The new LUNA-MV facility

Matthias Junker

INFN-- Laboratori Nazionali del Gran Sasso

WILLIAM A. FOWLER Nature 238, 24 - 26 (07 July 1972)

"What Cooks with Solar Neutrinos ?"

“Two desperate explanations of the solar neutrino puzzle are proposed, one involving experimental nuclear physics and the other theoretical solar structure and evolution."

Photo:

John Bahcall and W. A. Fowler
at the
"Caltech Centennial Nuclear Astrophysics Symposium
in honor of Fowler's 80th Birthday",
August 11-13, 1991.

Corrigendum

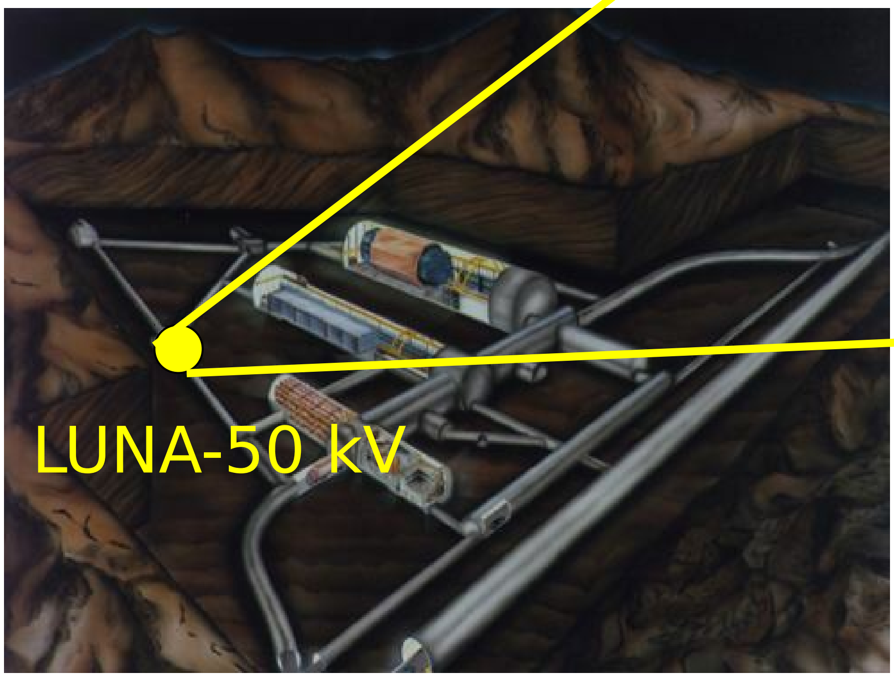
IN the article What Cooks with Solar Neutrinos? by William A. Fowler (*Nature*, **238**, 24; 1972), the first part of the second paragraph under "Experimental Physics" should read: "In some rudimentary calculations I have assigned optimum properties to this proposed resonance. The resonant energy, $E_r = 20$ keV, and the width, $\Gamma_r = 10$ eV, were chosen to match the most effective energy and to be less than the effective interval (10 keV) in energy for $^3He + {}^3He$ in the Sun, respectively. The narrow width chosen also guarantees that the resonance is not detectable at the lowest energies of measurement on $^3He(^3He,2p)^4He$. The spin and parity were taken to be O^+ so that an $l = 0$ interaction was possible and the dimensionless reduced width in the incoming channel was taken to be unity, yielding $\Gamma(^3He + {}^3He) \approx 10^{-6}$ eV at resonance. The reaction rate from the resonance is $\sim 10^4$ times that extrapolated without resonance from the low energy measurements[7]. This result is approximately independent of the choice of Γ_r as long as it is small compared to 10 keV." I am grateful to Dr M. R. Dwarakanath for pointing out the necessity for this correction.

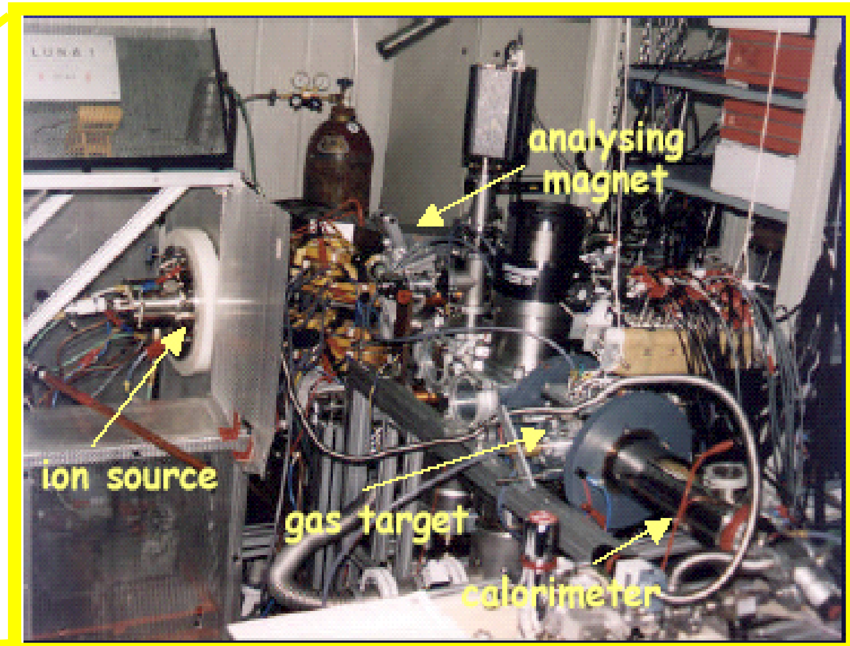
NATURE VOL. 242 APRIL 6 1973

First steps: LUNA-50 kV (1997-2002)

Collaboration of Ruhr University Bochum (Germany) and INFN
Setup build as PhD Student projects (some still or again at LUNA)

1992 – 2002
Voltage Range: 1 - 50 kV
Output Current: 1 mA
Beam energy spread: 20 eV





Important contributions to
- "Solar Neutrino Problem" ($^3He(^3He,2p)^4He$
- Bing bang $d(p,g)^3He$

Z. Phys A 350, 289–301 (1995)

ZEITSCHRIFT
FÜR PHYSIK A
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Prospects for underground accelerator research

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Received: 17 August 1994

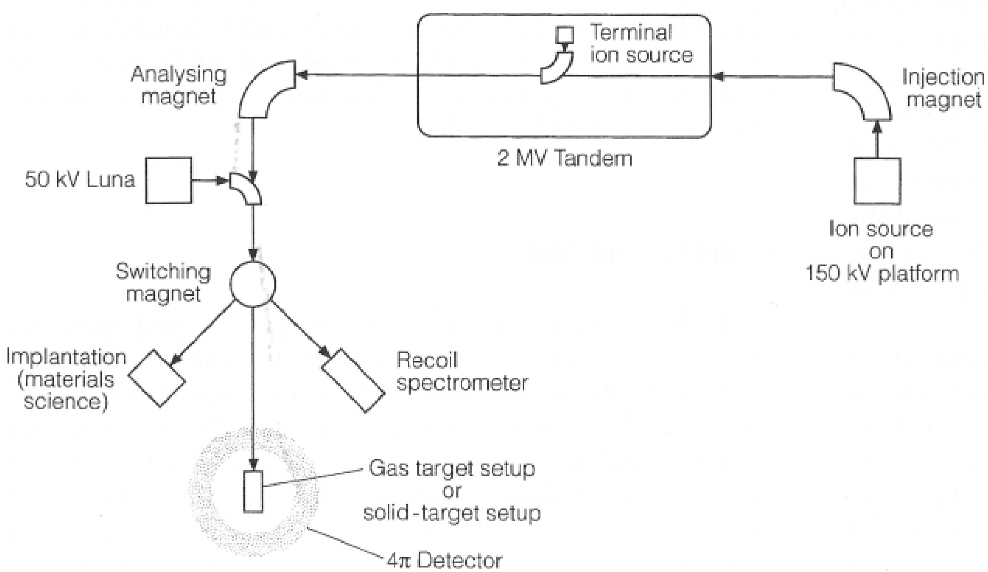


Fig. 5. Schematic diagram of the layout of an underground accelerator facility

19 December 1996

PHYSICS LETTERS B

Physics Letters B 389 (1996) 452–456

LUNA MV

Measurement of the $^3He(^3He,2p)^4He$ cross section within the solar Gamow peak

C. Arpesella [a], E. Bellotti [b], C. Broggini [c], P. Corvisiero [d,1], G. Fiorentini [e], A. Fubini [f], G. Gervino [g], U. Greife [h], C. Gustavino [a], M. Junker [a,h], J. Lambert [i], P. Prati [d], W.S. Rodney [i], C. Rolfs [h], H.P. Trautvetter [h], D. Zahnow [h], S. Zavatarelli [d]

PHYSICAL REVIEW C VOLUME 57, NUMBER 5 MAY 1998

Cross section of $^3He(^3He,2p)^4He$ measured at solar energies

M. Junker,[1,2] A. D'Alessandro,[1] S. Zavatarelli,[3] C. Arpesella,[1] E. Bellotti,[4] C. Broggini,[5] P. Corvisiero,[3] G. Fiorentini,[6] A. Fubini,[7] G. Gervino,[8] U. Greife,[2] C. Gustavino,[1] J. Lambert,[9] P. Prati,[3] W. S. Rodney,[9] C. Rolfs,[2] F. Strieder,[2] H. P. Trautvetter,[2] and D. Zahnow[2]

(The Luna Collaboration)

VOLUME 82, NUMBER 26 PHYSICAL REVIEW LETTERS 28 JUNE 1999

First Measurement of the $^3He(^3He,2p)^4He$ Cross Section down to the Lower Edge of the Solar Gamow Peak

R. Bonetti,[1] C. Broggini,[2,*] L. Campajola,[3] P. Corvisiero,[4] A. D'Alessandro,[5] M. Dessalvi,[4] A. D'Onofrio,[6] A. Fubini,[7] G. Gervino,[8] L. Gialanella,[9] U. Greife,[9] A. Guglielmetti,[1] C. Gustavino,[5] G. Imbriani,[3] M. Junker,[5] P. Prati,[4] V. Roca,[3] C. Rolfs,[9] M. Romano,[3] F. Schuemann,[9] F. Strieder,[9] F. Terrasi,[3] H.P. Trautvetter,[9] and S. Zavatarelli[4]

(LUNA Collaboration)

SCHOOL OF NATURAL SCIENCES

JOHN N. BAHCALL

28 May 1997

Professor P. Corvisiero
Professor C. Rolfs
Spokesmen for the LUNA-Collaboration

Dear Professors Corvisiero and Rolfs:

American Astronomical Society. I can say, with the perspective provided by these previous assignments, that the work of the LUNA collaboration is unique and essential for further progress in solar neutrino studies and for understanding how main sequence stars evolve. I personally would rank the LUNA project among the highest priorities internationally for research in nuclear astrophysics, in stellar evolution, in solar neutrinos, and in particle phenomenology.

Please inform the individuals responsible for making the crucial budgetary decisions regarding the 200 kV high current machine of my eagerness to be personally available for more detailed discussions.

Sincerely yours,

John N. Bahcall
Professor of Natural Science

JNB:jnb

The Rising of LUNA: LUNA 400 (2000 – ?)

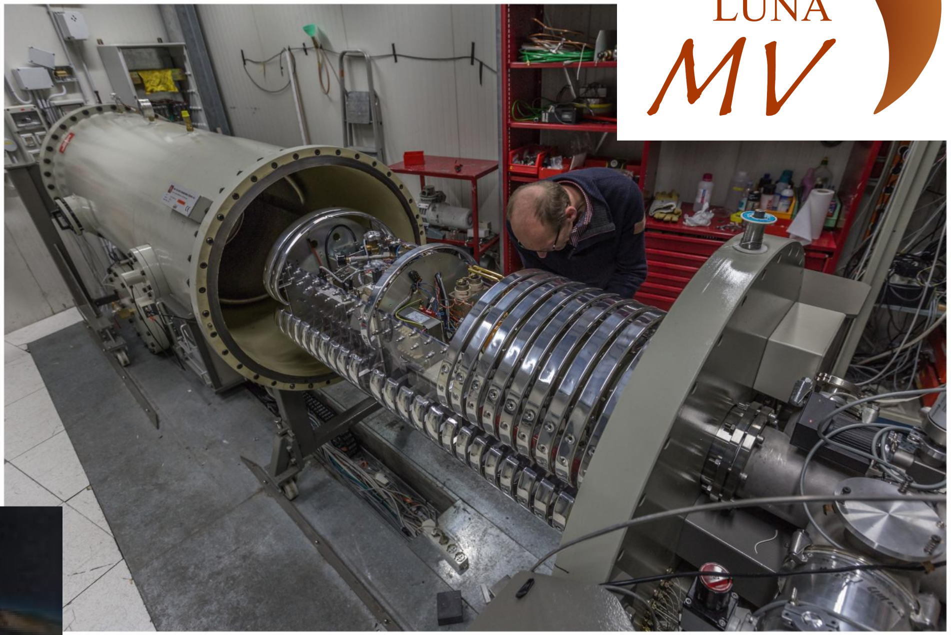
“Real” (Commercial) Accelerator (HVEE)

$U_{terminal}$ = 50 – 400kV

I_{max} = 500μA (on target)

ΔE = 0.07keV

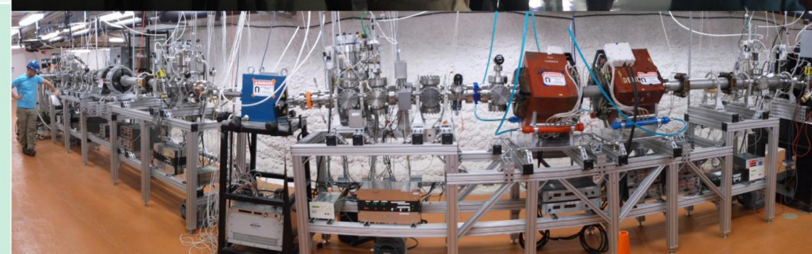
Allowed beams: H^+, ^4He, (^3He)



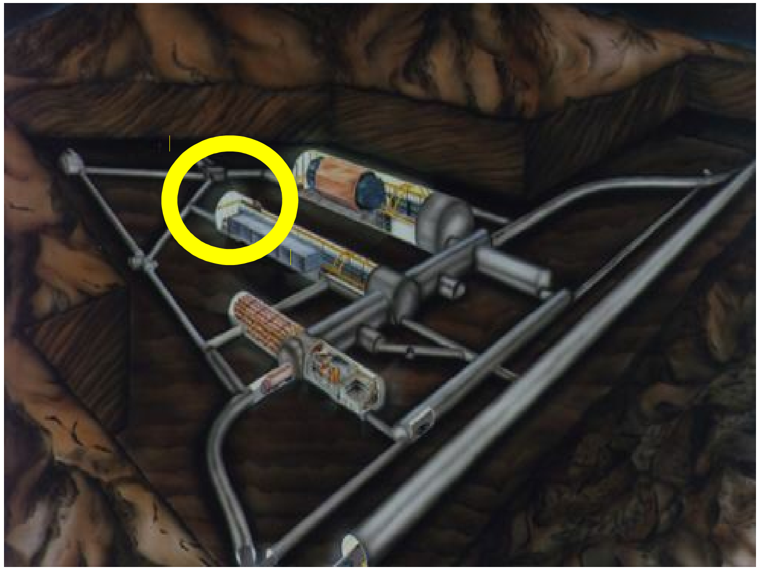
LUNA & Friends

	Bck.	Acceler.	Beam intensity
LUNA	LNGS	LUNA 400	~300 μA
JUNA	~ 2 OoM better	400 kV – ECR	10 mA
Caspar	~ LUNA	Old 1 MV	150 μA
CUNA	> LUNA		
LUNA MV	LNGS	3.5 MV + ECR	1 mA

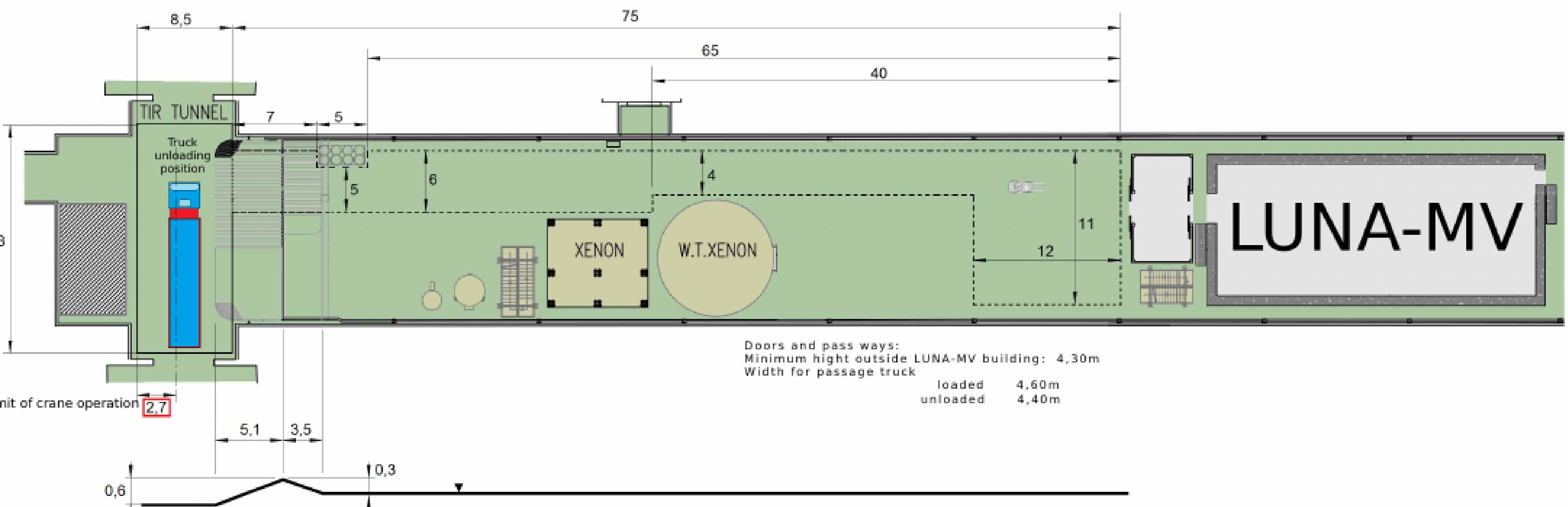





LUNA MV inside Gran Sasso Laboratories

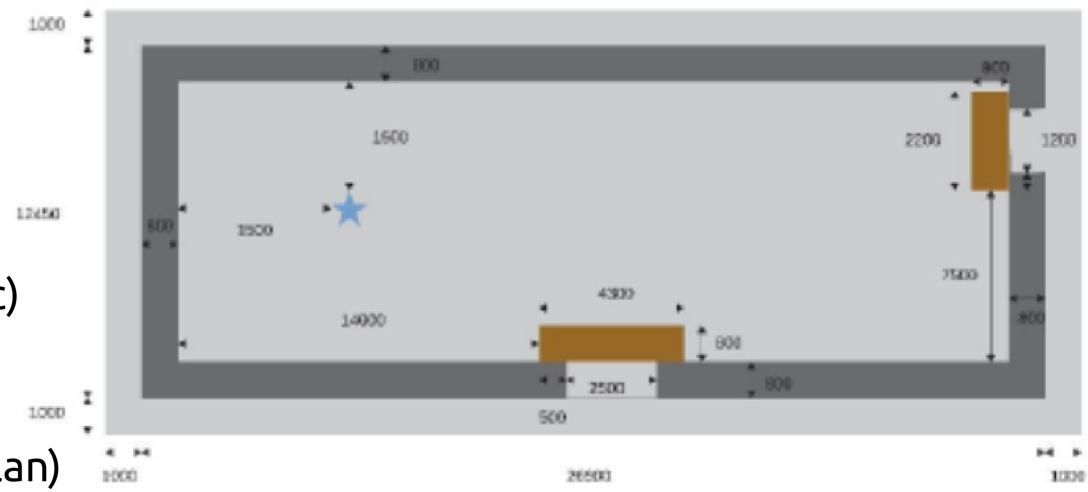


LUNA-MV will be installed in the North part of Hall B



LUNA-MV is not alone → neutron shielding

- Neutron flux at LNGS = 3×10^{-6} n/(cm^2 s)
- Neutron flux simulations
  - Setup:
    - 80 cm thick concrete shielding
    - E_n = 5.6 MeV
    - LUNA-MV flux 2×10^3 n/s (isotropic)
  - Two independent simulations:
    - GEANT4 by LUNA (D. Trezzi, Milan)
    - MCNP by INFN-FISMEL service (A. Esposito, O. Frasciello)



- Neutron flux produced by LUNA-MV just outside the shielding ≈ 1.4 – 3.4×10^{-7} n/(cm^2 s)

	LNF FISMEL MCNP6	LUNA-MV GEANT4
Surface	Flux $\left[\frac{n}{cm^2 s}\right]$	
Left (on XY plane)	$5.69888 \cdot 10^{-7} \pm 0.00007$	$1.23 \cdot 10^{-6} \pm 0.01$
Upper (on XY plane)	$2.58450 \cdot 10^{-7} \pm 0.00003$	$5.71 \cdot 10^{-7} \pm 0.05$
Lower (on XY plane)	$6.7484 \cdot 10^{-8} \pm 0.0002$	$1.53 \cdot 10^{-7} \pm 0.03$
Right (on XY plane)	$2.9462 \cdot 10^{-8} \pm 0.0002$	$6.4 \cdot 10^{-8} \pm 0.2$
Roof	$6.8379 \cdot 10^{-8} \pm 0.0001$	$1.96 \cdot 10^{-7} \pm 0.02$
Total (areas weighted mean)	$1.38535 \cdot 10^{-7} \pm 0.00001$	$3.40 \cdot 10^{-7} \pm 0.02$

The LUNA-MV we want to have

LUNA MV

H
He
C

$^{1}H^{+}$ (TV: 0.3 – 0.5 MV): 500 μA
$^{1}H^{+}$ (TV: 0.5 – 3.5 MV): 1000 μA

$^{4}He^{+}$ (TV: 0.3 – 0.5 MV): 300 μA
$^{4}He^{+}$ (TV: 0.5 – 3.5 MV): 500 μA

$^{12}C^{+}$ (TV: 0.3 – 0.5 MV): 100 μA
$^{12}C^{+}$ (TV: 0.5 – 3.5 MV): 150 μA
$^{12}C^{++}$ (TV: 0.5 – 3.5 MV): 100 μA

inline Cockcroft Walton accelerator

TERMINAL VOLTAGE: 0.2 – 3.5 MV

Precision of terminal voltage reading: 350 V

Beam energy reproducibility: 0.01% TV

Beam energy stability: 0.001% TV / hrs

Beam current stability: < 5% / hrs

ISTITUTO NAZIONALE DI FISICA NUCLEARE DIREZIONE AFFARI CONTRATTUALI

ISTITUTO NAZIONALE DI FISICA NUCLEARE

CONTRATTO DI APPALTO

CIG n° 62076380EF – CUP n° I54G14000140005

L'anno 2016 il giorno 14 del mese di APRILE

TRA

l'ISTITUTO NAZIONALE DI FISICA NUCLEARE, in seguito indicato come INFN, con sede legale in Frascati (ROMA), Via Enrico Fermi n. 40 - Codice Fiscale n. 84001850589 - nella persona del suo Presidente pro tempore Prof. Fernando FERRONI, in qualità di legale rappresentante, da una parte

E

la società HIGH VOLTAGE ENGINEERING EUROPA B.V., in seguito indicata come IMPRESA, con sede legale in Olanda P.O. Box 99 – 3800 AB Amersfoort - Partita I.V.A. NL00157534B01 , nella persona del Mr. Henri VAN OOSTERHOUT, in qualità di legale rappresentante, dall'altra parte

ISTITUTO NAZIONALE DI FISICA NUCLEARE IL PRESIDENTE (Prof. Fernando Ferroni)

HIGH VOLTAGE ENGINEERING EUROPA

(Mr. Henri VAN OOSTERHOUT)

Istituto Nazionale di Fisica Nucleare

IL PRESIDENTE

(Prof. Fernando FERRONI)

The new LUNA-MV facility

LUNA
MV

Thickness of shielding walls: 80 cm

Ouside (inside) Dimensions shielding

L= 27,00 (25,40) m

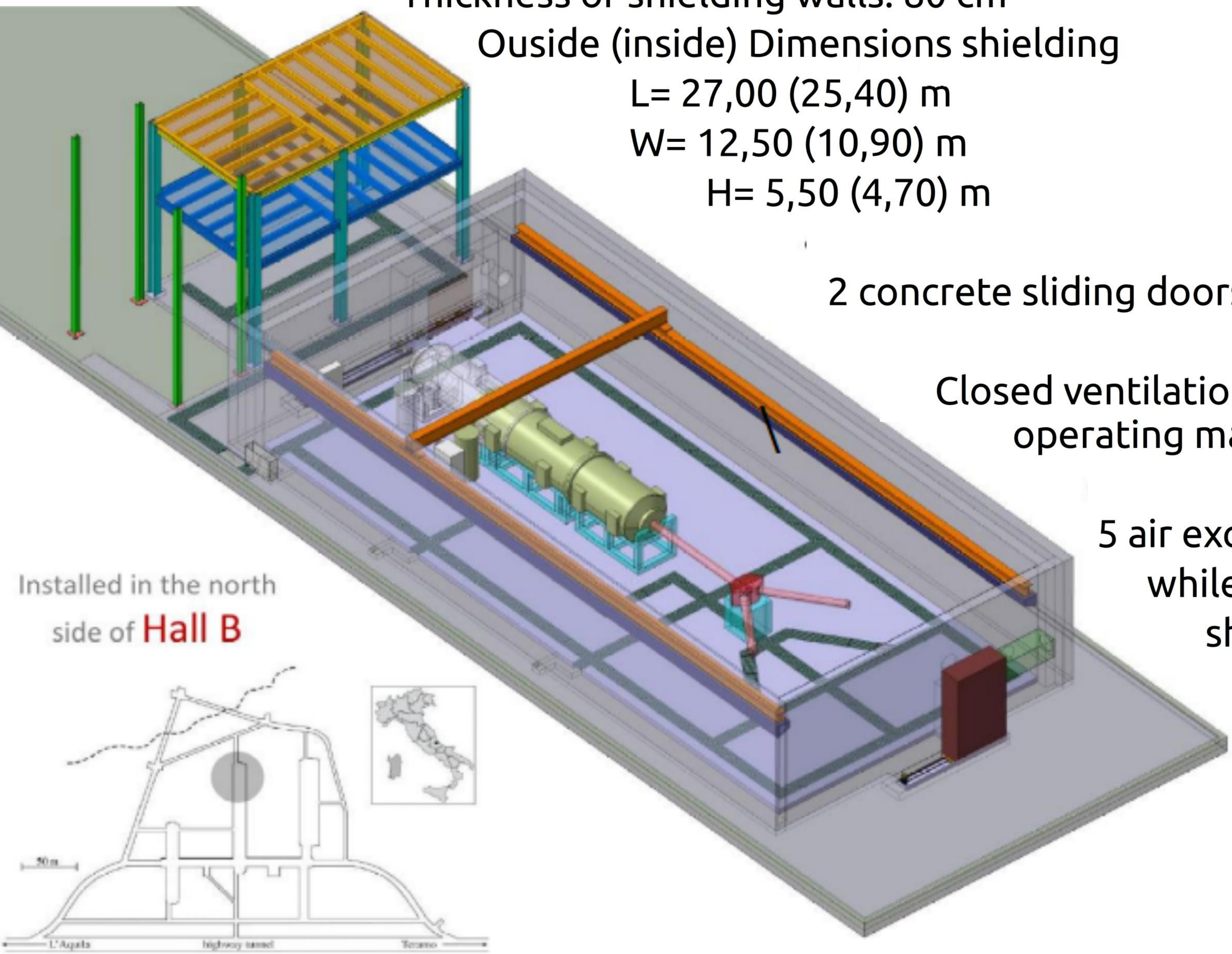
W= 12,50 (10,90) m

H= 5,50 (4,70) m

2 concrete sliding doors (80cm)

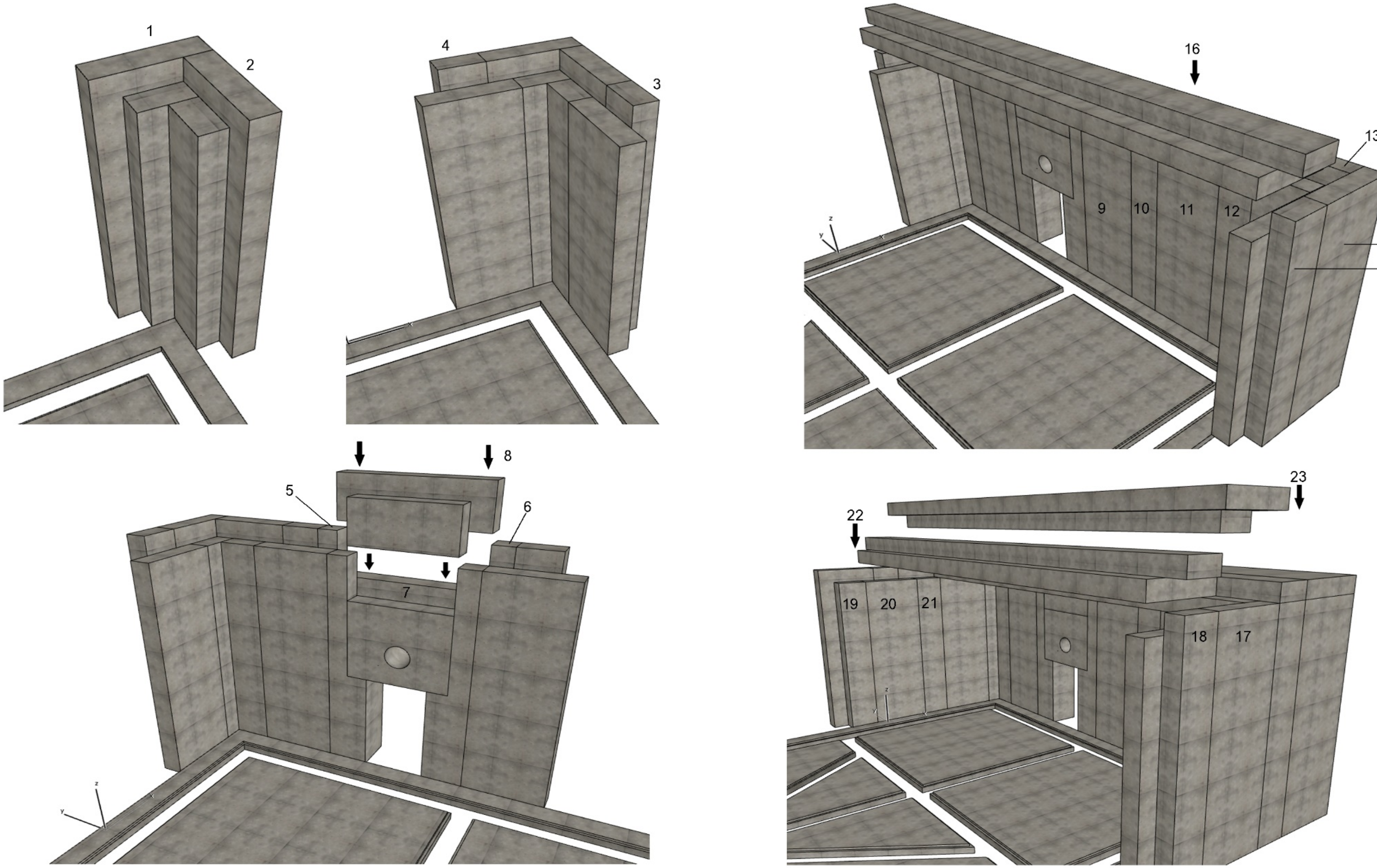
Closed ventilation while operating machine

5 air exchanges / h while persons inside shielding and accelerator is off

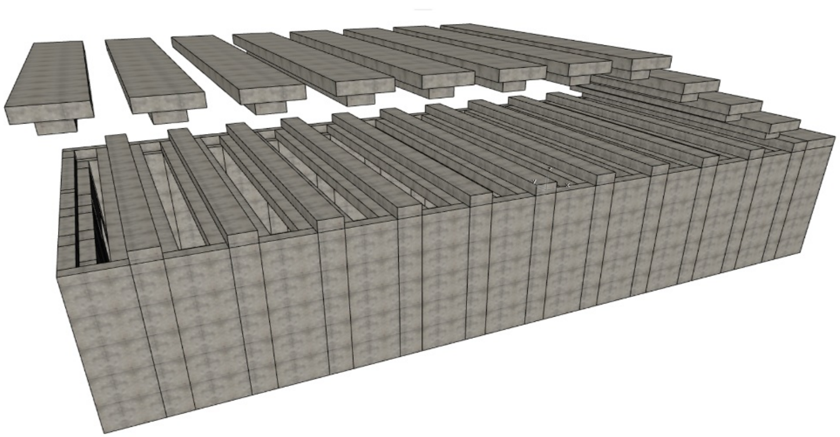


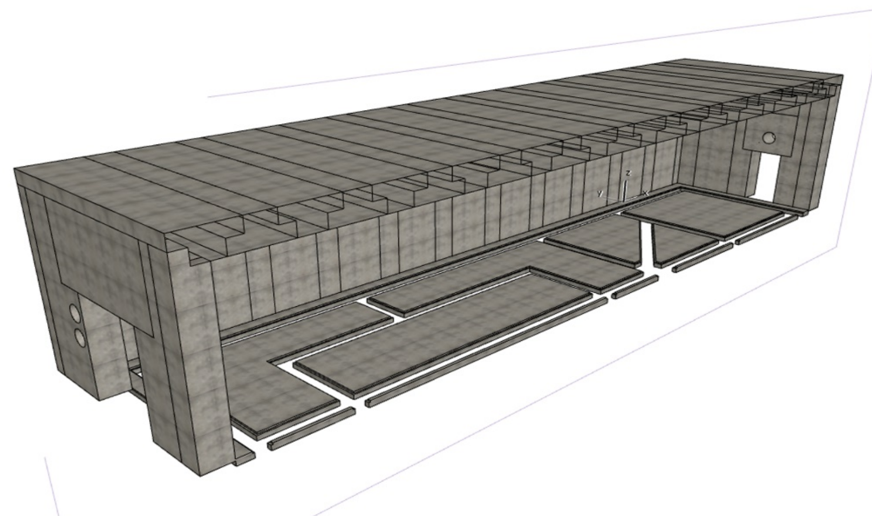
Installed in the north side of Hall B

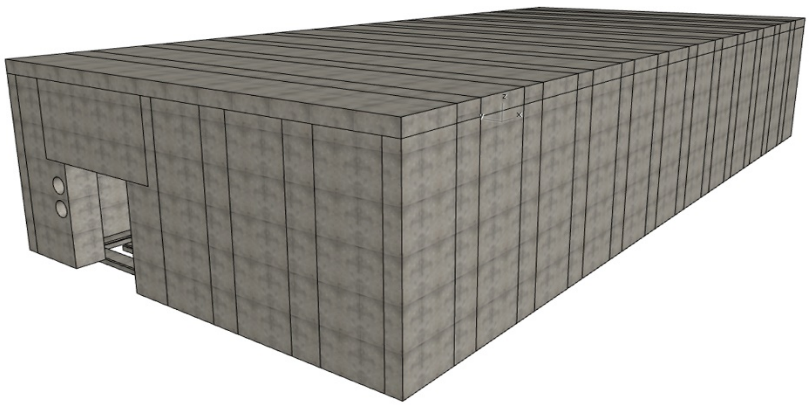
LUNA-MV: details of the construction procedure

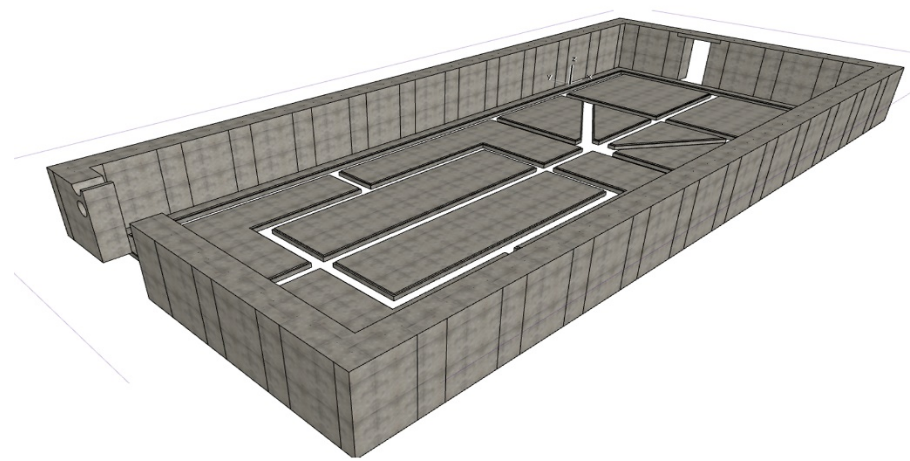


LUNA-MV: details of the construction procedure

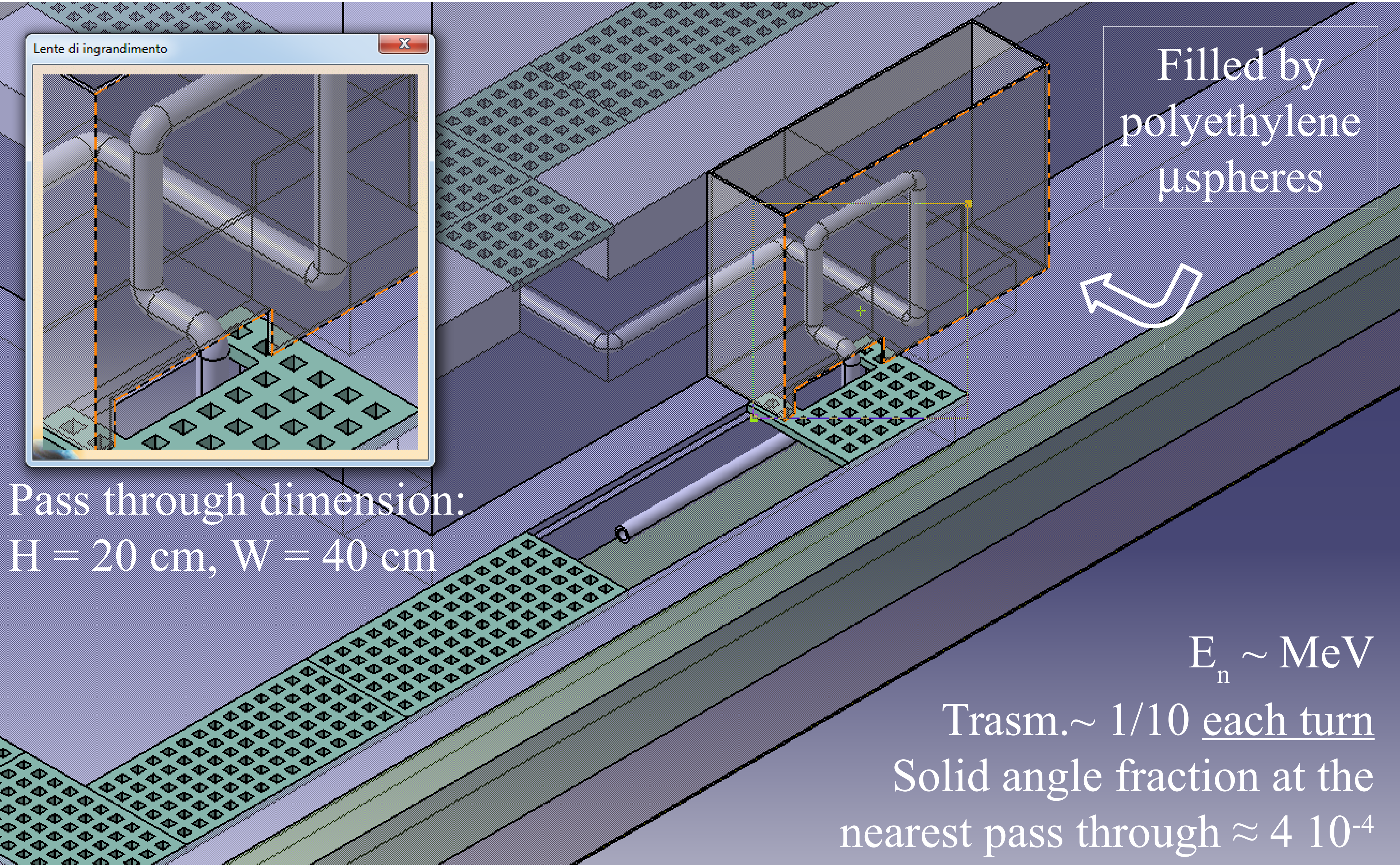








LUNA MV – no neutron may escape …
Detail of the shielding pass through



Filled by polyethylene μspheres

Pass through dimension:
H = 20 cm, W = 40 cm

$E_n \sim$ MeV

Trasm.~ 1/10 each turn

Solid angle fraction at the nearest pass through ≈ 4 10^{-4}

Power to LUNA-MV

Gruppi e sottogruppi		Pos.	PW	UPS [5 min] + Note	
ACC.	Acceleratore	SA	5.6 kW	5.6 kW	
	Vacuum System	SA	4 kW	4 kW	
	Magnete di analisi	SA	2.4 kW	2.4 kW	
	Controllo	SC	1.6 kW	1.6 kW	
ST	Vacuum pumps	SA	3 kW	3 kW	
GT	Riscaldatore	SA	10 kW	10 kW	
	Vacuum pumps	SA	20 kW	20 kW	
JGT	Catcher pumps	SA	20 kW	20 kW	Non richiesti prima del 2022-2023. Quota aggiuntiva al fabbisogno già coperto nel GT.
	Compressors	SA	50 kW	50 kW	
DAQ	Line 1	SA	3 kW	3 kW	
	Line 2	SA	3 kW	3 kW	
SF6	Compressore	SA	5 kW	n.r.	In rigenerazione: collegato alla rete normale. In fase di recupero e refill: processo ortogonale che sfrutta la quota UPS destinata all'HVE. Servono opportuni Switch
	Vacuum pumps	SA	3 kW	n.r.	
	Evaporatore	SA	4 kW	n.r.	
AUX	Ausiliari 1 (SA)	SA	10 kW	3 kW	La parte restante sotto normale.
	Ausiliari 2 (SC)	SC	15 kW	5 kW	La parte restante sotto normale.
UTA	Ventilazione ciclo chiuso	SA	5 kW	No	
	Controllo	SA	<1 kW	n.r.	Gestiti dalla rete LNGS (?)
	Ventilazione	SC	3 kW	No	
	Controllo	SC	<1 kW	n.r.	Gestiti dalla rete LNGS (?)
VENT.	Azionamenti	SA	?? kW	No	
	Controlli	SA	<1 kW	n.r.	Gestiti dalla rete LNGS (?)
COOL.	Sistema demineralizzato	SA	Max 1 kW	Max 1 kW	
	Sistema naturale	SA	Max 1 kW	Max 1 kW	
DOORS	Motore portone sud	SA	2 kW	2 kW	Valutare integrazione in ronda. Processo ortogonale (UPS da HVE con opportuni switch).
	Motore portone nord	SA	2 kW	2 kW	
	Controllo	SA	<1 kW	n.r.	Gestiti dalla rete LNGS (?)
	Sicurezza	SA	<1 kW	n.r.	Gestiti dalla rete LNGS (?)
	Interblocco e ronda	SA	<1 kW	n.r.	Gestiti dalla rete LNGS (?)
LUCI	Normale	SA/SC	?? kW	No	
	Emergenza	SA/SC	?? kW	n.r.	Gestiti dalla rete LNGS (?)
CRANE	Motore	SA	2 kW	No	
	Controllo	SA	<1 kW	n.r.	
	Emergenza	SA	<1 kW	n.r.	
CNTRL	PLC	SA/SC	?? kW	n.r.	Gestiti dalla rete LNGS (?)
	Sensoristica	SA/SC	?? kW	n.r.	Gestiti dalla rete LNGS (?)
	Segnali	SA/SC	?? kW	n.r.	Gestiti dalla rete LNGS (?)
Tot	2018/19: + di **113.6 kW** (93+ SA, 20,6+ SC) 2022/23: + di **183,6 kW** (+70 SA)			2018/19: 62,6 kW (56 SA, 6,6 SC) 2022/23:132,6 kW (+70 SA)	

LUNA-MV: Ipotesi sulle condizioni operative

App.	'18	'19	'20	'21	'22/'23
Acc.					
ST					
GT					
JGT					
DAQ.					
SF6 S.					
Aux1					
Aux2					

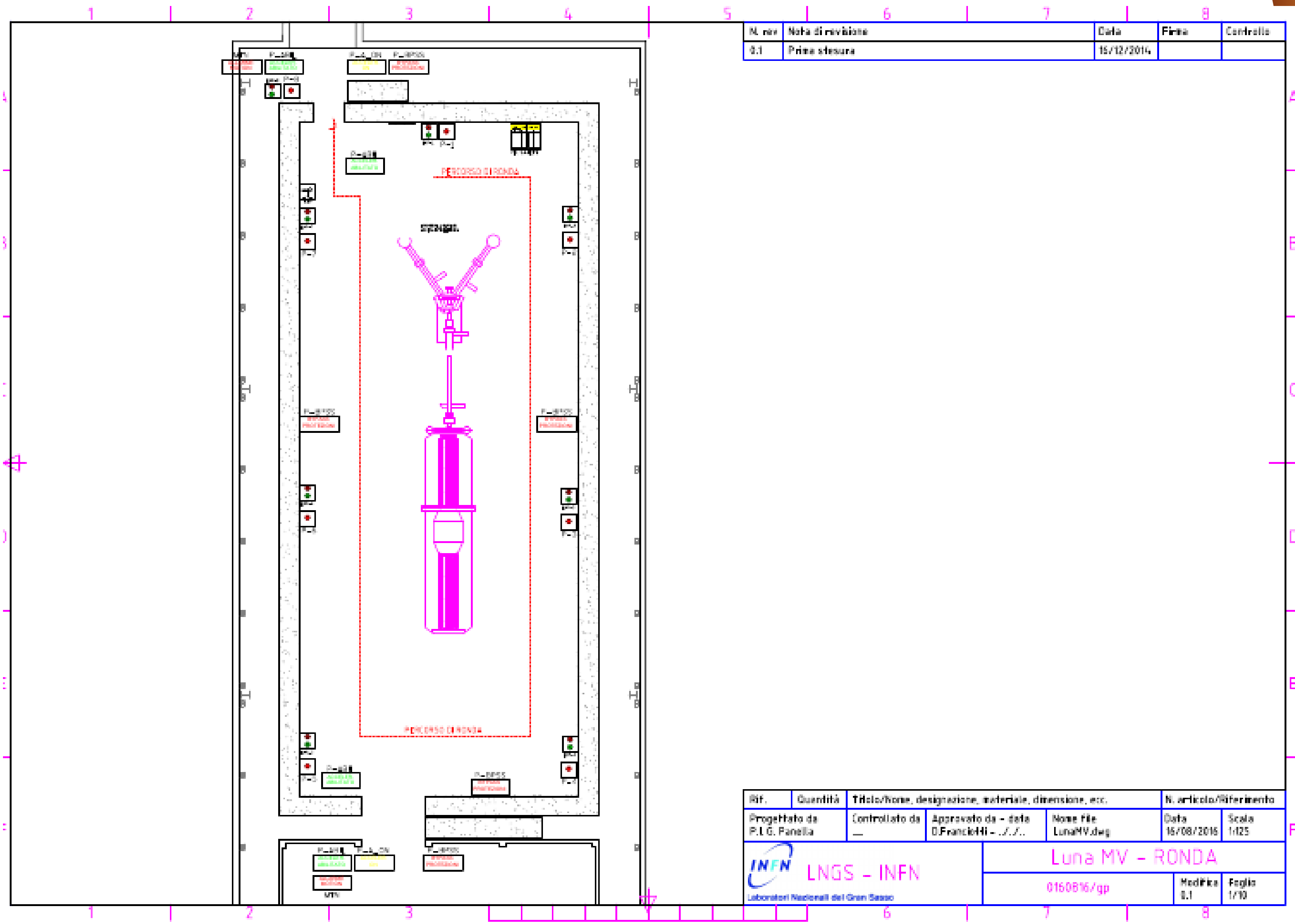
- 2018/19 ~ 110 kW
  - Acceleratore
  - Controllo Acc.
  - ST
  - GT
  - DAQs
  - SF6
  - UTA a ciclo chiuso in SA
  - UTA + impianti in SC
  - Controlli, accessi e routine
  - Aux
- 2022/23: ~ 180 kW
  - Acceleratore
  - Controllo Acc.
  - ST
  - JGT
  - DAQs
  - SF6
  - UTA a ciclo chiuso in SA
  - UTA + impianti in SC
  - Controlli, accessi e routine
  - Aux
- QM
  - Predisporre tutti i kW fin dal 2018/19 o splittare in due momenti?
  - Quadri, sezionatori e switch possono essere predisposti? Vanno dimensionati fin da subito per il carico massimo o si possono includere nella progettazione successiva?
  - Discorso sulle ortogonalità. Predisposizione dei devices necessari.
  - Possibilità di ottimizzare il JGT plant come upgrade del GT plant

Cooling, Venting, Technical gases for LUNA-MV

Servizio	Sottogruppi	Interfaccia	Tipo di Richiesta
WATER COOLING	Deionizzata	Scambiatore (primario H2O LNGS – secondario Acceleratore)	10 l/min Closed Loop
	Normale	Scambiatore (primario H2O LNGS – secondario UTA, Targets…)	Vedi next slide
VENTING	Controllo RH% e T	UTA interna SA	Circuito chiuso (HVE)
	Lavaggio e ricambi	Circuito Sala B	3-5 times/h
	Exhaust (pompa)		30/40 m^3 h (HVE)
GAS	ARIA COMP.	Circuito Sala B	6 bar, 4 l/s
	LN2	SA Forniti dalla Collaborazione	
	GN2		
	He		0,4 l a 150 bar
	H2		0,4 l a 150 bar

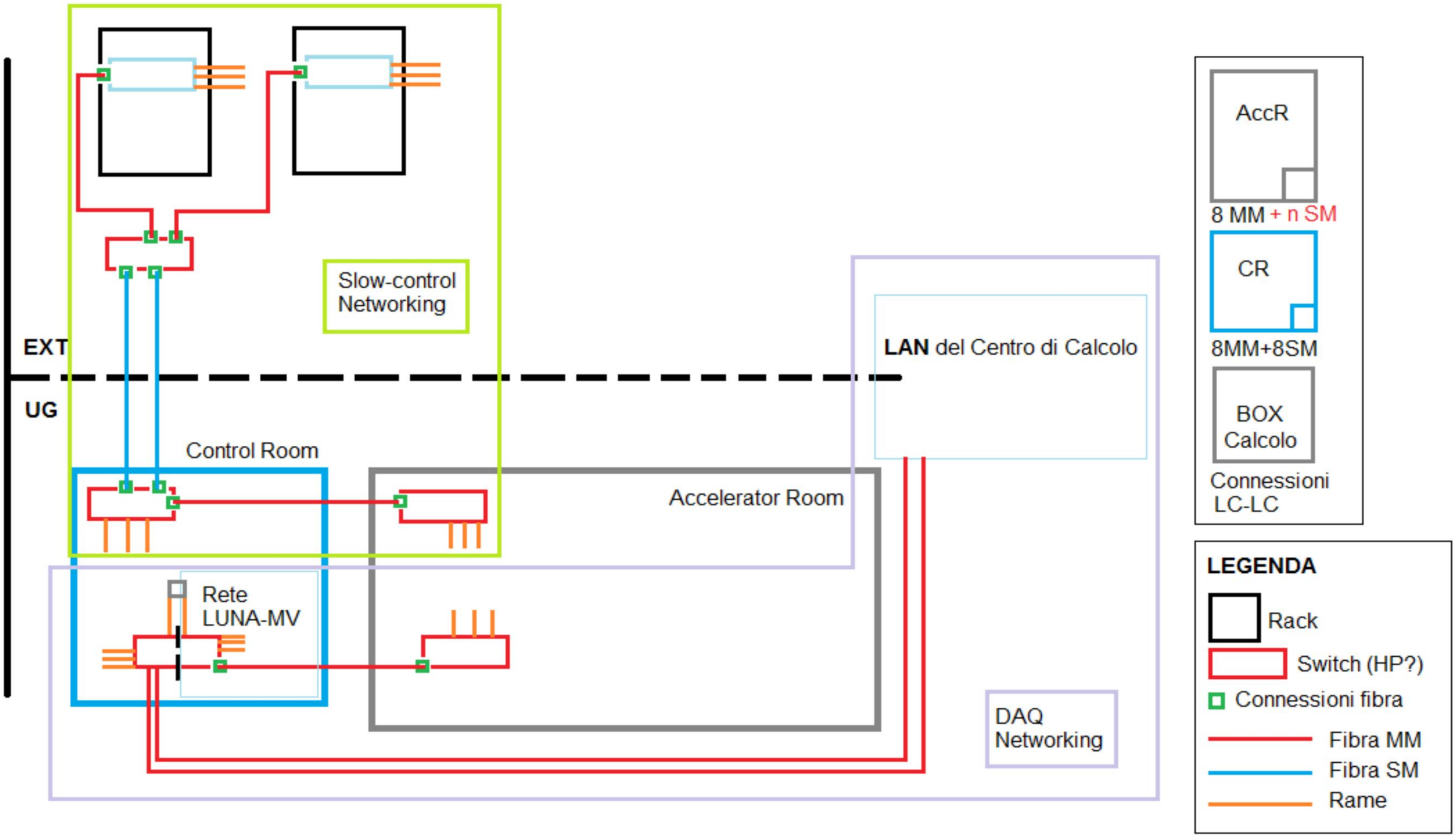
Do it the Safe Way ….

LUNA



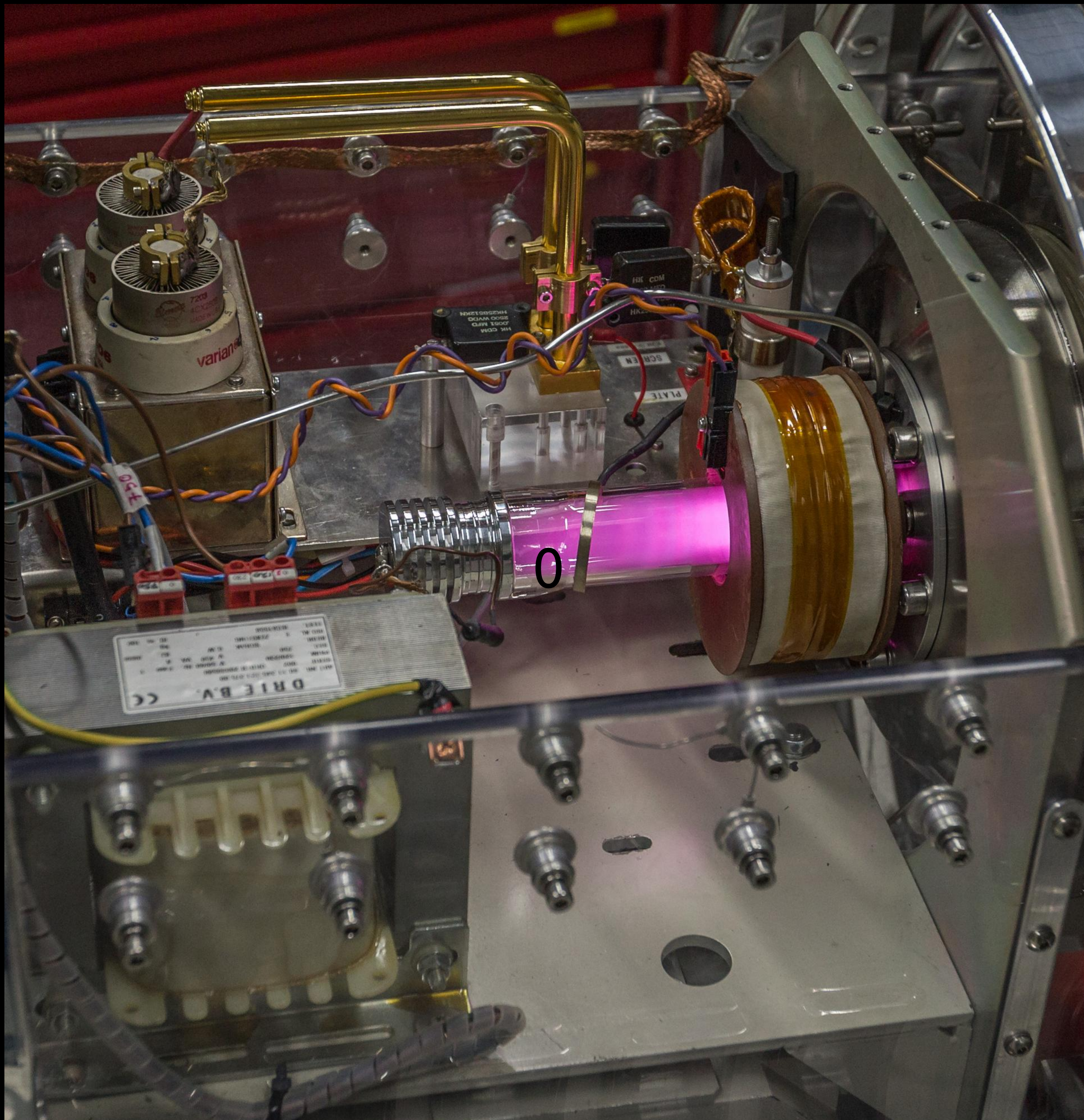
Controlling LUNA-MV and storing the data

Private network link between surface faclities and LUNA-MV for equipment control (incl accelerator)
Gbit network link between LUNA-MV and LNGS computing center for data transfer



LUNA-MV : basic schedule

Action	Date
Delivering of the first HVEE technical design	October 2016
Opening of the tendering procedure for LUNA-MV plants	November 2016
Submission of the Authorization request to «Prefettura dell'Aquila»	December 2016
Beginning of the clearing works in Hall B	February 2017
End of the tendering procedure for the new LUNA-MV building	May 2017
Beginning of the construction works in Hall B	September 2017
End of the tendering procedure for LUNA-MV plants	July 2017
Beginning of the construction of the plants in the LUNA-MV building	January 2018
In-house acceptance test for the new LUNA-MV accelerator	June 2018
Completion of the new LUNA-MV building and plants	April 2018
LUNA-MV accelerator delivering at LNGS	July 2018
Conclusion of the commissioning phase	December 2018
Beginning First Experiment	January 2019



Thank you for your attention