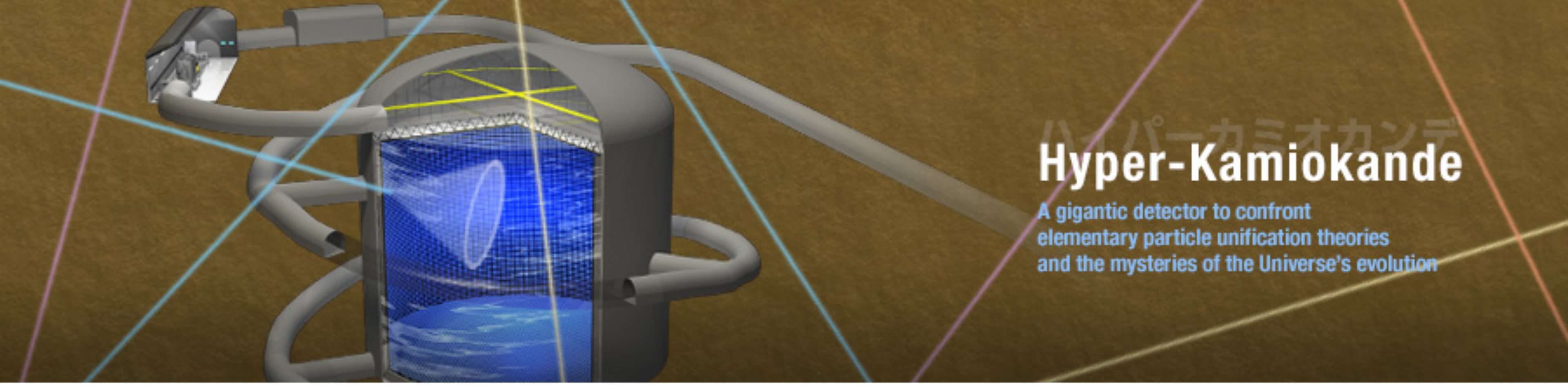

A multi-PMT photodetector system for the Hyper-Kamiokande experiment

Vincenzo Berardi

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On behalf of the Hyper-Kamiokande Proto-Collaboration

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Hyper-Kamiokande

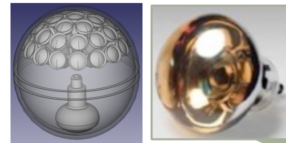
Water Cherenkov detector in Kamioka, Japan

Hyper-Kamiokande (HK)

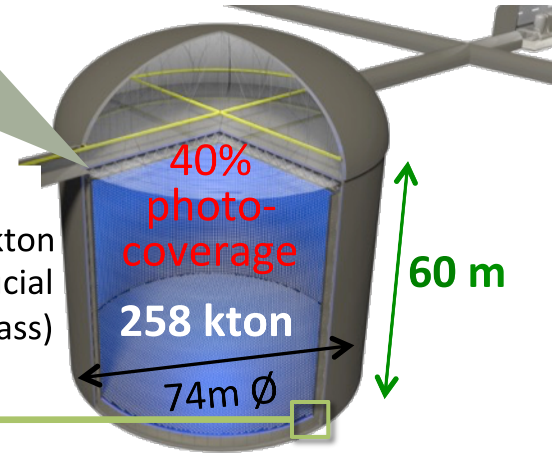
New high-QE 50 cm Box&Line PMT

×2 high pressure bearing for 60 m depth

×2 high detection efficiency
and half time&charge resolutions



Planned 40,000 photosensors
Baseline option: 20'' PMTs
Alternative option:
50% 20'' MPTs and 50% mPMTs



(187 kton Fiducial Mass)

compared to Super-K PMT (up to ~40m depth)

About 7,000 PMTs
for Outer Veto Detector

Requirements

Rich physics programs

- ν oscillations
  - Leptonic CP violation, ν mass hierarchy, …
- Nucleon decay discovery
- ν astrophysics
  - Supernova burst ν, …

→ Wide dynamic range

→ High time&charge resolutions, high detection efficiency, ..

→ ~nsec time resolution,

→ Clear photon counting,

low background

→ High rate tolerance

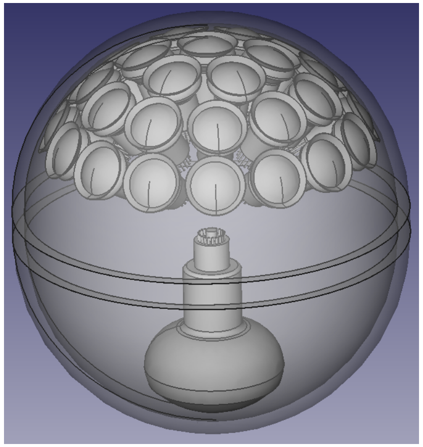
- *Large aperture photodetectors are essential for physics sensitivities.*

Multi-PMT Option for Hyper-K

- Multi-channel optical module

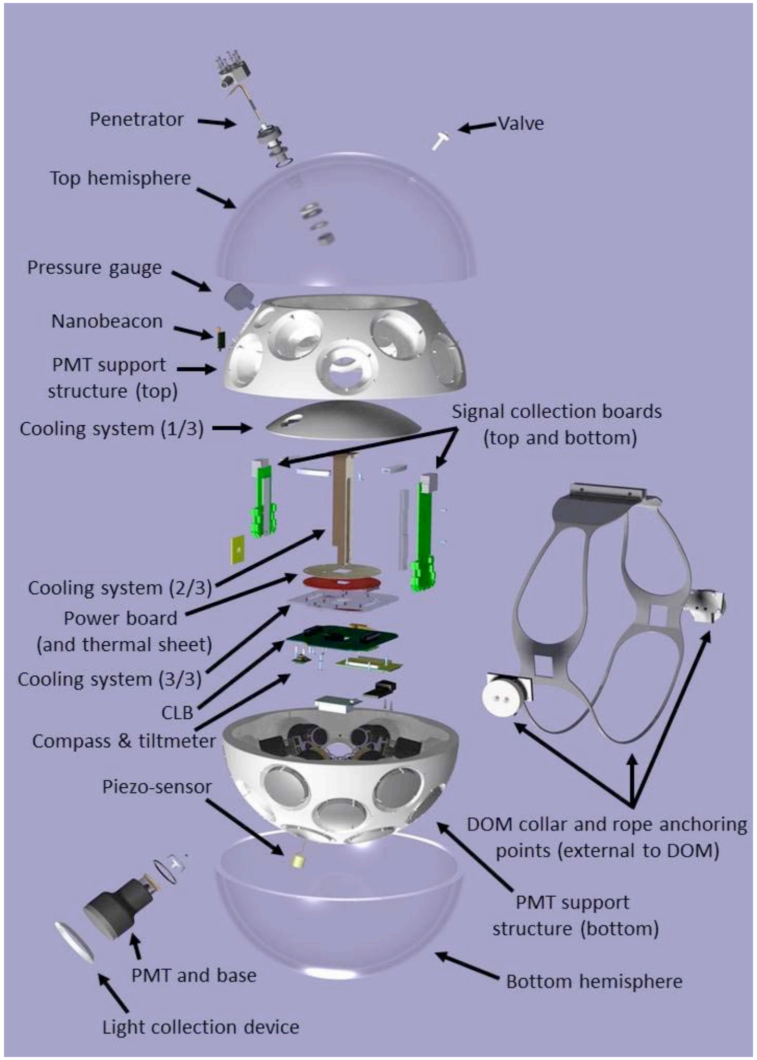
Photodetectors and electronics arranged inside a pressure resistent vessel

- (Almost) uniform coverage by PMTs
- Directionality
- Several manifacturers



(Concept design)
3-inch PMTx33

Based on KM3NeT optical module



mPMT Prototype

Main limits of KM3NeT solution for HK project:

- Vessel:
  Km3Net experience demonstrated that glass spheres are characterized by high ^{40}K and other radioactive contamination.

- PMT Read-Out:
  In Km3Net the time over threshold (ToT) strategy is exploited; this is not a good solution for HyperK project in which charge measurement is important

Large PMT vs mPMT?

Detector	Directional sensitivity	TTS	QE	Dark rate
mPMT (3'' PMT)	1/6 of solid angle	1.3 ns	27% (35% super-alkaline PhotoC.)	10 kHz
20'' PMT	1/2 of solid angle	2.7 ns	30%	8 kHz

- CC1π:
  - Increase in acceptance for long baseline neutrinos
  - currently, large background from π^0 with 1γ missed
    - ➢ *missed 1γ may be tagged with finer granularity with mPMT.*
- Exclusive multi-ring event reconstruction:
  - Important for mass hierarchy study
    - ➢ *Reduces the systematics from τ contributions*.
  - multi-ring efficiency can be improved by finer granularity

- **More physics justifications for mPMT.**
- **Many efforts how to manage mPMT tasks (ph**otosensor, readout electronics, support structure, calibration, (DAQ, software))

3'' PMT by Hamamatsu

PMT R-12199 Hamamatsu

QE: 21% (@470nm); 26.9% (@390nm)

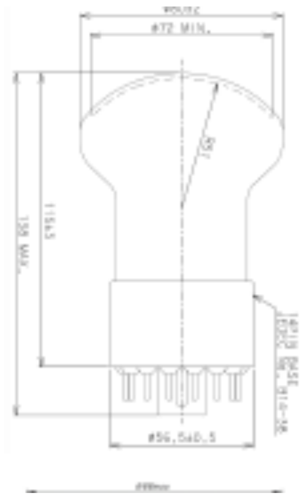
TTS: 1.67 ns

Dark Counts: 86% tested for KM3NeT < 2 kHz

Gain: $5 \cdot 10^6$

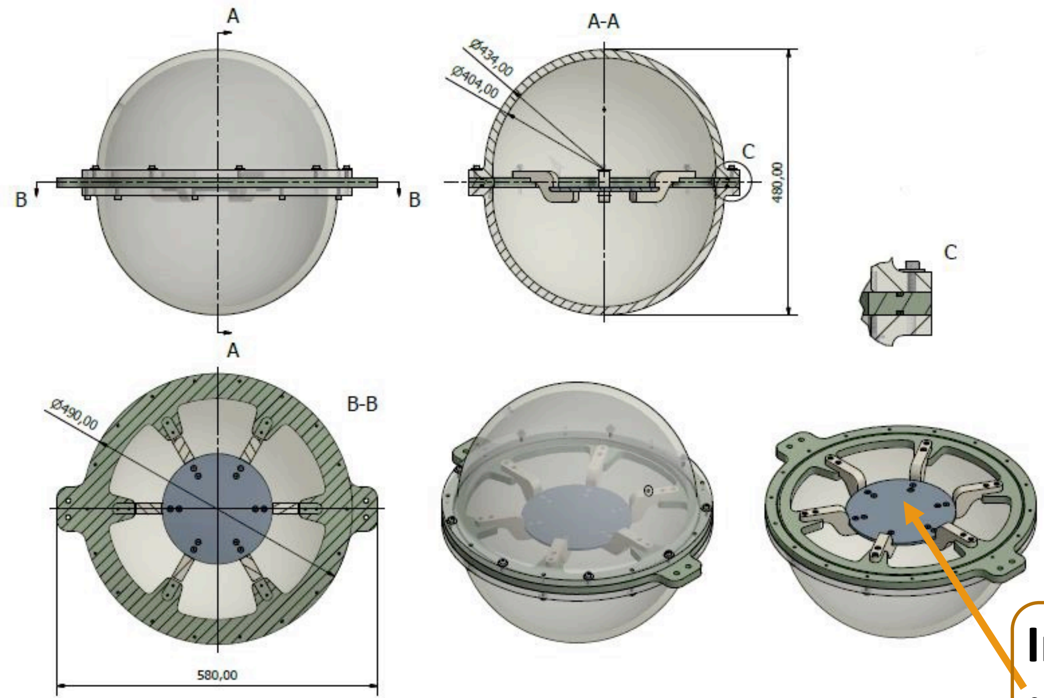
Peak-to-valley ratio: 3.3 @ 1.1 kV

- Hamamatsu R14374 new 3-inch PMT
  - modified version of R12199 used by Km3net
  - QE=28% @400nm
  - TTS(FWHM) = 1.3nsec (4.5nsec for R12199)
  - Dark rate = 500-1000Hz



PressureVessel

The acrylic vessel of the first prototype will be a sphere with a **diameter of about 17”** (432 mm, like in Km3NeT) and a thickness of 18 mm.



A **preliminary** sketch for acrylic spherical vessel + cooling (seal) system

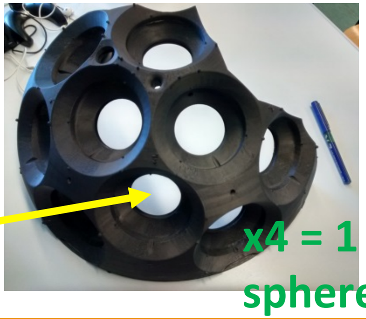
A seal will be used between the acrylic hemispheres and metal support.

A mechanical closure guarantees:

- longer endurance
- Easier and better assembling
- Good cooling system by a metallic flange

Inside:

- Read-out system
- PMT support
- 3’’ PMTs



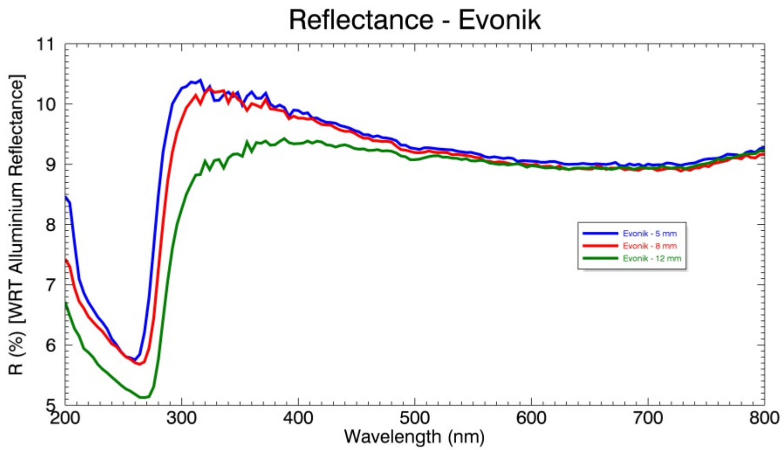
Requirements (from SK)

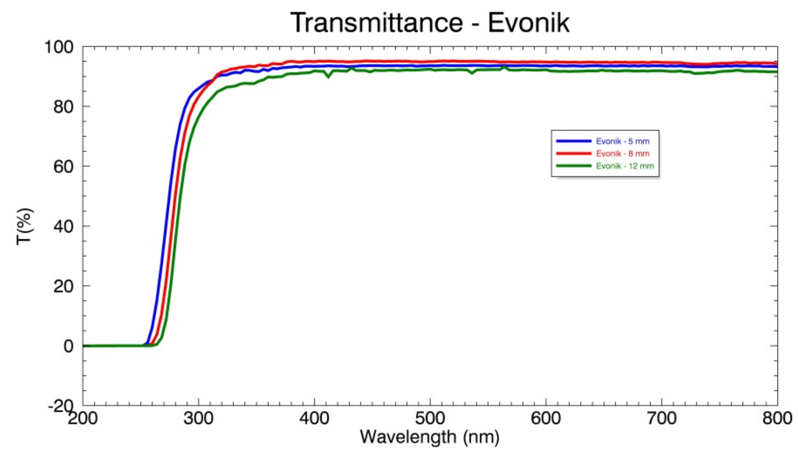
wavelength (nm)	minimum(%)	maximum(%)
300	76.5	83.8
310	80.0	86.0
320	81.7	87.0
325	83.0	87.5
340	85.0	89.3
350	86.5	90.3
360	87.5	91.0
375	89.0	92.0
380	89.2	92.3
400	90.0	93.0
800	91.0	94.0

Table 1: Transparency of Super-Kamiokande acrylic

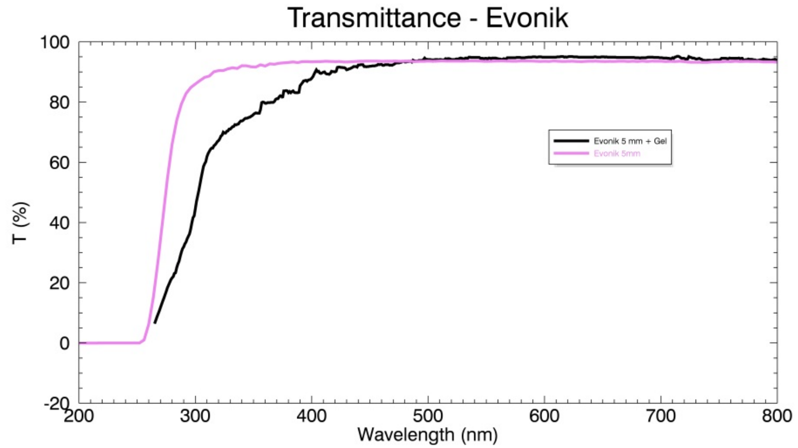
PressureVessel

Several acrylics tested: **PLEXIGLAS® GS UV Transmitting by Evonik** choosen for the construction of the first mPMT prototype for Hyper-K





Checked compatibility between optical gel and acrylic and measuread the transparency of acrylic+optical gel.



Radioactivity

- **Radioactivity measurements** (at LNGS)
- Contamination results are here reported

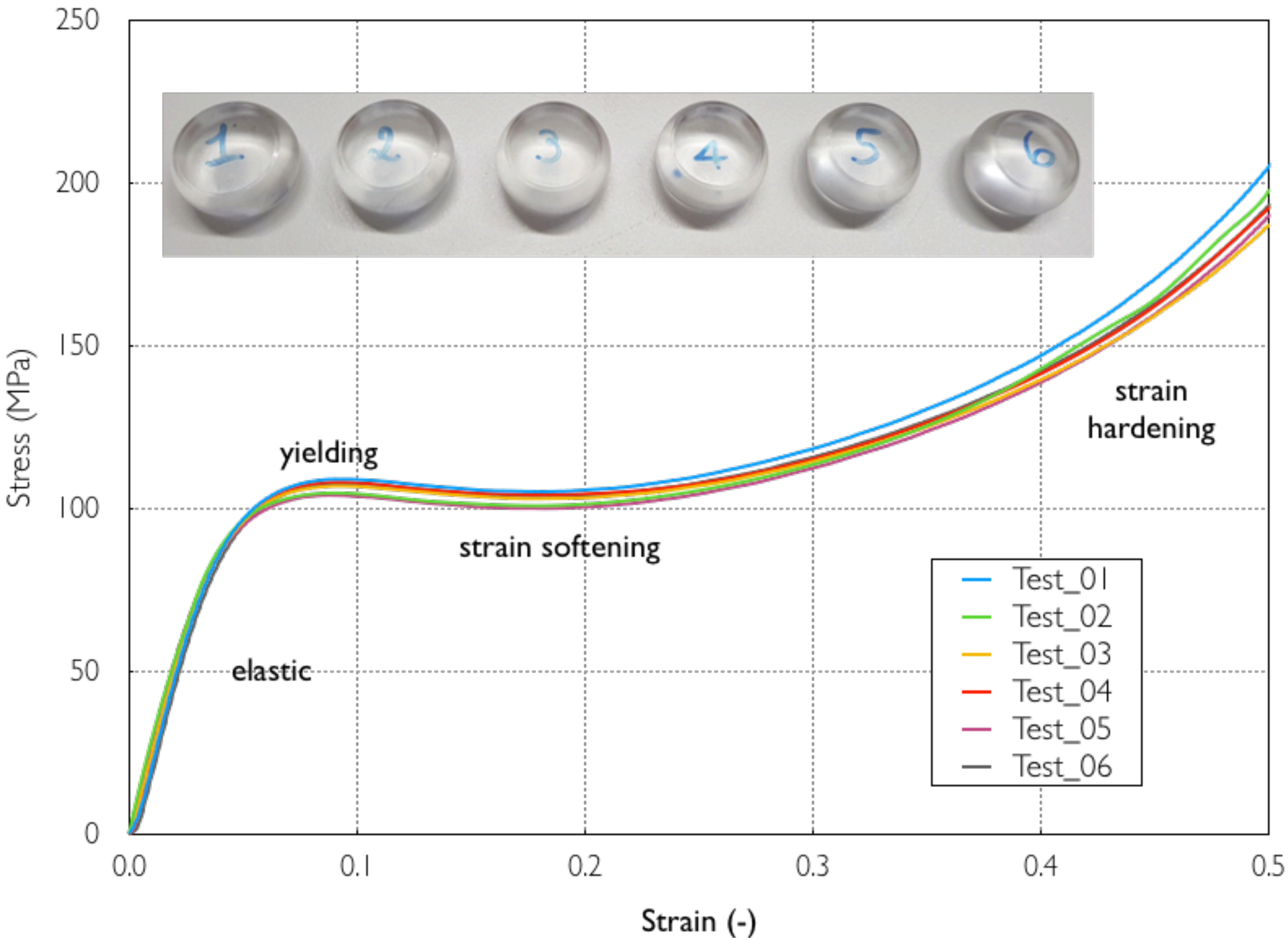
Isotope	Activity	Contamination
	^{232}Th: Thorium series	
Ra-228	< 0.11 mBq/kg	< 0.027 ppb
Th-228	< 93 μBq/kg	< 0.023 ppb
	^{238}U: Uranium series	
Ra-226	< 65 μBq/kg	< 0.0052 ppb
Th-234	< 4.6 mBq/kg	< 0.38 ppb
Pa-234m	< 2.5 mBq/kg	< 0.20 ppb
U-235	(0.15 ± 0.07) mBq/kg	$(3 \pm 1) \cdot 10^{-1}$ ppb
K-40	< 0.69 mBq/kg	< 0.022 ppm
Cs-137	< 25 μBq/kg	-

Evonik acrylic.
Weight: 13.4567 kg;
Live time: 22 days

Requirements:
U-238 < 0.3 ppb
Th-232 < 1 ppb
K-40 < 0.3 ppm

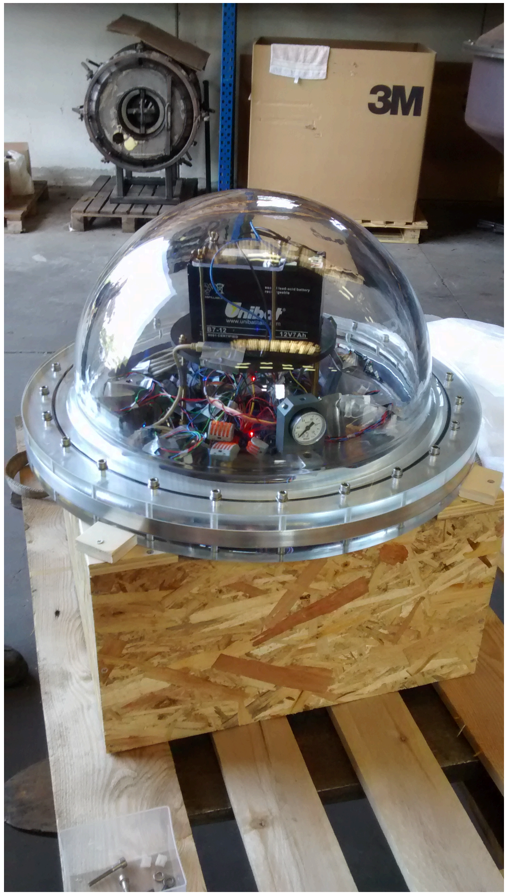
This positive concentration of U-235 has been investigated in detail.

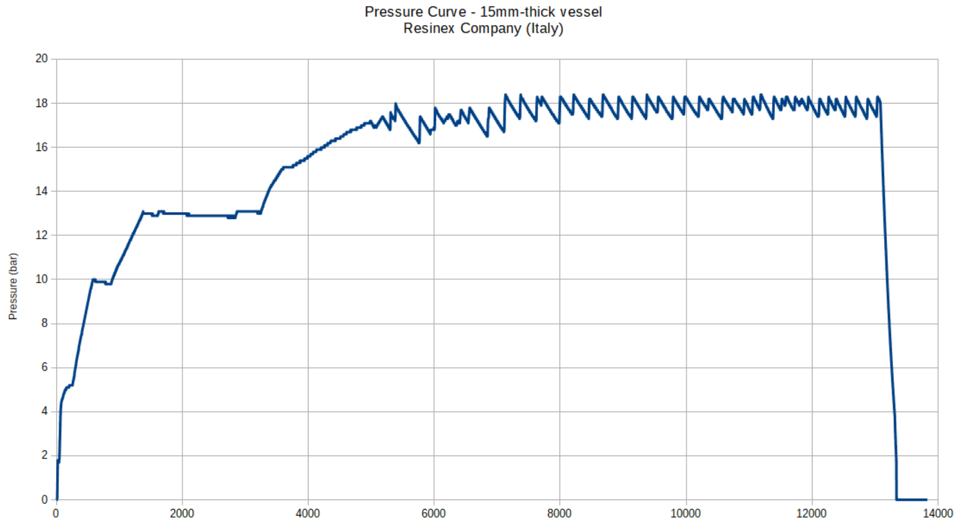
The Evonik acrylic is very clean, no radioactivity contamination

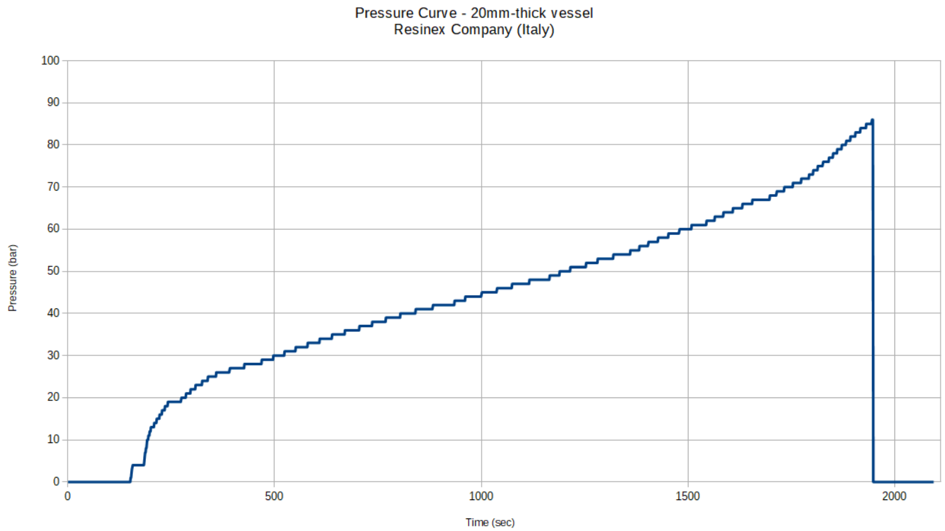


Stress (MPa)
Strain (-)
yielding
strain softening
strain
hardening
elastic
Test_01
Test_02
Test_03
Test_04
Test_05
Test_06
0
50
100
150
200
250
0.0
0.1
0.2
0.3
0.4
0.5
1
2
3
4
5
6

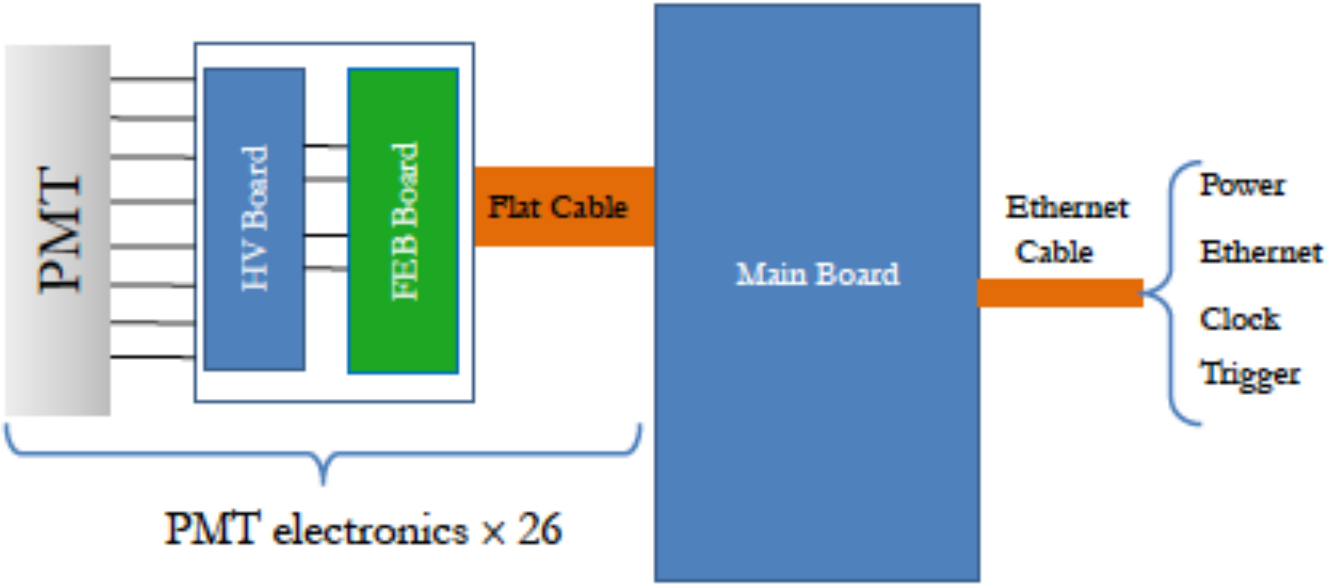
Pressure Tests







mPMT electronics



Requirement : Total Power consumption <4W

HV Board Caracteristics

HV circuit power consumption

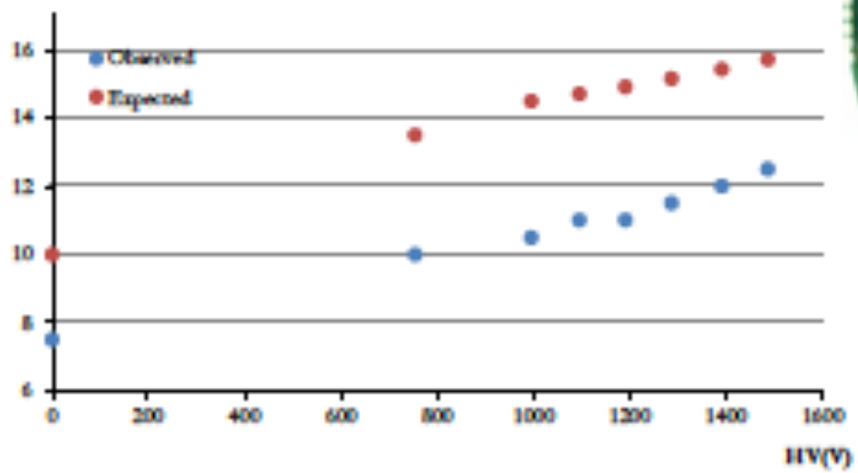
Electrodes	K	Dy1	Dy2	Dy3	Dy4	Dy5	Dy6	Dy7	Dy8	Dy9	Dy10	P
Ratio	3	1	1	1	1	1	1	1	1	1	1	

K: Cathode, Dy: Dynode, P: Anode

Total power dissipated for HV in mPMT module is about:

26×12.5 mW = 325 mW

17×12.5 mW = 213 mW



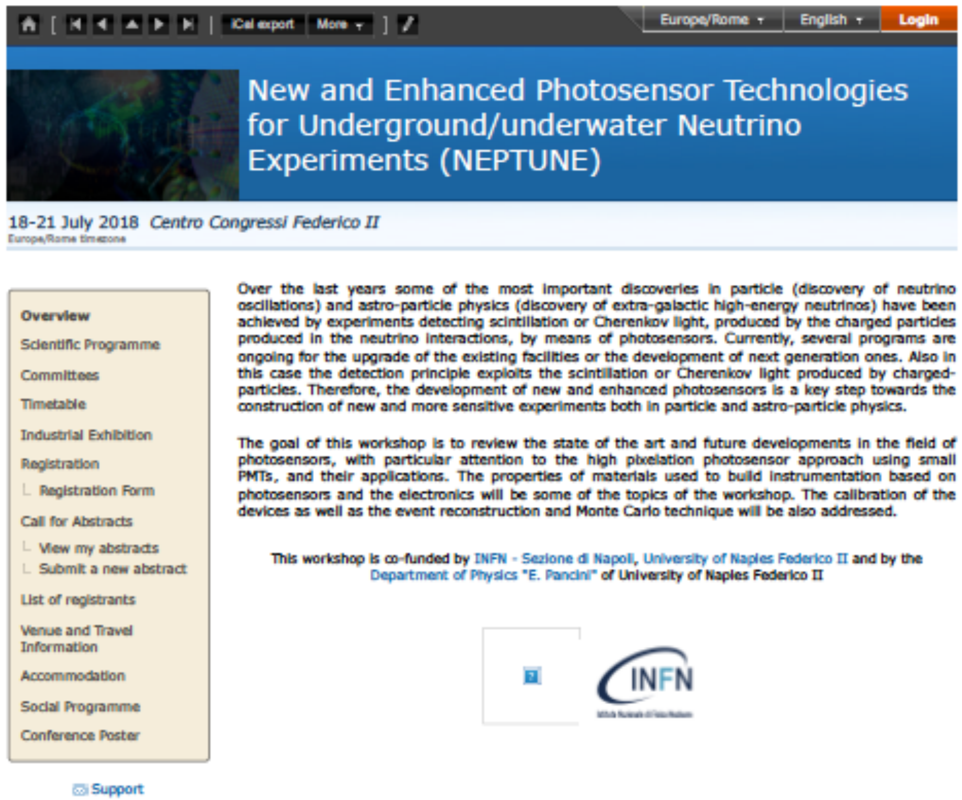
PMT Read-out

- System integrated with the HV board
- Same MCU for both boards and only one connection
- Very compact system thanks to te design of HV board

Ready and under test
at INFN-Na

Conclusions

mPMT R&D is well advanced and a mPMT module prototype will be ready by fall 2018.



iCal export More Europe/Rome English Login

New and Enhanced Photosensor Technologies for Underground/underwater Neutrino Experiments (NEPTUNE)

18-21 July 2018 *Centro Congressi Federico II*
Europe/Rome timezone

Overview
Scientific Programme
Committees
Timetable
Industrial Exhibition
Registration
Registration Form
Call for Abstracts
View my abstracts
Submit a new abstract
List of registrants
Venue and Travel Information
Accommodation
Social Programme
Conference Poster

Support

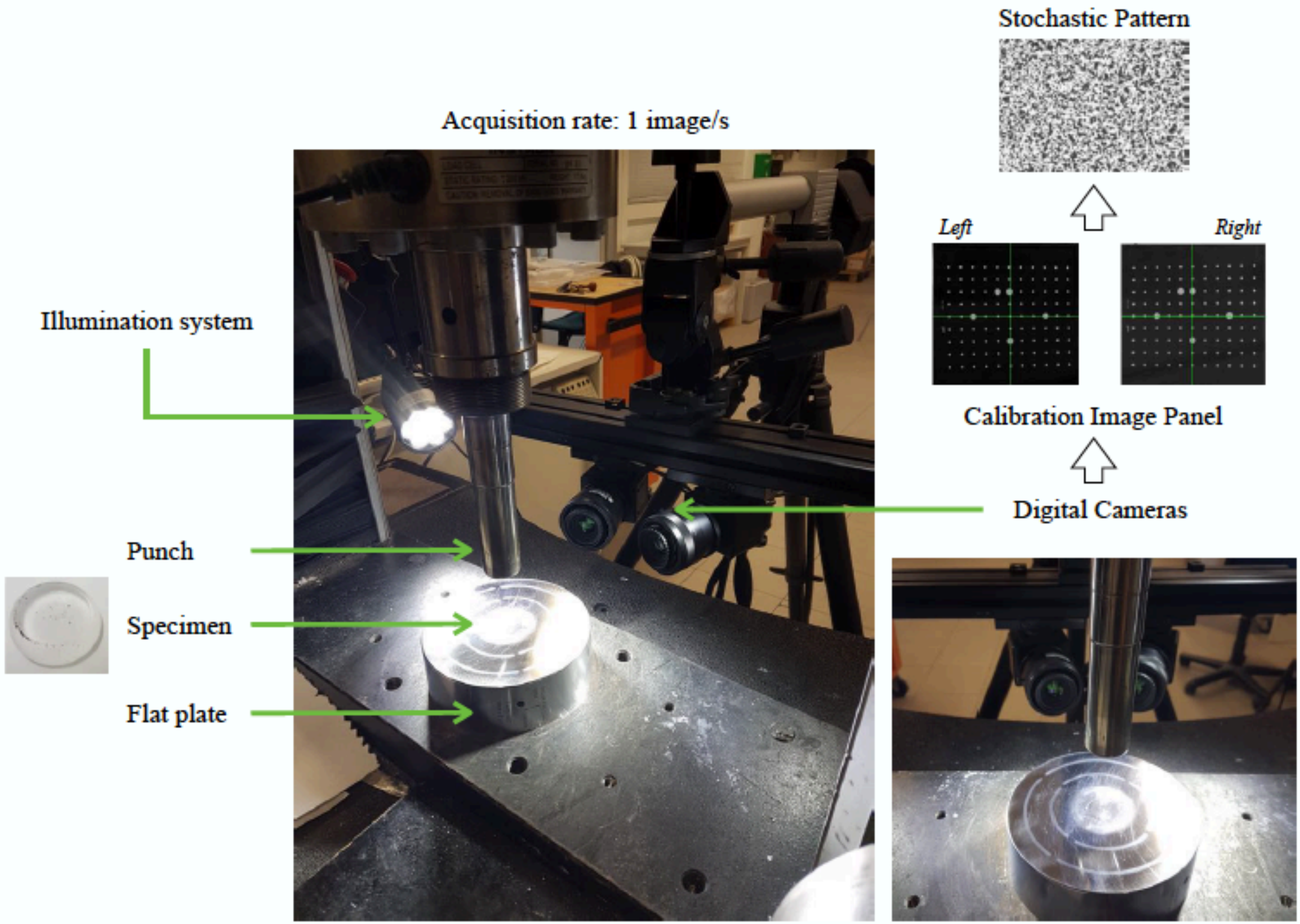
Over the last years some of the most important discoveries in particle (discovery of neutrino oscillations) and astro-particle physics (discovery of extra-galactic high-energy neutrinos) have been achieved by experiments detecting scintillation or Cherenkov light, produced by the charged particles produced in the neutrino interactions, by means of photosensors. Currently, several programs are ongoing for the upgrade of the existing facilities or the development of next generation ones. Also in this case the detection principle exploits the scintillation or Cherenkov light produced by charged-particles. Therefore, the development of new and enhanced photosensors is a key step towards the construction of new and more sensitive experiments both in particle and astro-particle physics.

The goal of this workshop is to review the state of the art and future developments in the field of photosensors, with particular attention to the high pixelation photosensor approach using small PMTs, and their applications. The properties of materials used to build instrumentation based on photosensors and the electronics will be some of the topics of the workshop. The calibration of the devices as well as the event reconstruction and Monte Carlo technique will be also addressed.

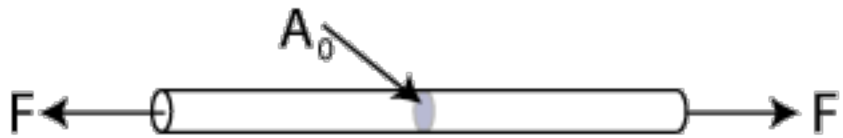
This workshop is co-funded by INFN - Sezione di Napoli, University of Naples Federico II and by the Department of Physics "E. Pancini" of University of Naples Federico II

INFN

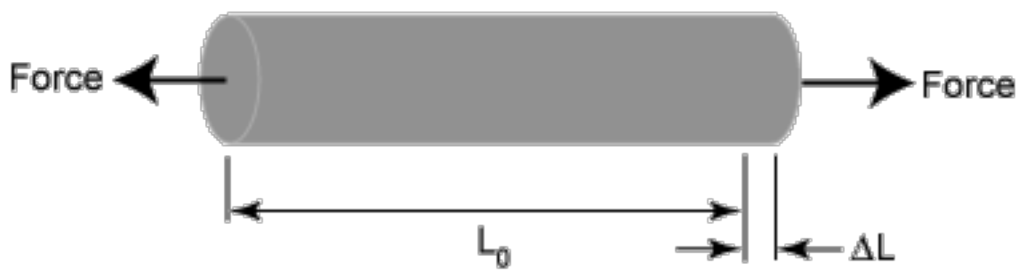
Backup Slides (mechanical)


Stochastic Pattern
Acquisition rate: 1 image/s
Left
Right
Illumination system
Calibration Image Panel
Digital Cameras
Punch
Specimen
Flat plate

Stress and Strain

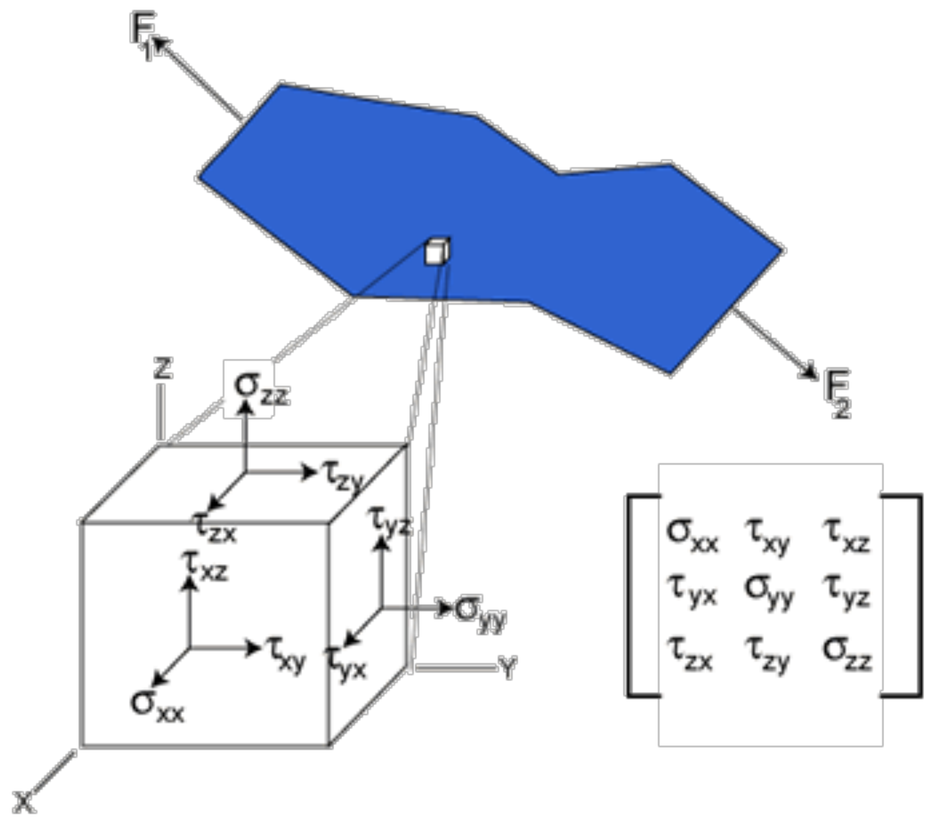


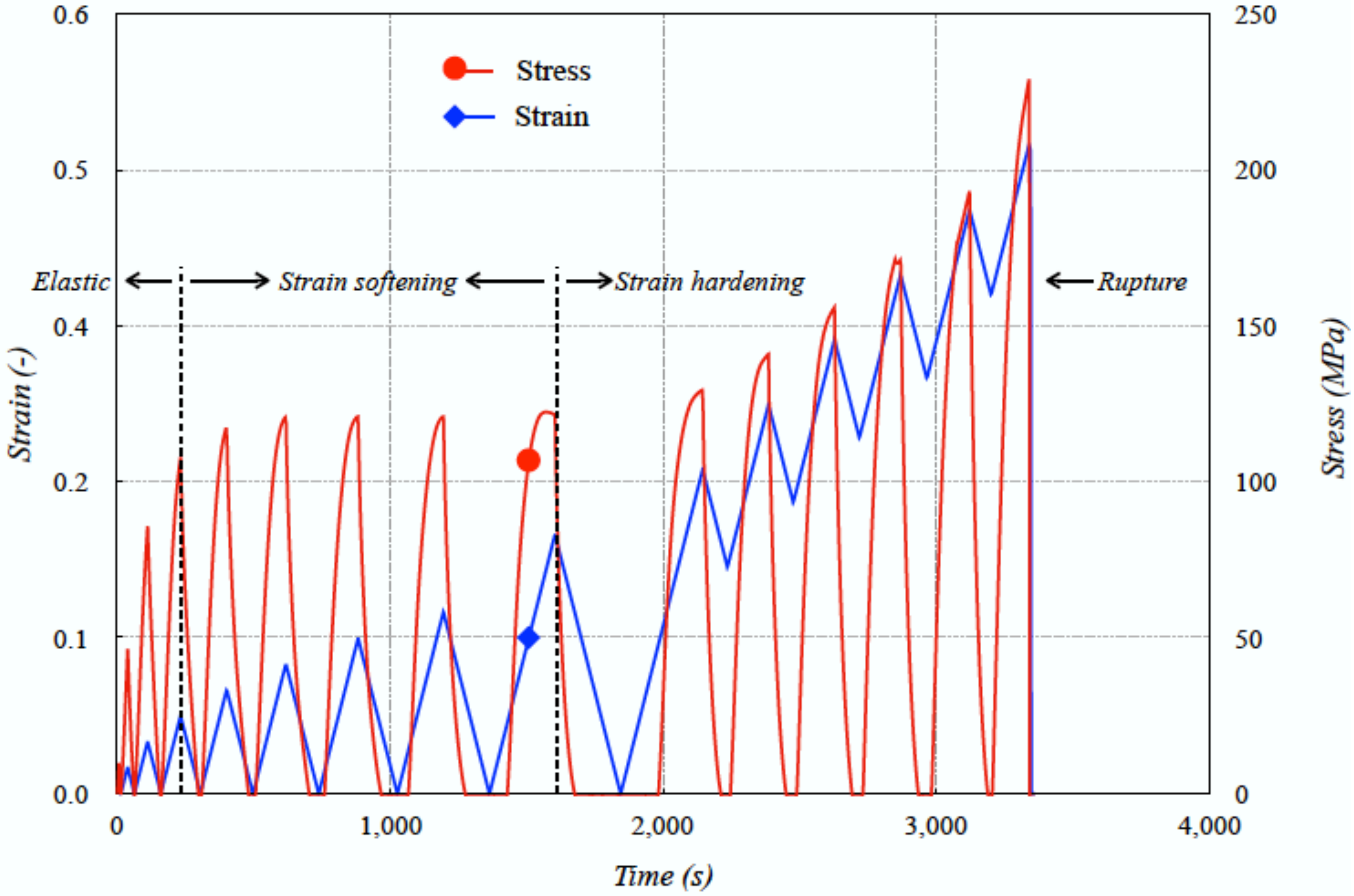
$$\text{Stress, } \sigma = \frac{\text{Force}}{\text{Cross-Sectional Area}} = \frac{F}{A_0}$$



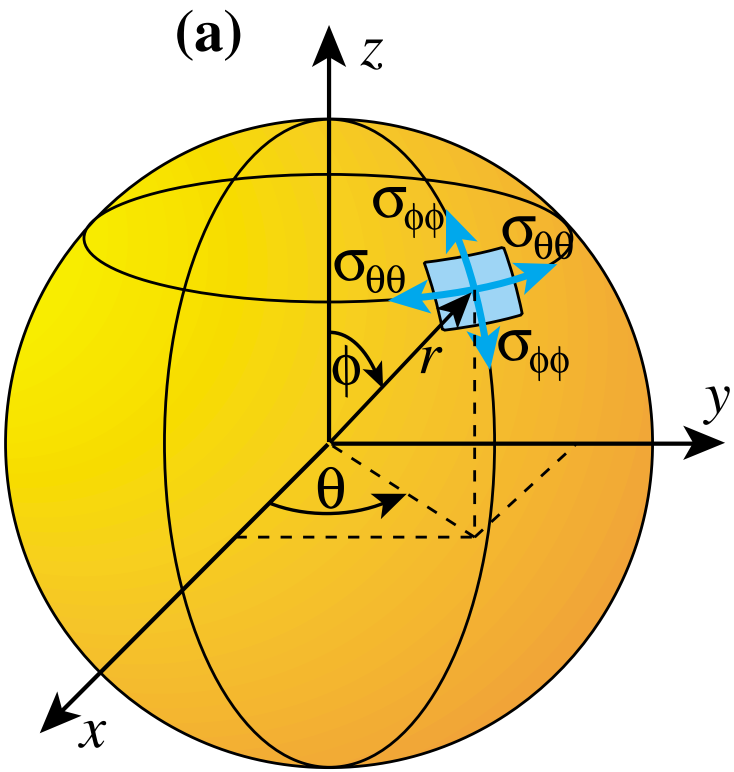
$$\text{Strain} = \frac{\text{Elongation}}{\text{Orininal Length}} = \frac{\Delta L}{L_0}$$

Stress and Strain 3D




Stress
Strain
Elastic
Strain softening
Strain hardening
Rupture
Strain (-)
Stress (MPa)
Time (s)
0.6
0.5
0.4
0.2
0.1
0.0
250
200
150
100
50
0
0
1,000
2,000
3,000
4,000

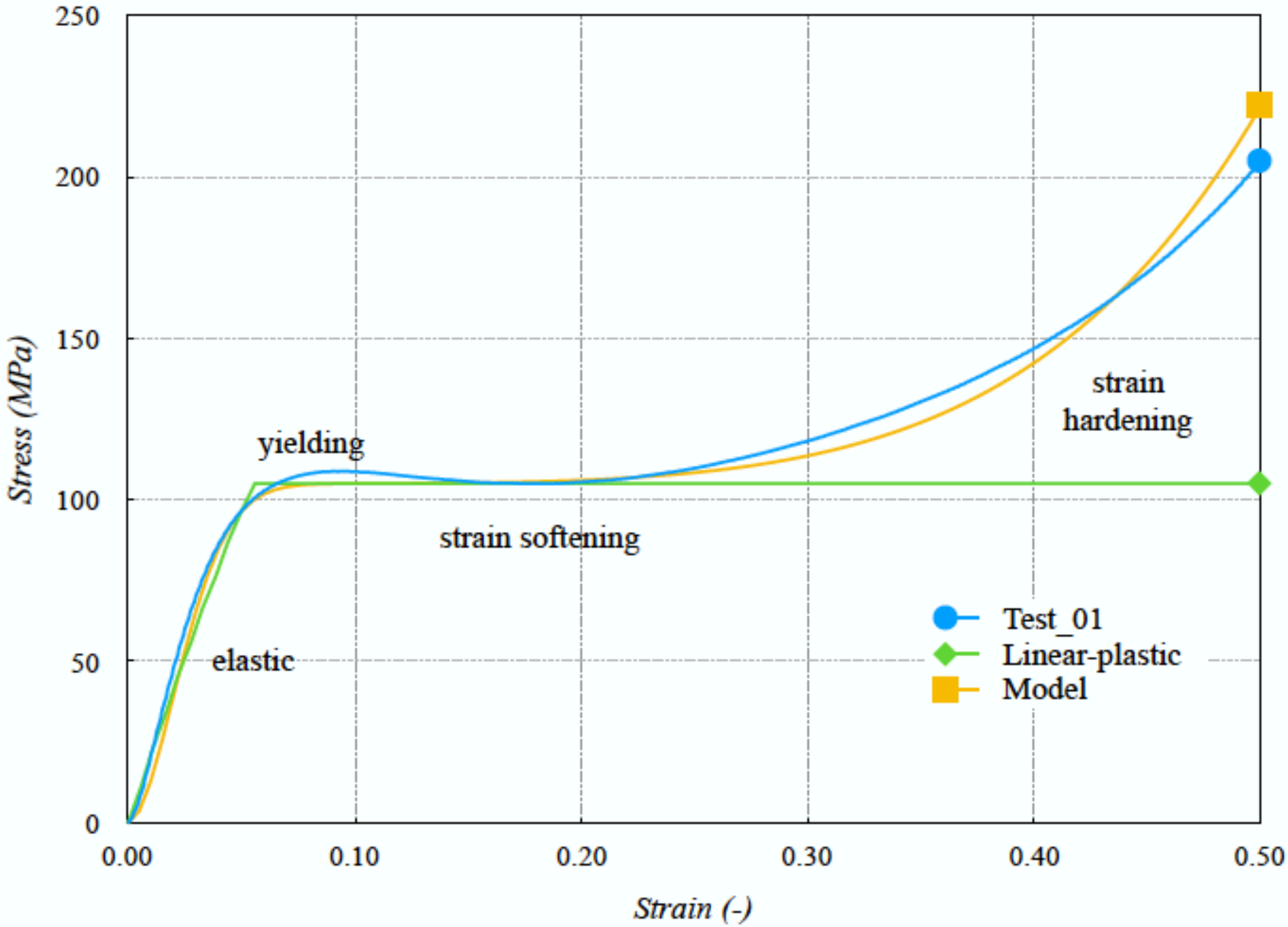
Mechanical tests: simulation



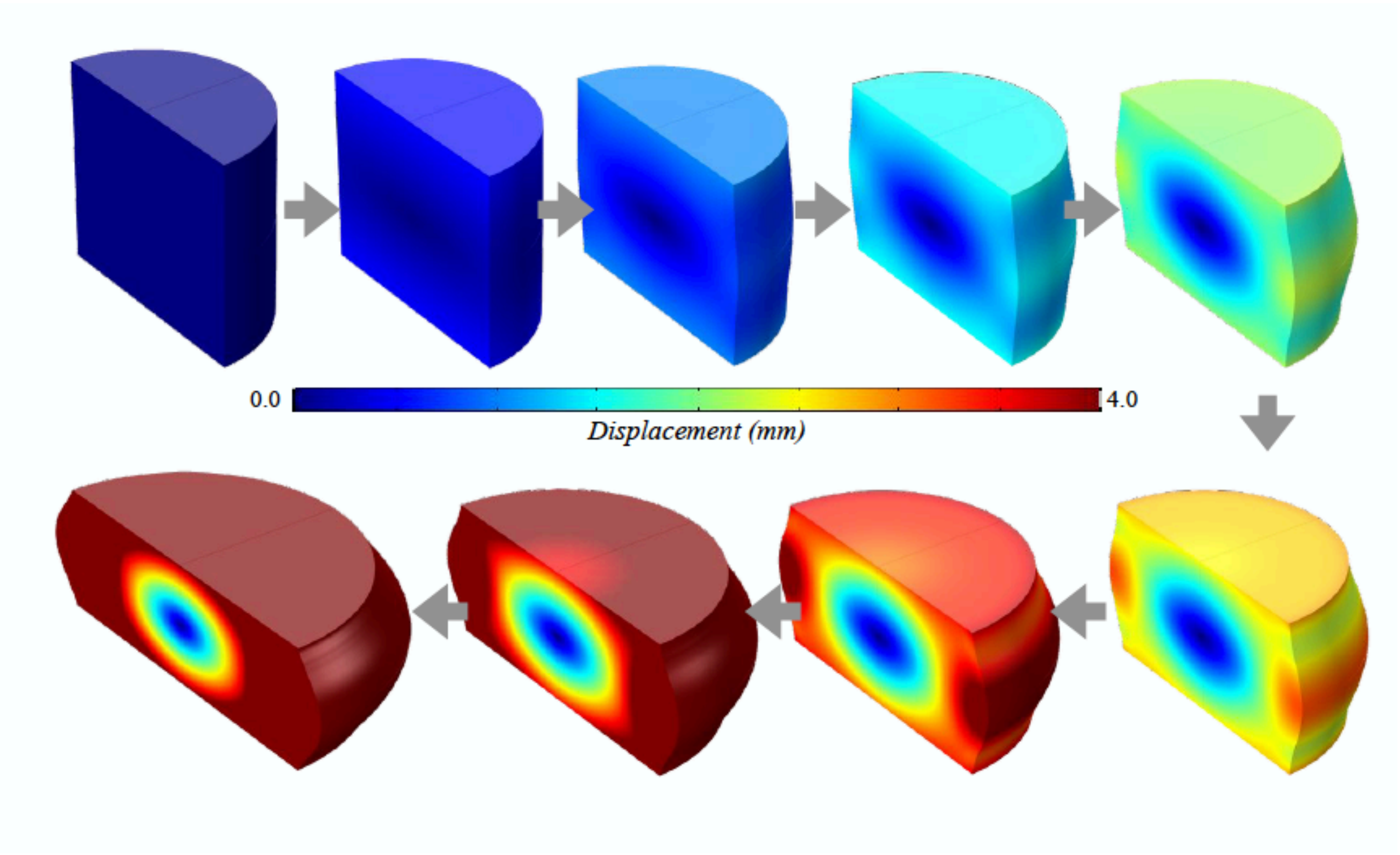
- All shear stresses are zero $\tau_{r\phi} = \tau_{\phi r} = 0$ and $\tau_{\theta\phi} = \tau_{\phi\theta} = 0$
- The normal stress σ_{rr} varies from zero on the inner free surface to the the pressure *p*.
- The normal stresses $\sigma_{\theta\theta}$ and $\sigma_{\phi\phi}$ are equal and constant over the entire vessel, equal to σ.

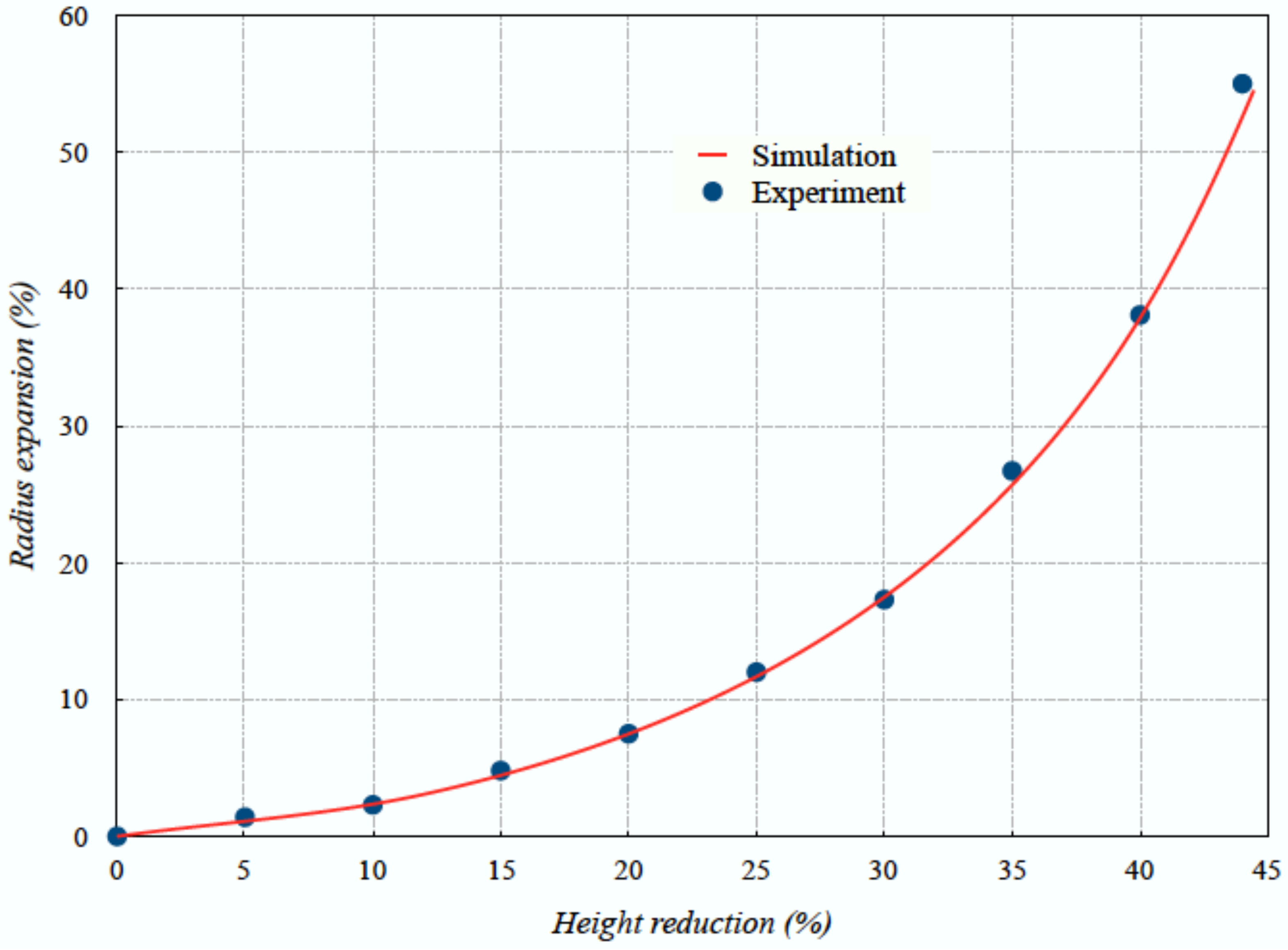
Mechanical tests: simulation

- **Wall Thickness.**The wall is assumed to be very thin compared to the other dimensions of the vessel. As a result, we may assume that stresses are uniform across the wall.
- **Symmetries**. In spherical vessels, the geometry and the loading are spherically symmetric. Therefore the stresses may be assumed to be independent from the two angular coordinates of the spherical coordinate system.
- **Uniform Internal Pressure**.
- **Ignoring End Effects**. This includes supports and cylinder end caps. The assumption is that disturbances of the basic stress state are confined to local regions and may be ignored.

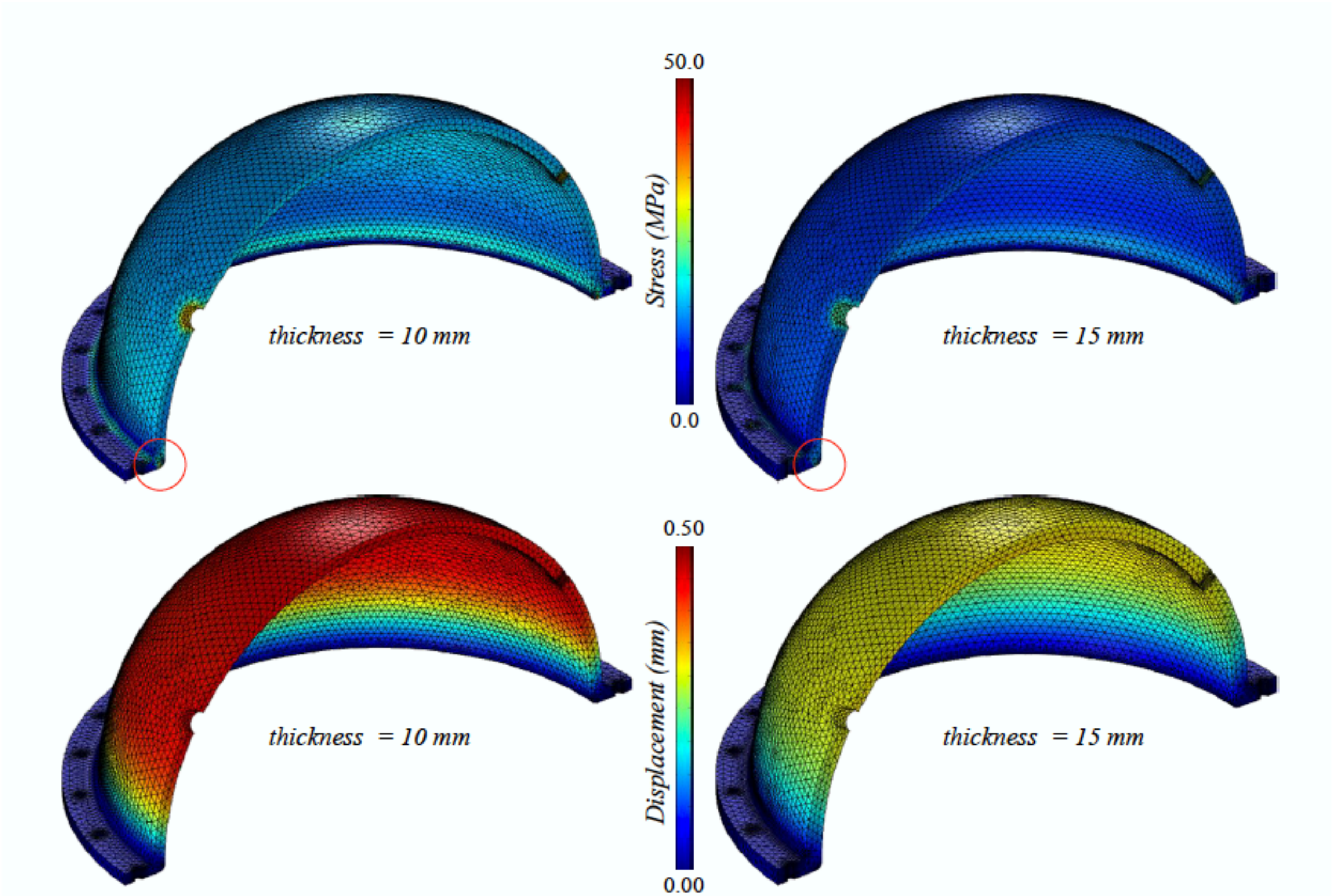

250
200
150
100
50
0
Stress (MPa)
0.00
0.10
0.20
0.30
0.40
0.50
Strain (-)
yielding
strain softening
elastic
strain
hardening
Test_01
Linear-plastic
Model

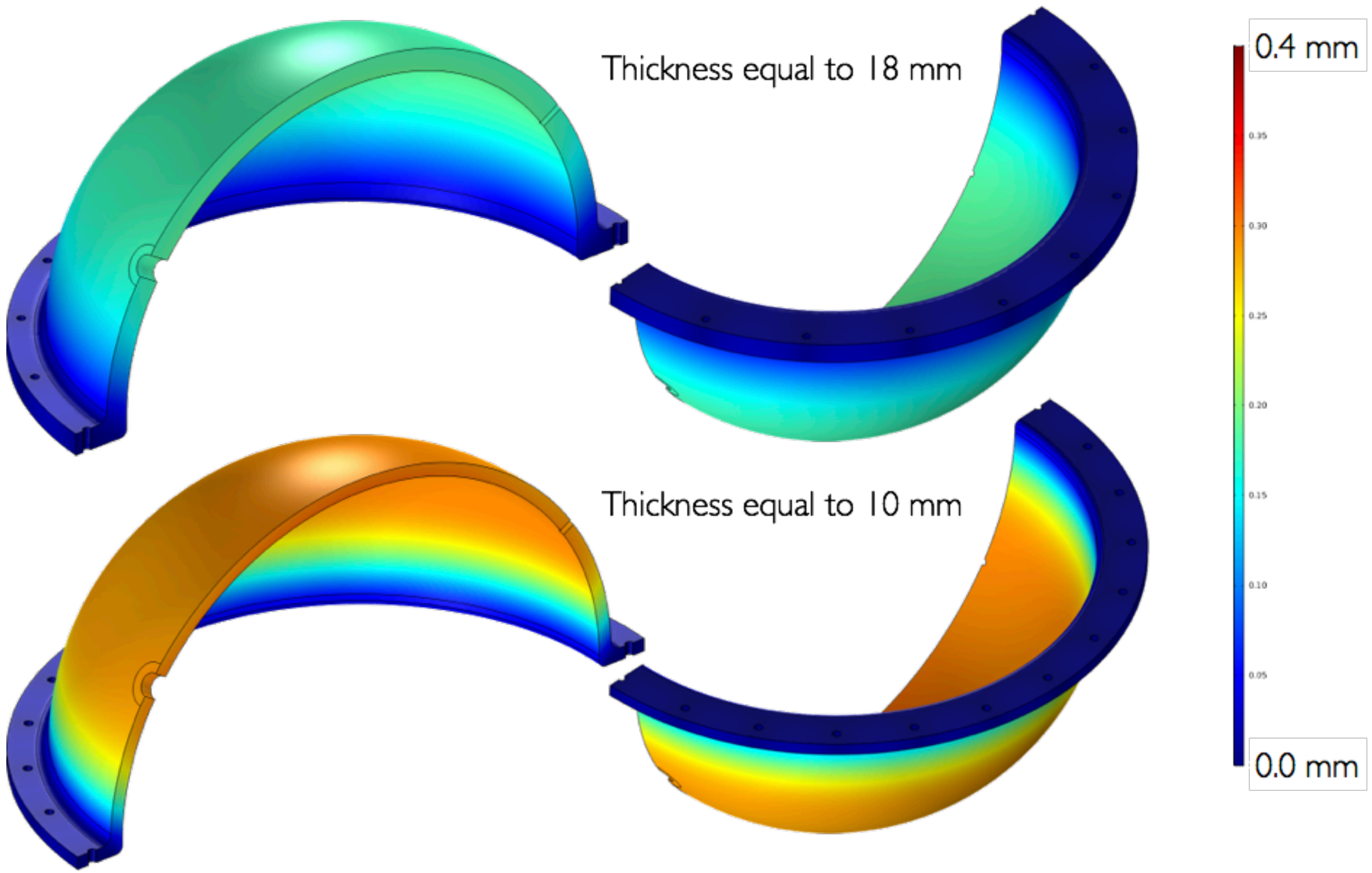
Evolution of displacement





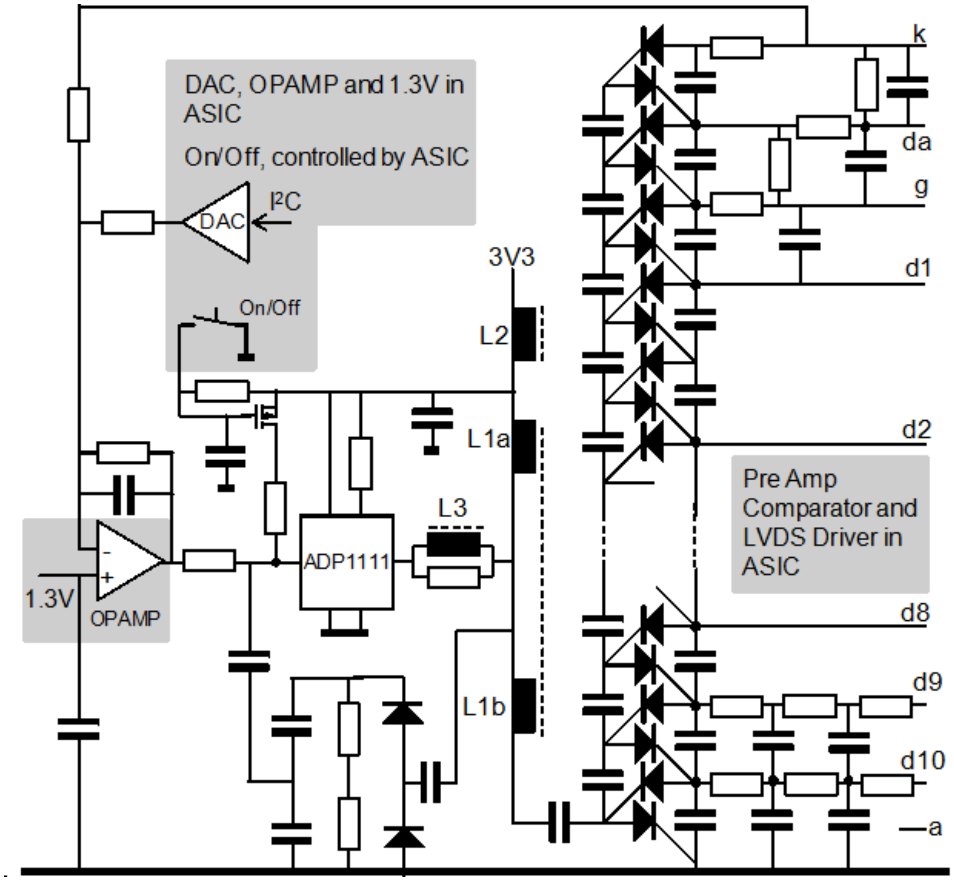
Simulation
Experiment
Radius expansion (%)
Height reduction (%)
0
10
20
30
40
50
60
0
5
10
15
20
25
30
35
40
45


50.0
Stress (MPa)
0.0
thickness = 10 mm
thickness = 15 mm
0.50
Displacement (mm)
0.00
thickness = 10 mm
thickness = 15 mm


Thickness equal to 18 mm
Thickness equal to 10 mm
0.4 mm
0.0 mm

Backup slides (electronics)

Voltage Multiplier Circuit



A basic Cockcroft-Walton (CW) voltage multiplier circuit design developed by Km3Net Collaboration (See P. Timmer, E. Heine, H. Peek, **JINST 5 (2010) C12049**) used to generate multiple voltages to drive the dynodes of the photomultiplier tube.

10 different voltages from 5 volt supply

Similar HV circuit developed at INFN-Na