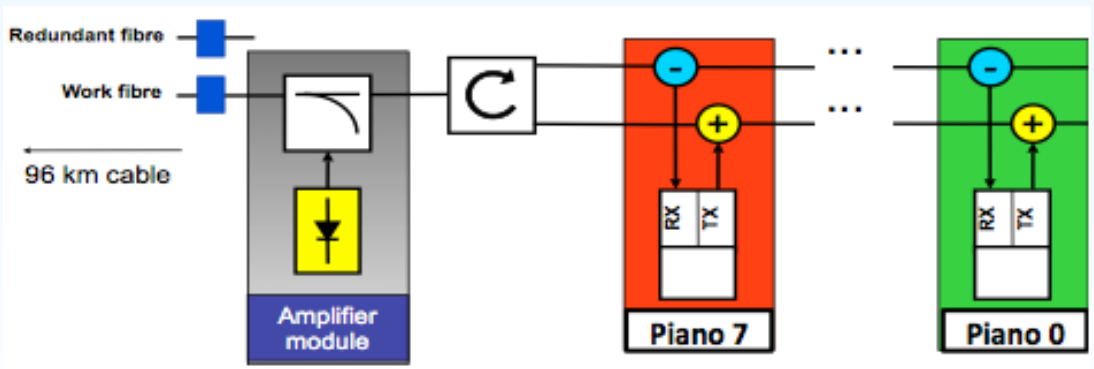
Link budget

Test bench: losses of passive components	Power levels [dBm]
Single Channel launched power	1,71
submarine cable output	-17,93
3 dB coupler	-20,93
Circulator	-21,25
Add & Drop - Power Control	-22,8
Add & Drop - Acoustic Positioning	-23,12
Add & Drop - 1° and 3°	-24,34
Add & Drop - 5° and 7°	-24,96
Add & Drop - 11° to 15°	-25
Circulator	-26,55
Add & Drop #8	-3,2

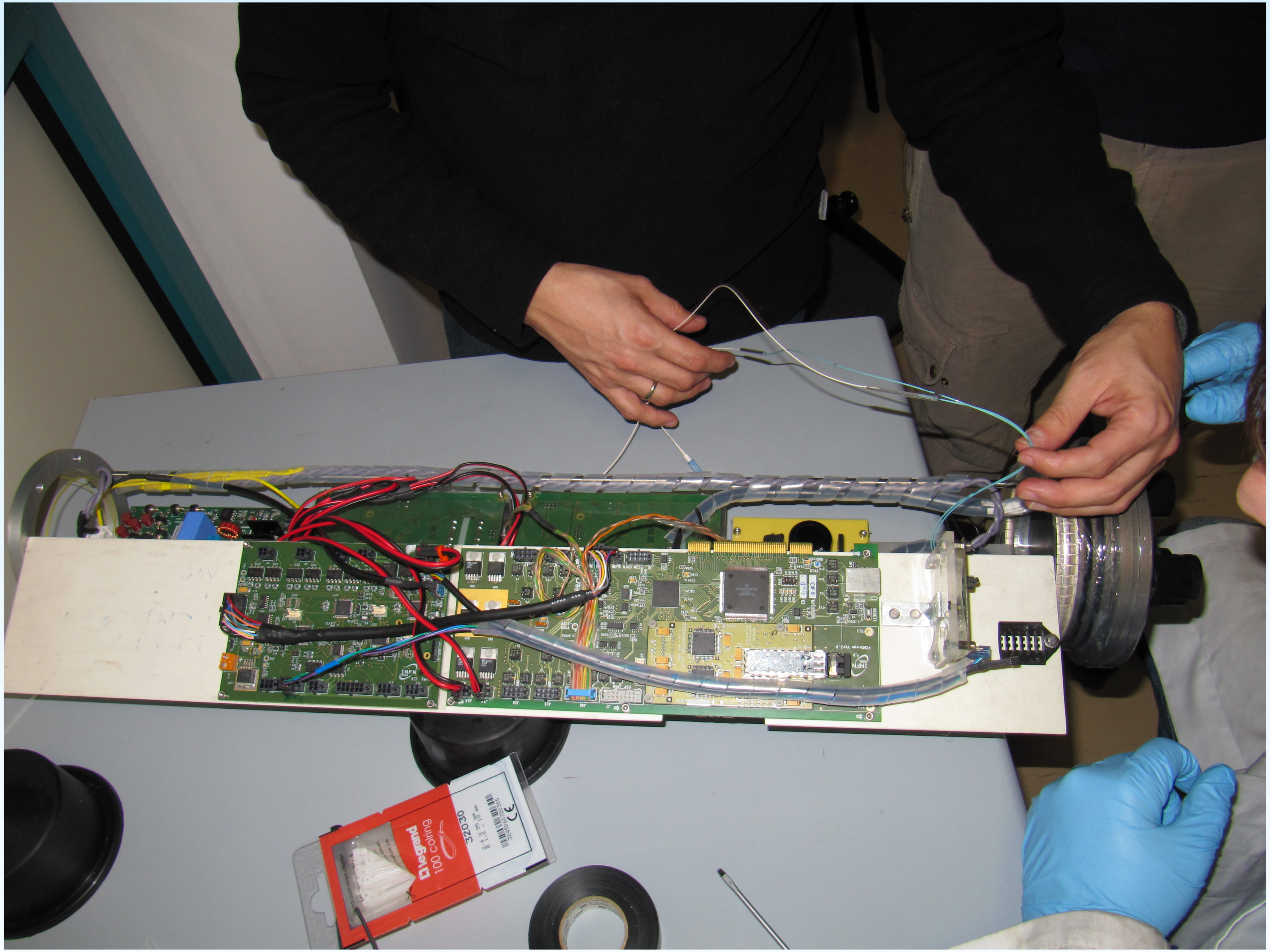
Cable Termination Assembly and VEOC losses	Worst Case	Mean Value
optical connector (ALCATEL CTA)	-0,75	-0,3
ROV mateable connector (ALCATEL CTA)	-0,75	-0,3
ROV mateable connector (DU)	-0,75	-0,3
Optical connector in VEOC	-0,75	-0,3
Add & Drop #8	-3,2	-1,6
Optical power at receiver input	-32,75	-29,35
Receiver sensitivity	-33	-33
Sistem Margin [dB]	0,25	3,65

38dB for a BER of 10^-12 at 800Mb/s

8.65dB margin without the raman amplifier



Floor integration



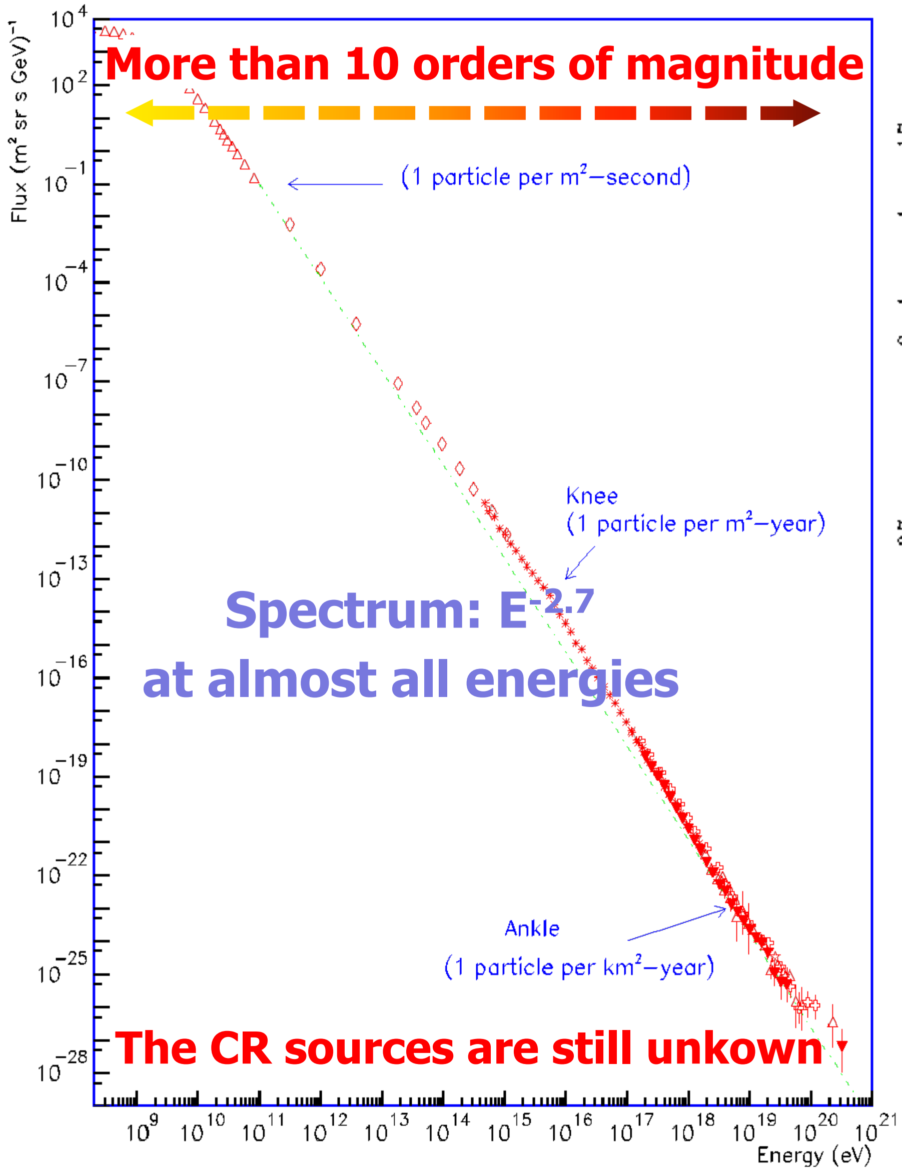
Floor vessel assembly

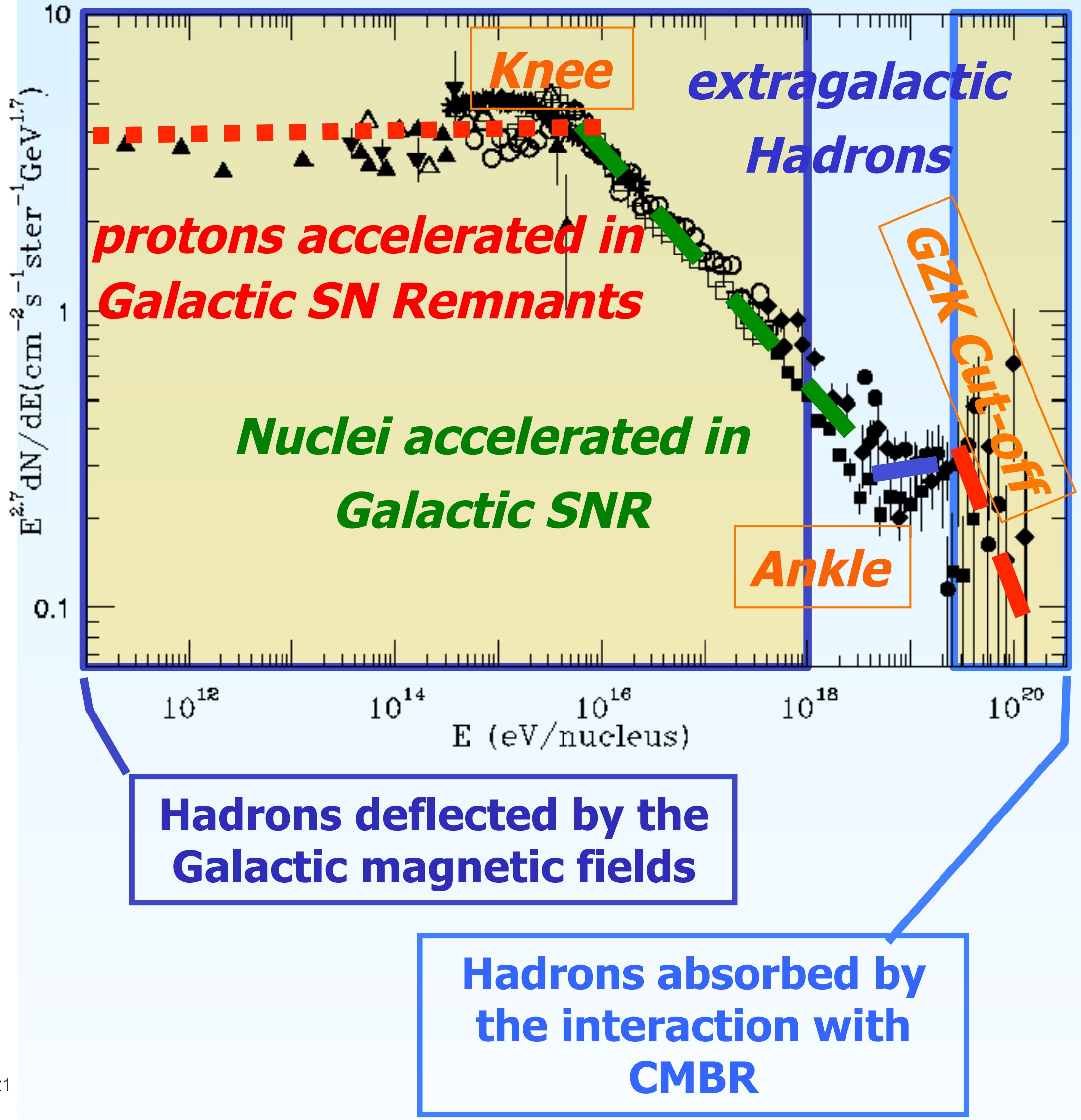
Conclusions

- The synchronous protocol simplifies the overall design
- Transmission exploits optical passive devices
- The transmission latency is fixed
- The FCM board implements a point to point synchronous link between boards and sensors using different protocols.
- Powerful mechanism of safe reconfiguration
- Usefulness of hit waveform for DAQ tuning
- Tower deployment foreseen by the end of the year

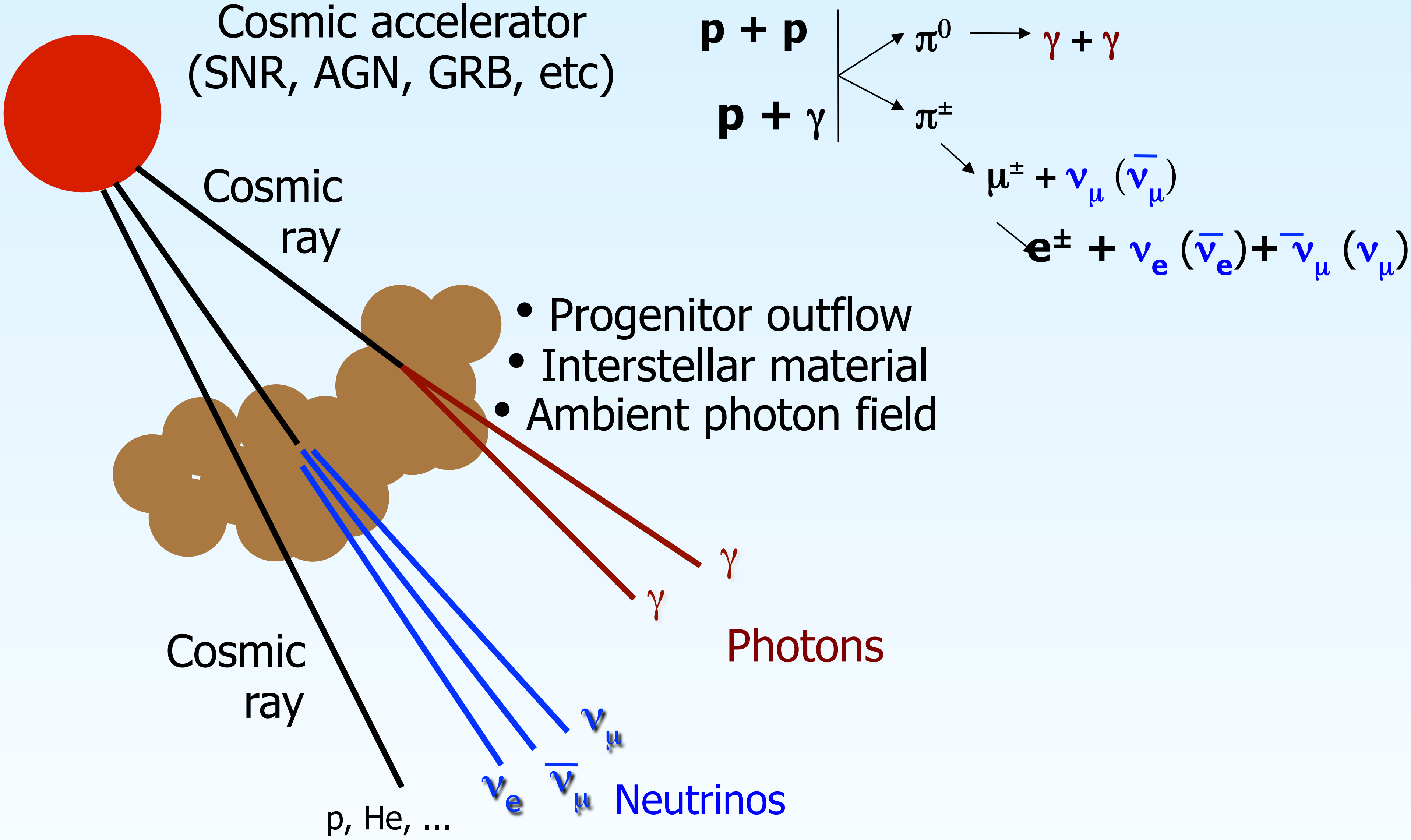
BACKUP SLIDES

The Cosmic Ray Spectrum

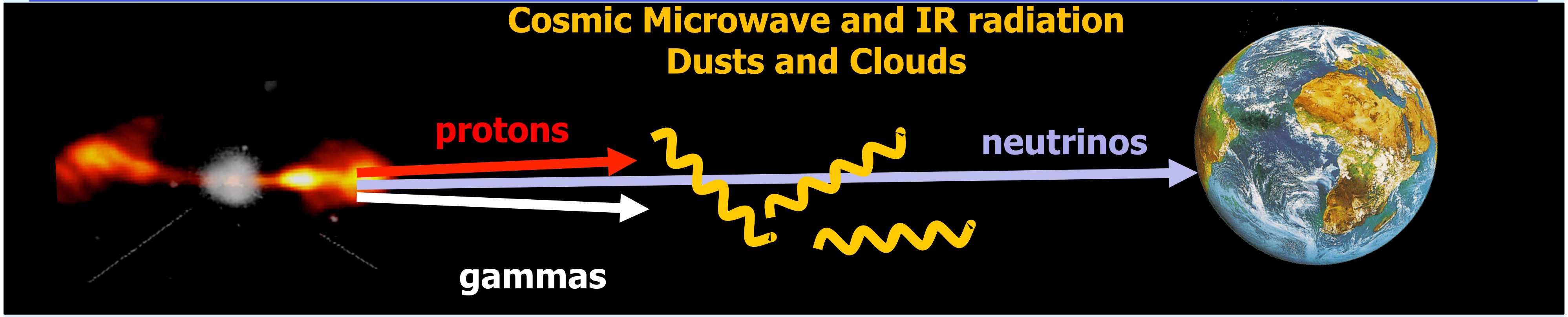


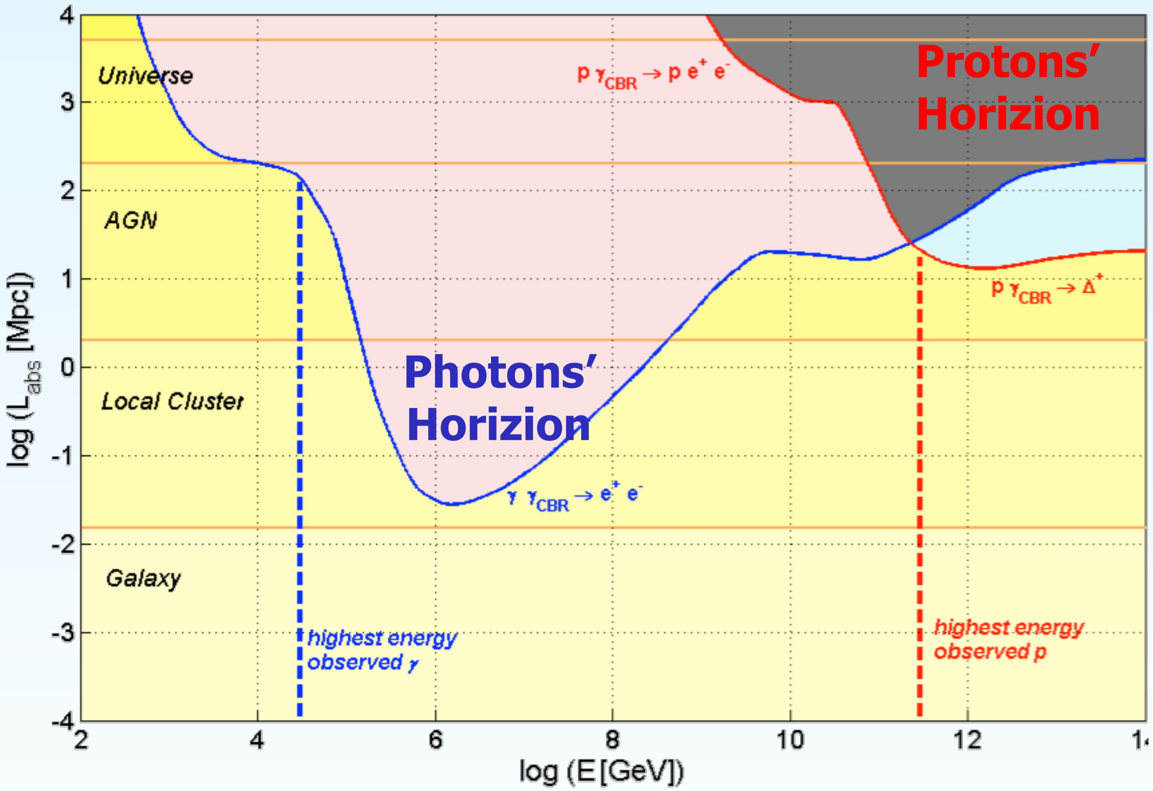


Cosmic Ray, Gamma Ray and Neutrinos



Absorption lenght of protons and gammas in the Universe



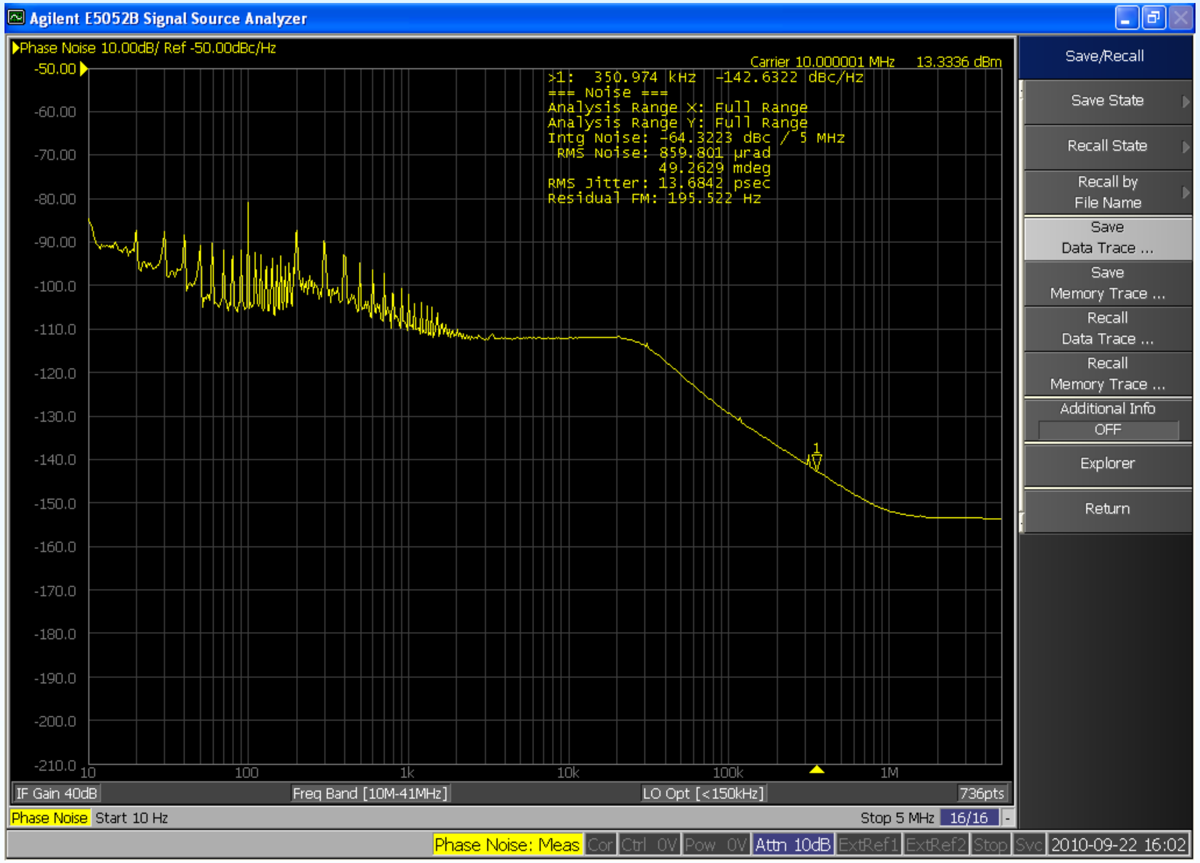


Neutrino astronomy can:

- ***probe the far and violent Universe***
- ***disentangle between pure leptonic and hadronic acceleration models***

Measures: Jitter

- Clock generator (80 MHz):
  - Jitter = 13 ps

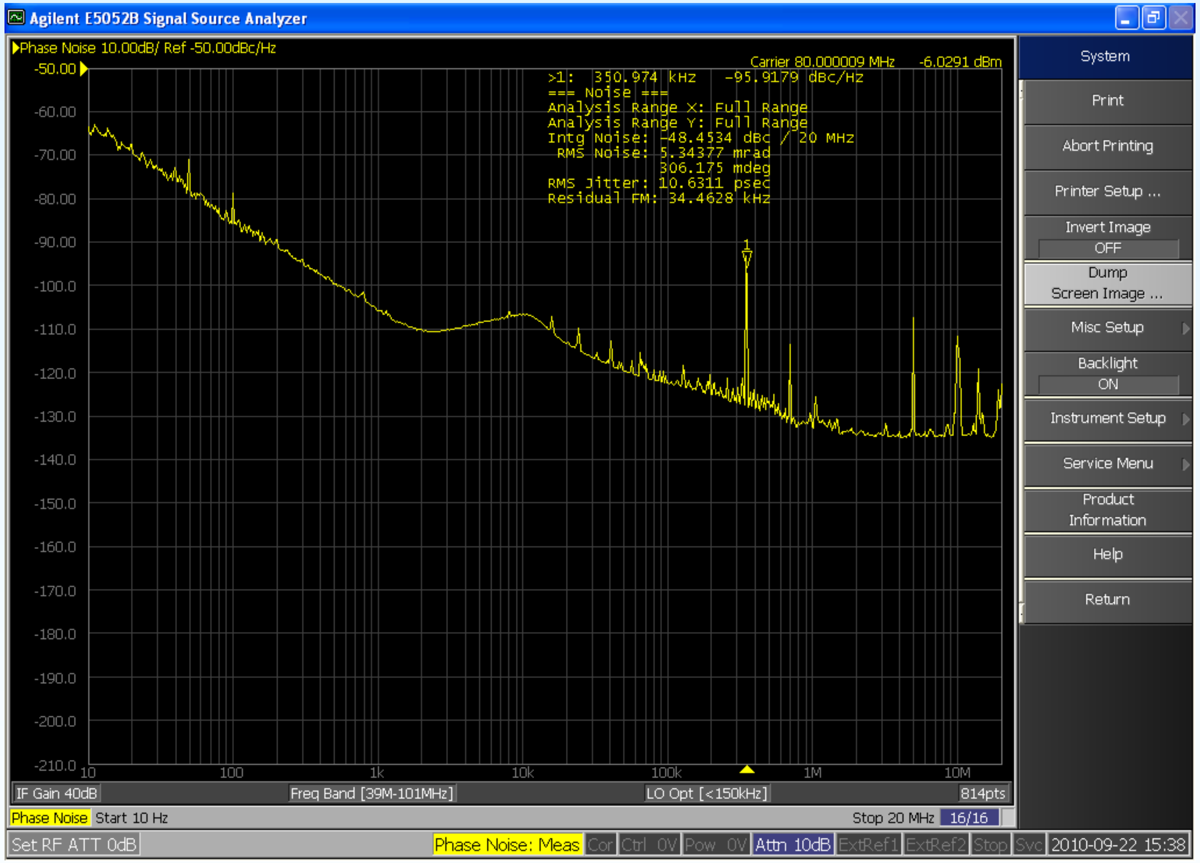


- Dejittered clock from PLL (80 MHz):
  - Jitter = 7.2ps

Measures: Jitter

- LVDS clock distributed by FanTime (80 MHz):
  - Jitter = 8.2 ps

- eFcm Transmit Clock (40 MHz):
  - Jitter = 10.6 ps
  - Measured on ML507 SMA connector;



Measures: Jitter

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- Off-Shore recovered clock (40 MHz):
  - Jitter = 15 ps