

无窗喷射气体靶研制

—LUNA-MV升级计划

连 钢

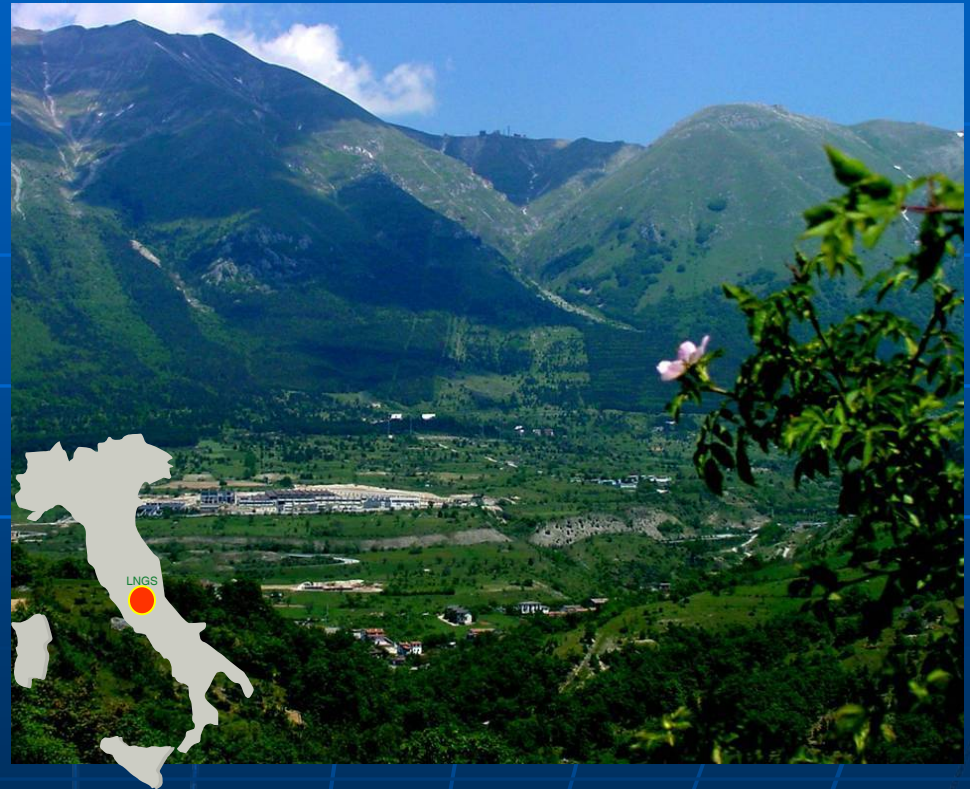
2011. 10. 13

主要内容:

- 背景: **Gran Sasso**地下实验室和 **LUNA** 项目
- **LUNA-MV** 计划圆桌会议
2011.2.6 - 2011.2.11 Gran Sasso
- **LUNA-MV** 计划最新进展
- 无窗喷射气体靶初步设计

Gran Sasso National Laboratory

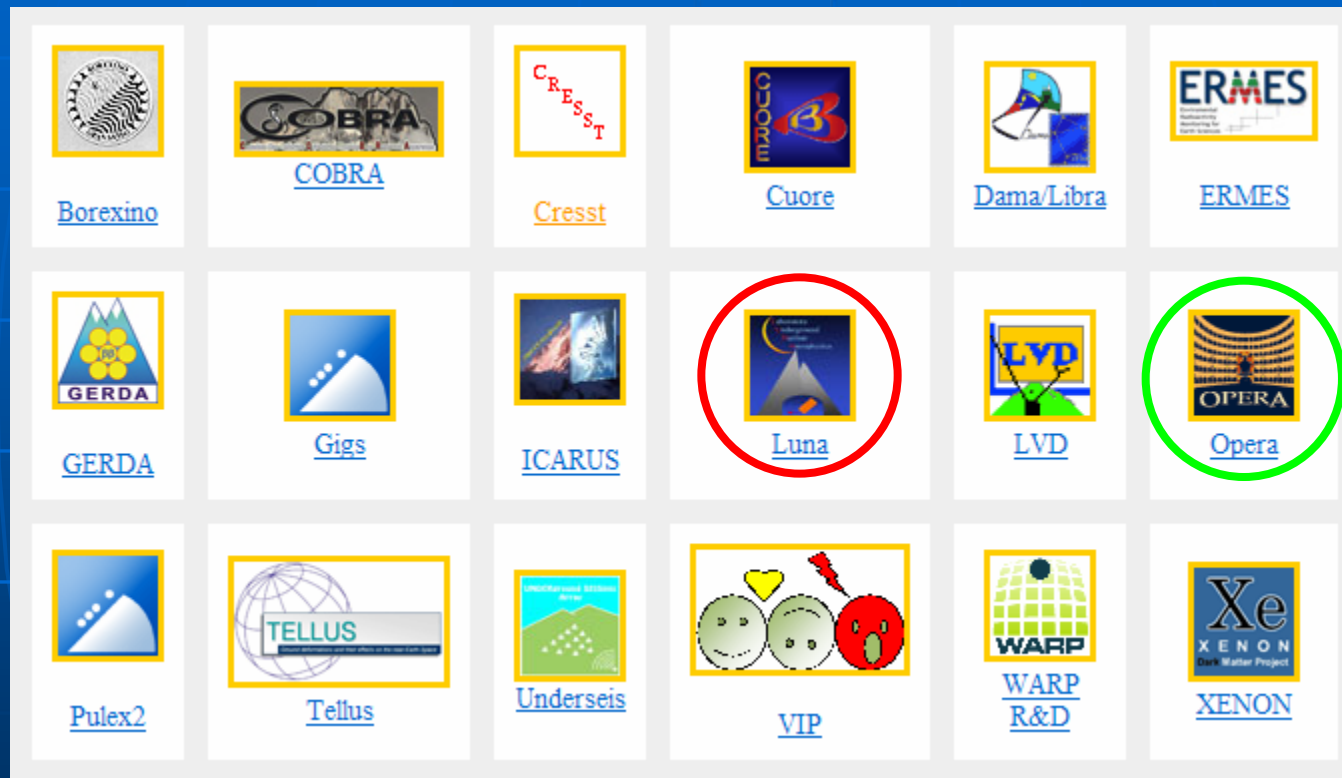
Operating Institution	Istituto Nazionale di Fisica Nucleare (INFN)
Location	Gran Sasso Tunnel (L'Aquila, Italy)
Excavation	1987
Underground area	3 halls A B C (100m x 18m x 20m) + service tunnels
Depth	1400 m
Total volume	180000 m ³
Surface	> 6000 m ²



Gran Sasso National Laboratory (**LNGS**)

Gran Sasso National Laboratory

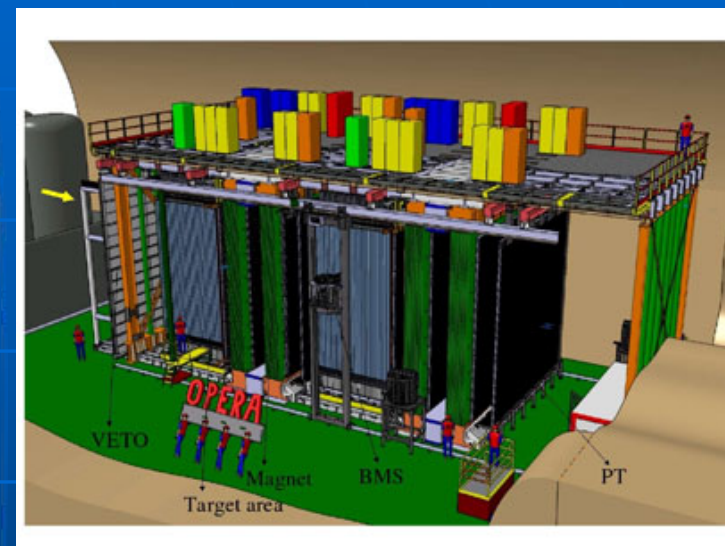
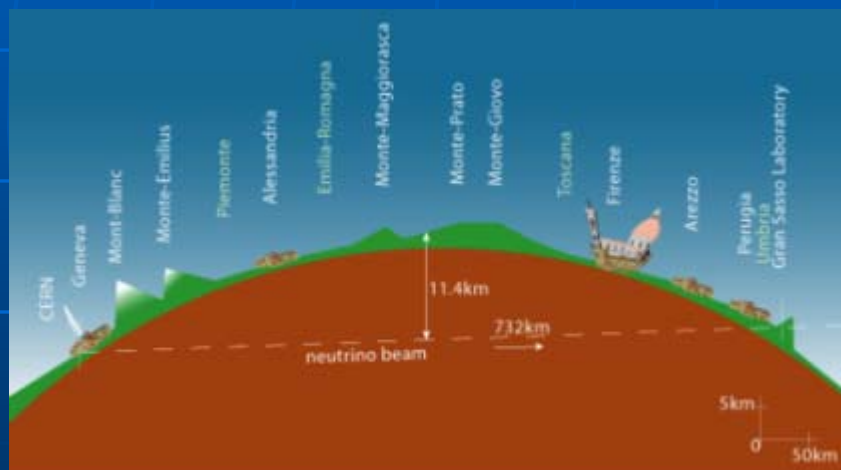
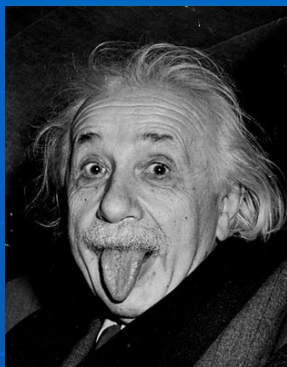
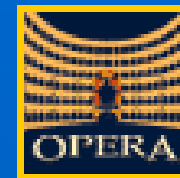
Current Experiments



LUNA Laboratory for Underground *Nuclear* Astrophysics

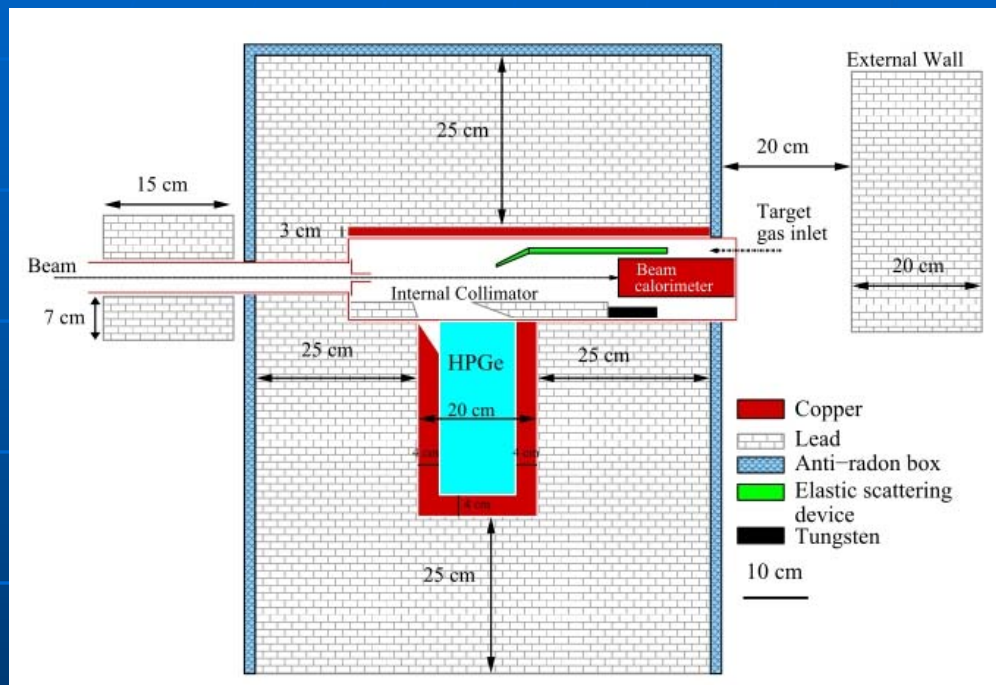


Gran Sasso National Laboratory



Artistic view of the OPERA detector : 150000 bricks (photographic emulsion films interleaved with lead plates) for a total mass of 1300 tons. The yellow arrow in front of the **VETO** indicates the direction of the incoming CNGS neutrino beam

299,799,953 m /s > 299,792,458 m /s ?

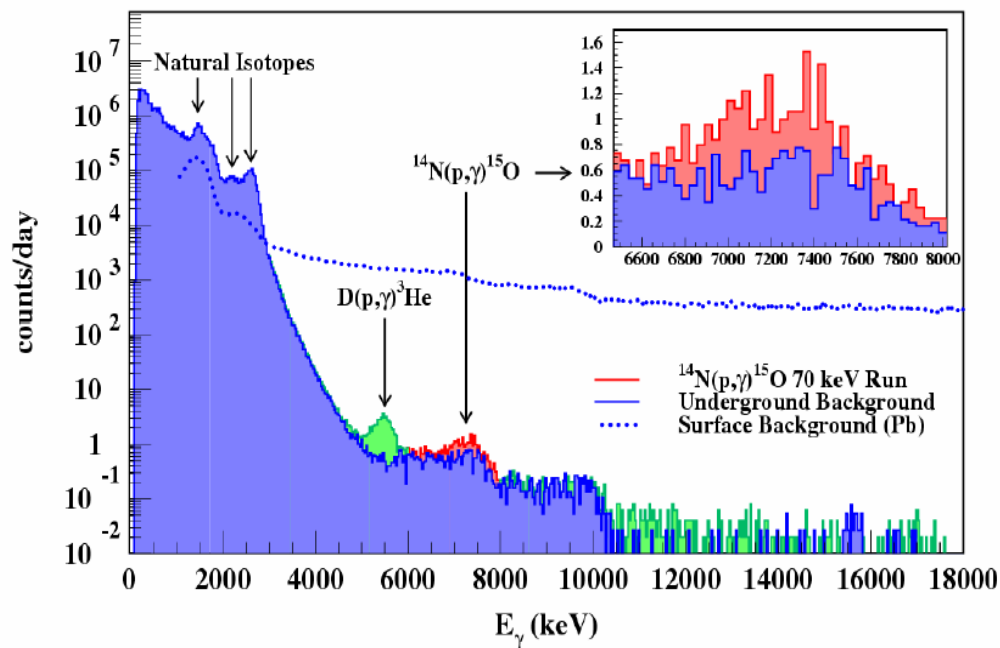


典型实验屏蔽示意图

A.Caciolli et al.,
Eur. Phys. J. A 39, 179 - 186 (2009)

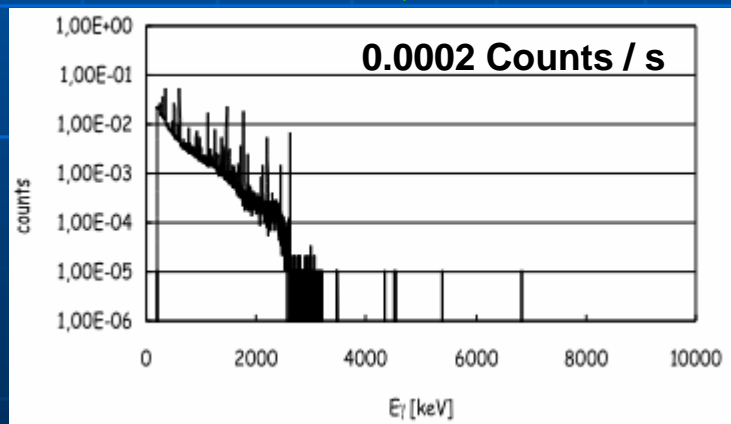
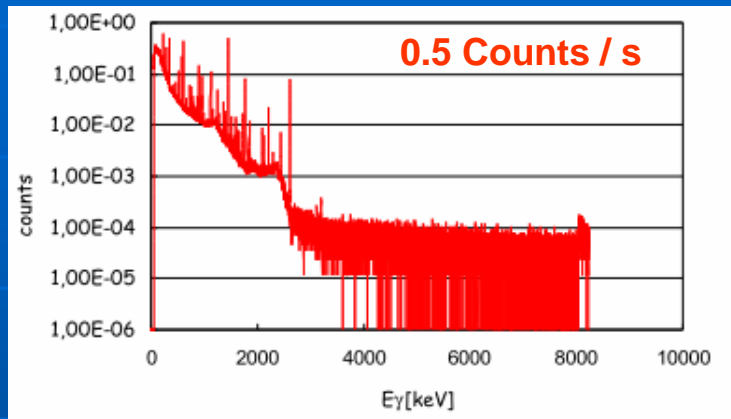


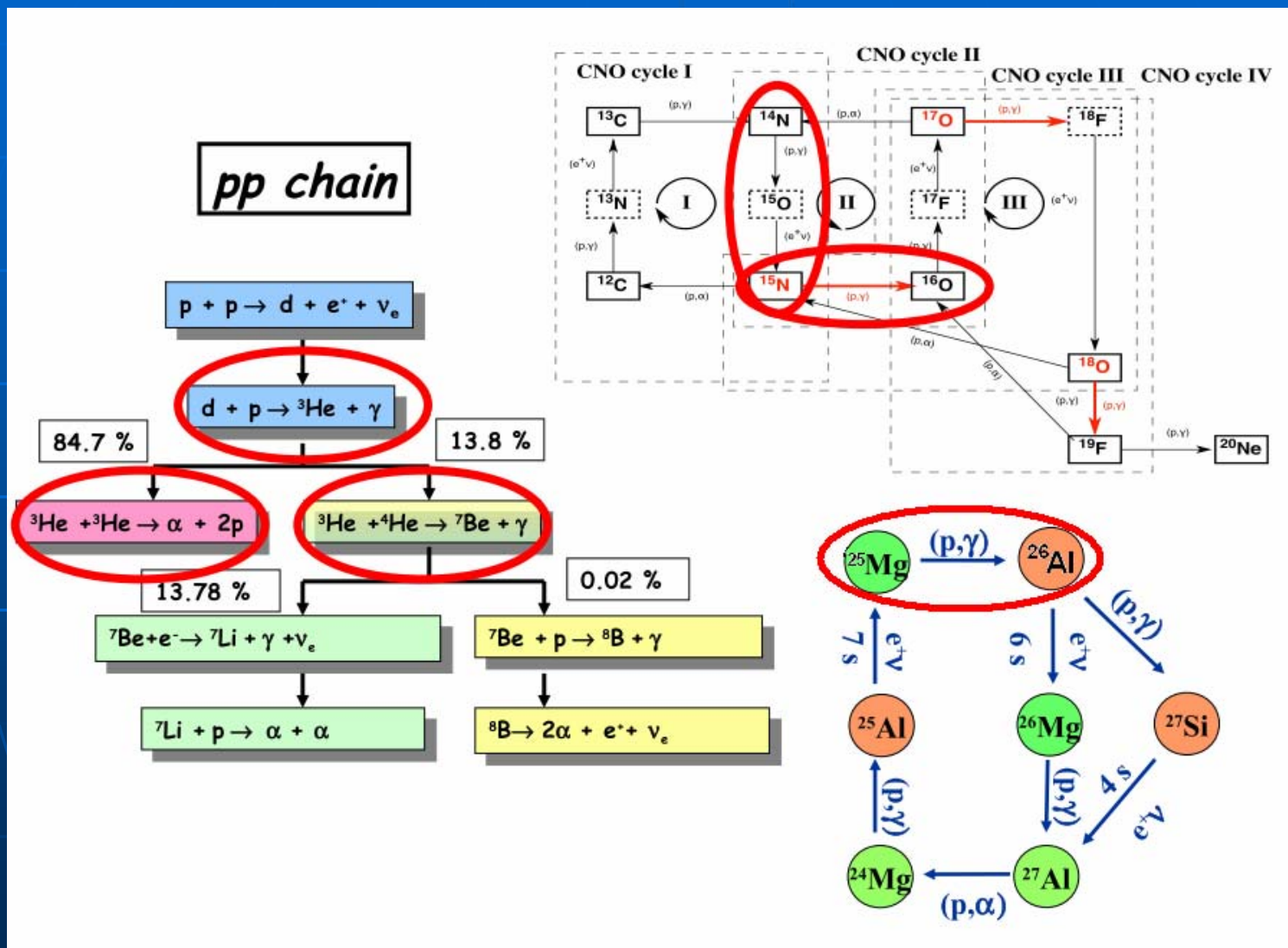
LUNA 地下核天体物理实验室



LUNA用 4π BGO探测器 + ^{14}N 无窗气体靶测量的 $^{14}\text{N}(p,\gamma)^{15}\text{O}$ 反应能谱($E=70$ keV). 测量耗时49天, 入射质子束的电荷累计达到 928库仑. 蓝线表示天然本底, 绿线是束流引起的本底, 蓝色点线为地面实验室本底(有铅屏蔽).

$3 \text{ MV} < E_\gamma < 8 \text{ MV}$



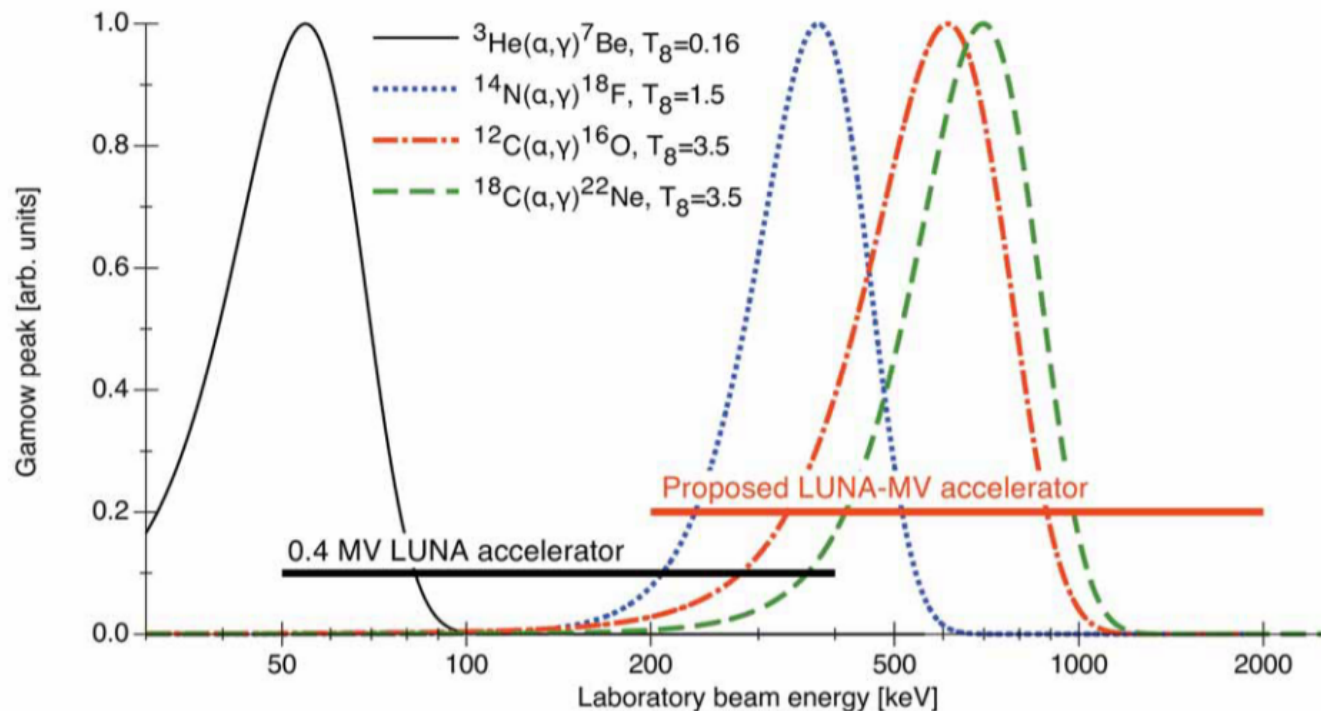


LUNA present program

	reaction	Q-value (MeV)	Gamow energy (keV)	Lowest meas. Energy (keV)	LUNA limit
CNO cycle {	$^{17}\text{O}(p,\gamma)^{18}\text{F}$	5.6	35-260	300	65
	$^{18}\text{O}(p,\gamma)^{19}\text{F}$	8.0	50-200	143	89
Ne-Na cycle {	$^{23}\text{Na}(p,\gamma)^{24}\text{Mg}$	11.7	100-200	240	138
	$^{22}\text{Ne}(p,\gamma)^{23}\text{Na}$	8.8	50-300	250	68
BBN	$\text{D}(\alpha,\gamma)^6\text{Li}$	1.47	50-300	700(direct) 50(indirect)	50

LUNA 地下核天体物理实验室

Gamow peaks for helium burning reactions



The key reactions of the He burning and neutron sources for the s-process are relevant at higher temperatures (larger energies) than reactions belonging to the hydrogen-burning studied so far at LUNA

➡ **Higher energy machine**

LUNA-MV计划圆桌会议



2011.2.6 - 2011.2.11 柳卫平、连钢

- 访问意大利 GranSasso 地下实验室
- 参加LUNA-MV计划圆桌会议



- LUNA-MV 计划进展
- 实验计划讨论
- 其他地下实验室进展
- 国际合作情况讨论
- 参观地下实验室



LUNA-MV计划圆桌会议

LUNA-MV 计划进展

A MV machine

to reach He burning and reactions producing the neutron sources for the s-process

April 2007:

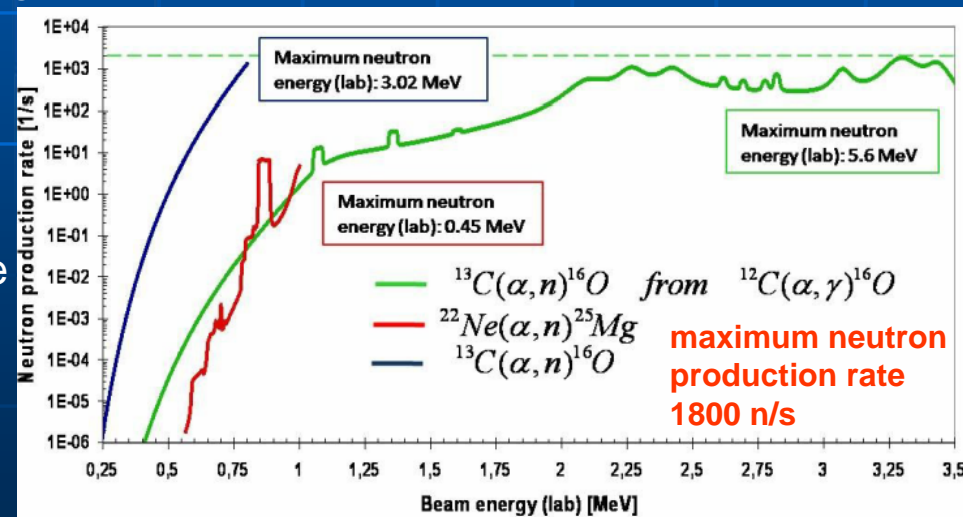
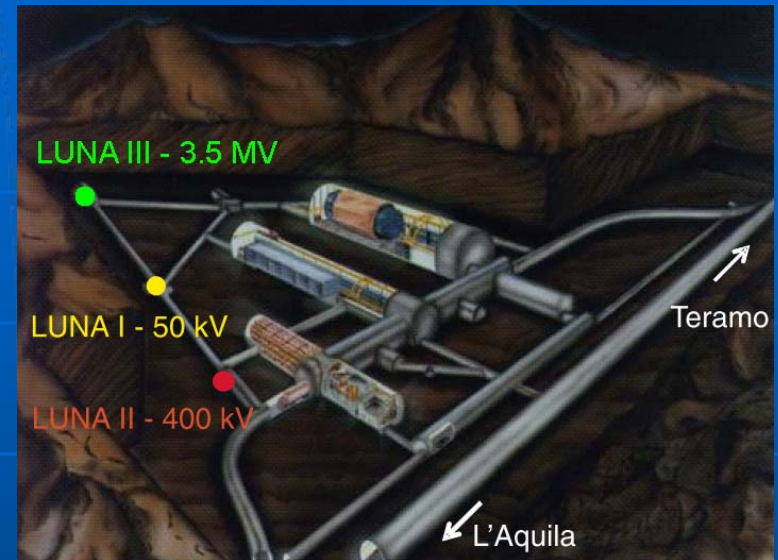
a Letter of Intent (LoI) was presented to the LNGS Scientific Committee (SC) containing key reactions of the He burning and neutron sources for the s-process

July 2008:

The INFN President and the Executive Board fully agree to continue the LUNA activity with the MV machine in Gran Sasso. A suitable place has been found to host the new accelerator

February 2011:

LUNA-MV project Roundtable



Science cases:

- $^{12}\text{C}(\alpha, \gamma)^{16}\text{O}$ is the “Holy Grail” of nuclear astrophysics.

The typical Gamow peak energy for helium-burning: ~ 300 keV

- (α, γ) reactions on $^{14,15}\text{N}$ and ^{18}O

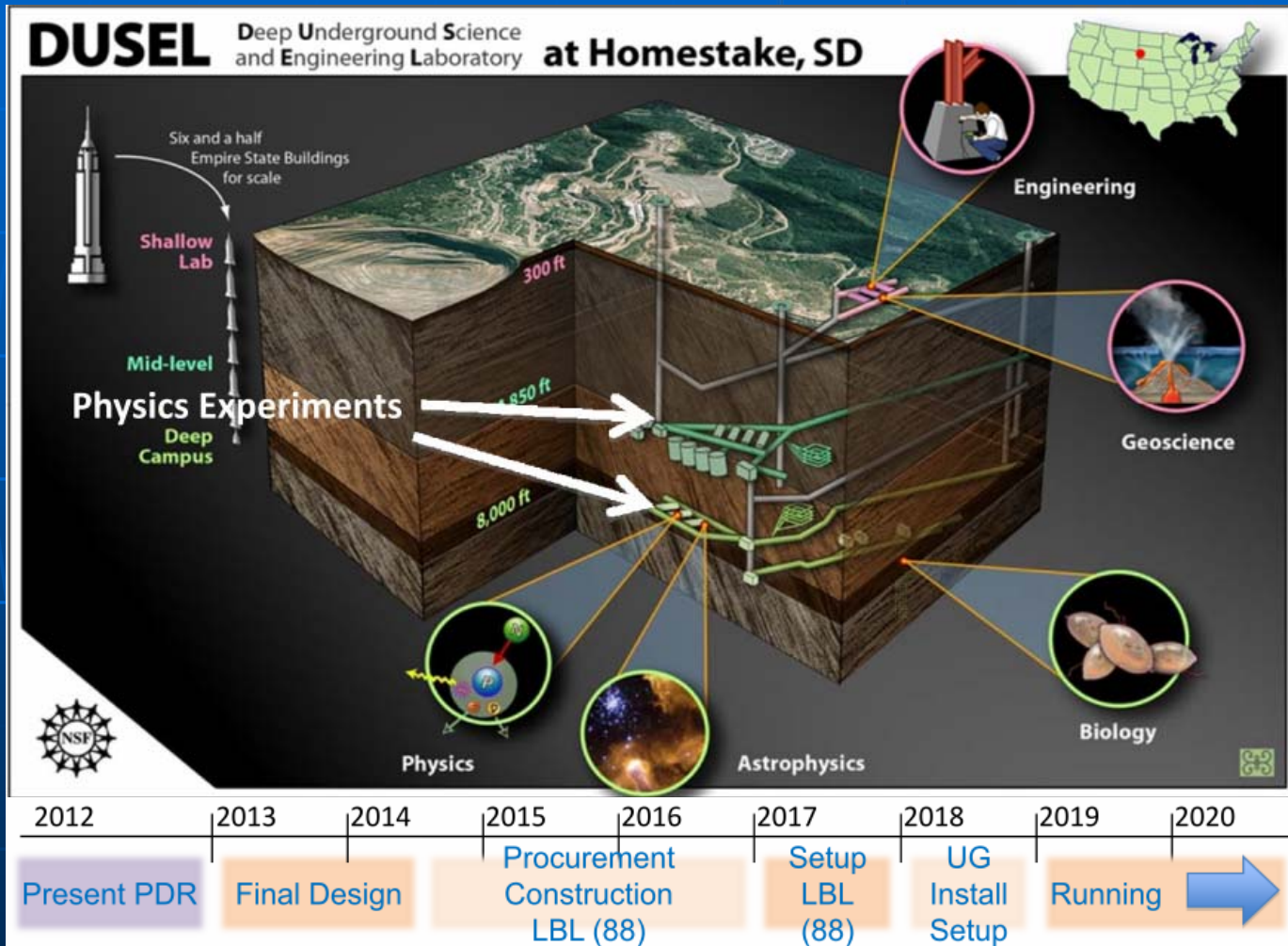
The other Helium-burning reactions

- $^{13}\text{C}(\alpha, n)^{16}\text{O}$ and $^{22}\text{Ne}(\alpha, n)^{25}\text{Mg}$

The neutron source for the s-process

LUNA-MV计划圆桌会议

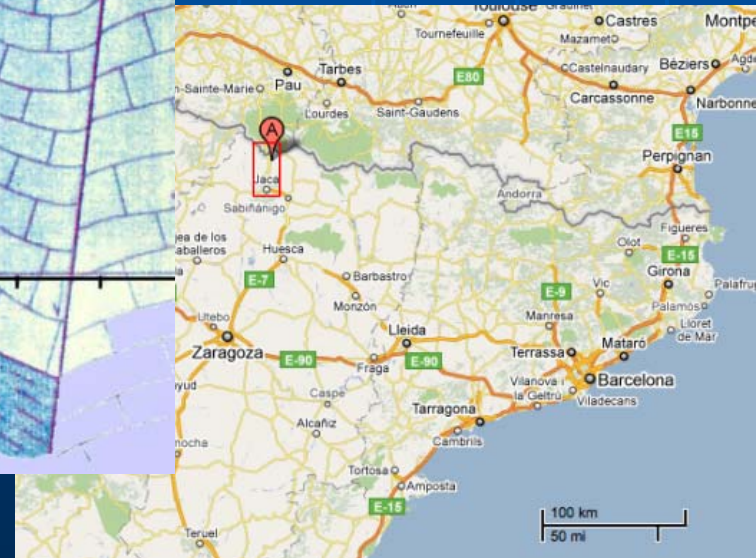
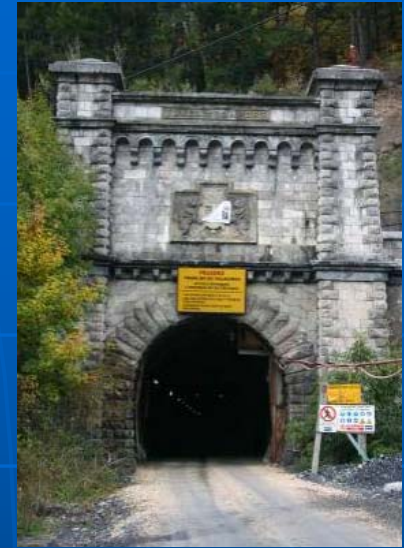
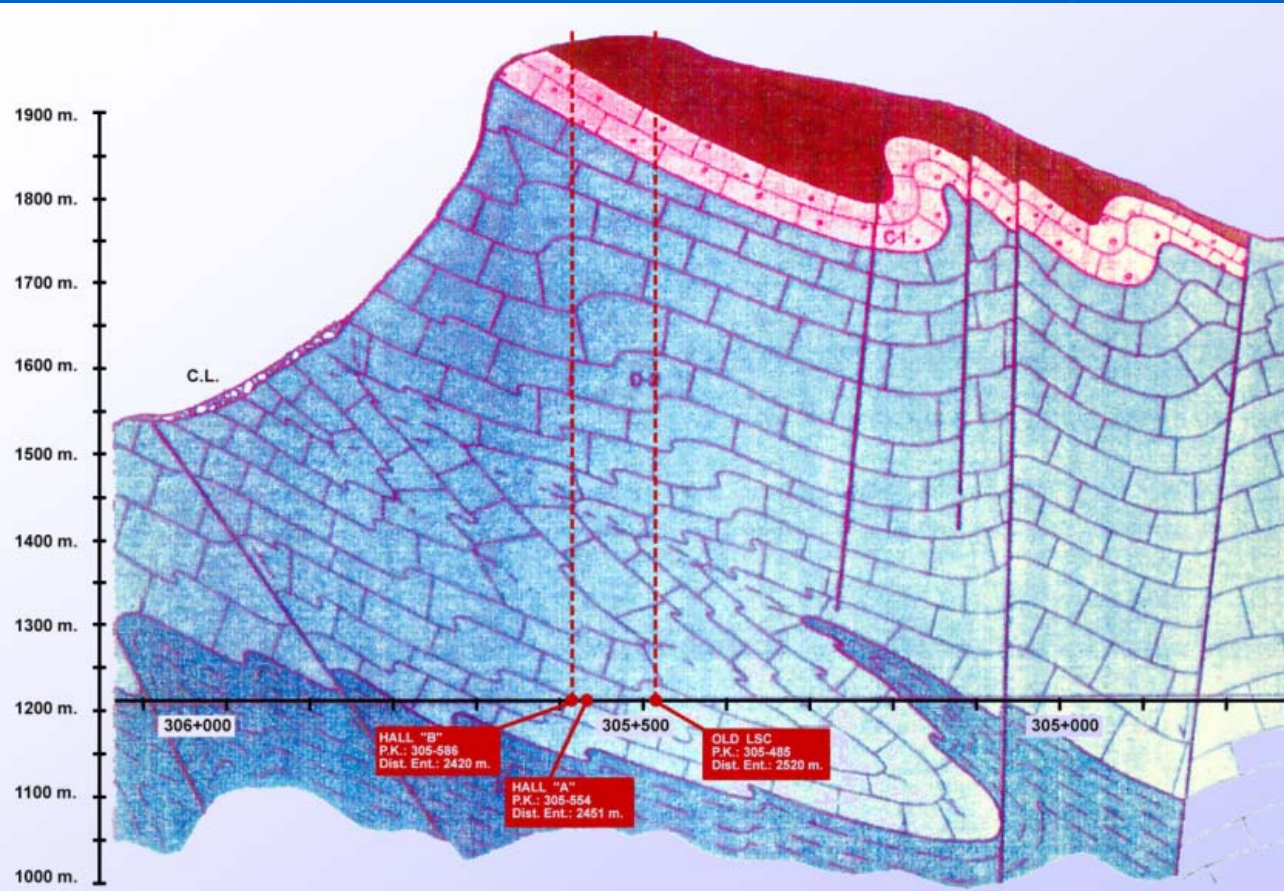
South Dakota(南达科他州), US



LUNA-MV计划圆桌会议

Canfranc (坎弗兰克), Spain

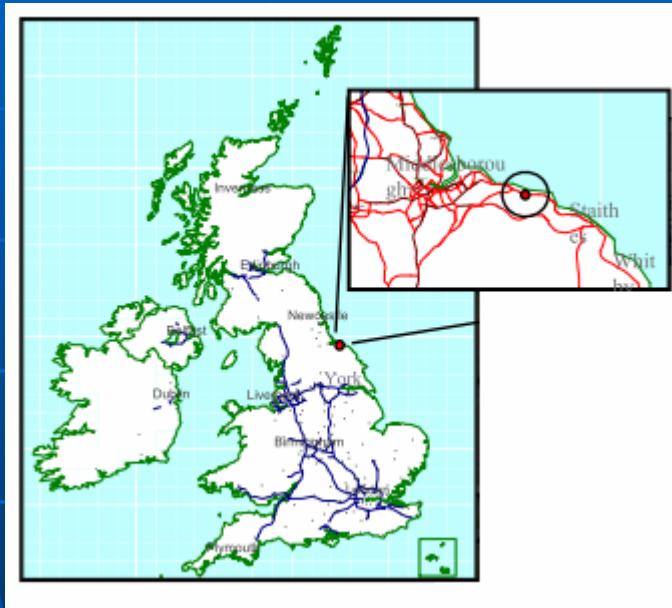
Under the Pyrenees (railway tunnel)



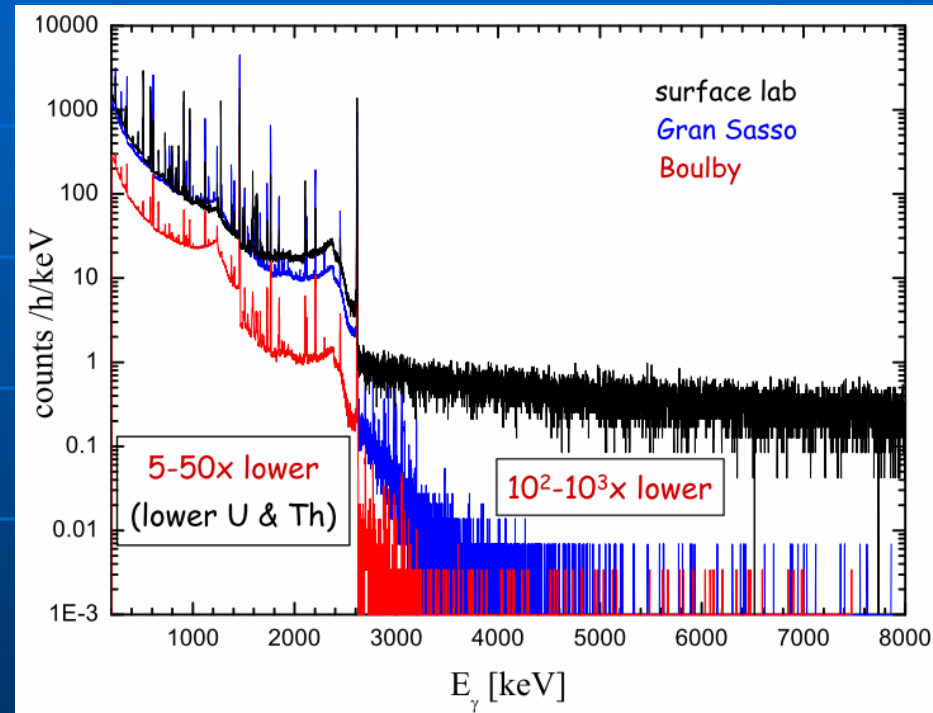
LSC: Laboratorio Subterráneo de Canfranc

LUNA-MV计划圆桌会议

Boulby: commercial potash and salt mine , North Yorkshire, England
(~ 1100 m deep)



European **L**aboratory for **E**xperimental **N**uclear **A**strophysics



LUNA-MV 计划最新进展



Workpackages :

- **WP1:** Accelerator + ion source
- **WP2:** Gamma detectors
- **WP3:** Neutron detectors
- **WP4:** Solid targets
- **WP5:** Gas target
- **WP6:** Simulations
- **WP7:** Stellar model calculations

LUNA-MV 计划最新进展

A board of four people :

M. Aliotta, L.M. Fraile, Z. Fülöp, A. Guglielmetti

A WP co-ordinator :

will be selected among the interested scientists in order to set the relevant milestones and deadlines

An overall coordinator/spokesperson :

to monitor the progress of each WP

serve as liaison for scientifically related questions among different WPs

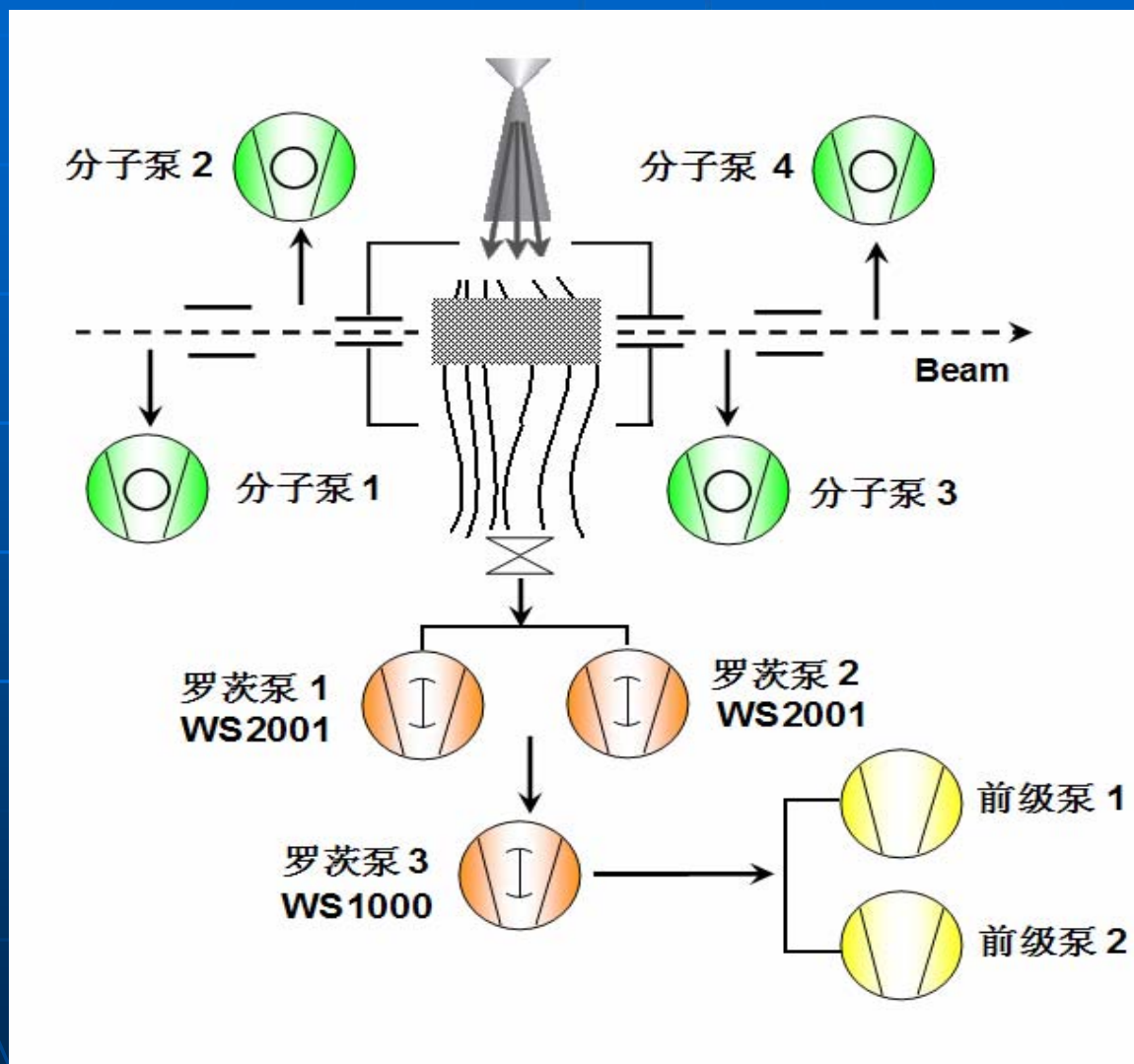
LUNA-MV 计划最新进展

Timeline of the LUNA-MV envisaged:

- 6 months for the site preparation;
- 6 months for implementation of power supply, ventilation, safety systems
- 12 months for accelerator installation and first beam line commissioning.

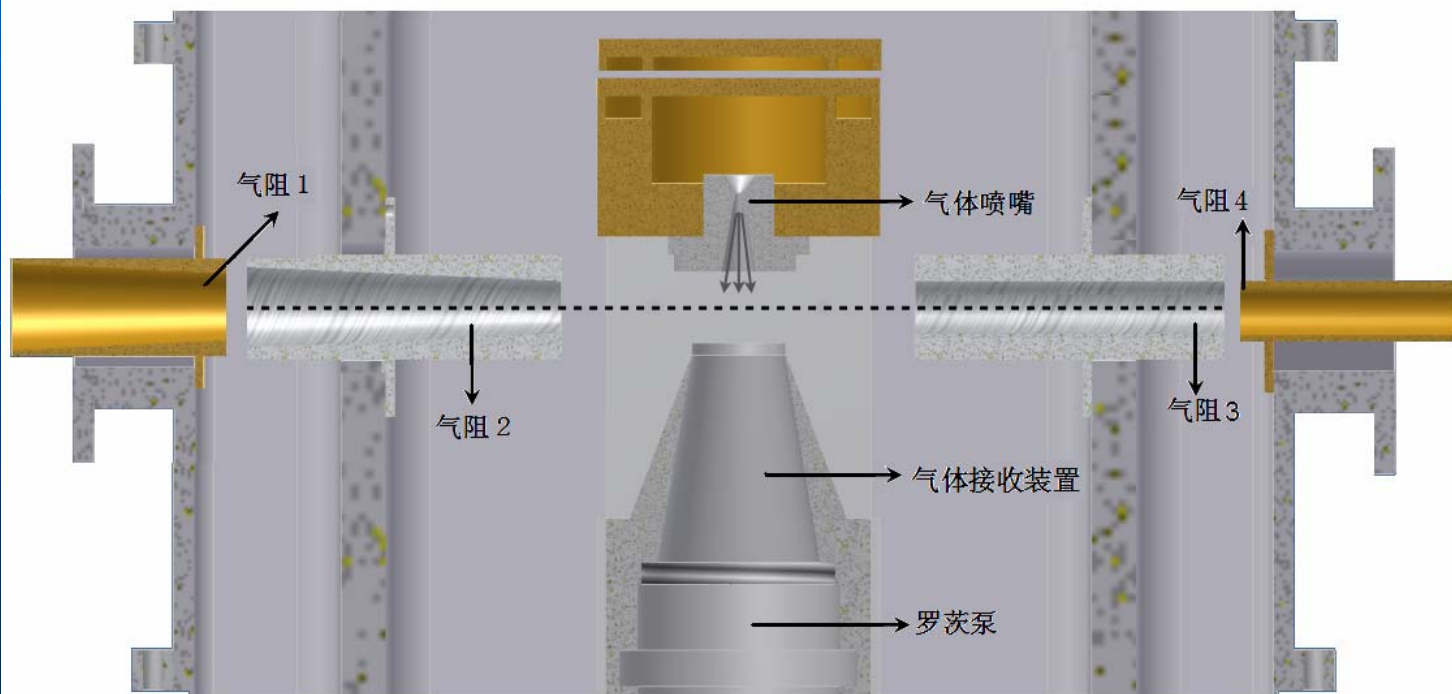
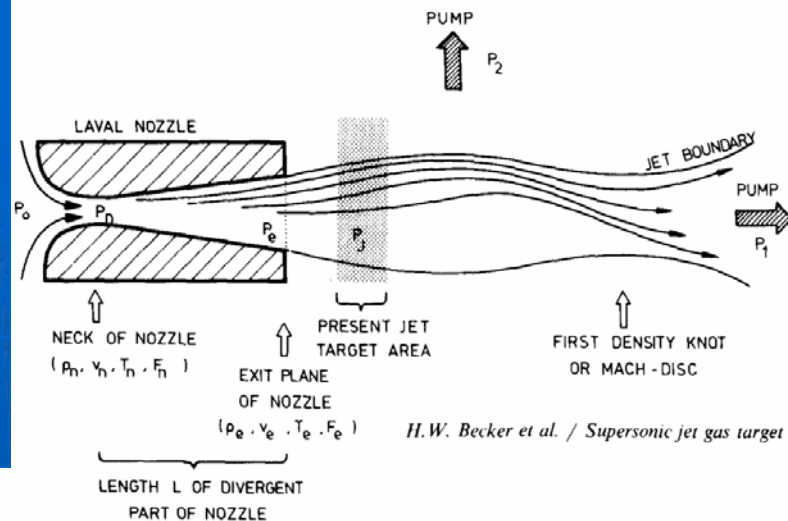
For the accelerator a bid will be necessary. Estimate of the necessary time for the bid is uncertain, being very much dependent on the regulations at the time when the bid will be realized (approximately 1 year).

无窗喷射气体靶初步设计



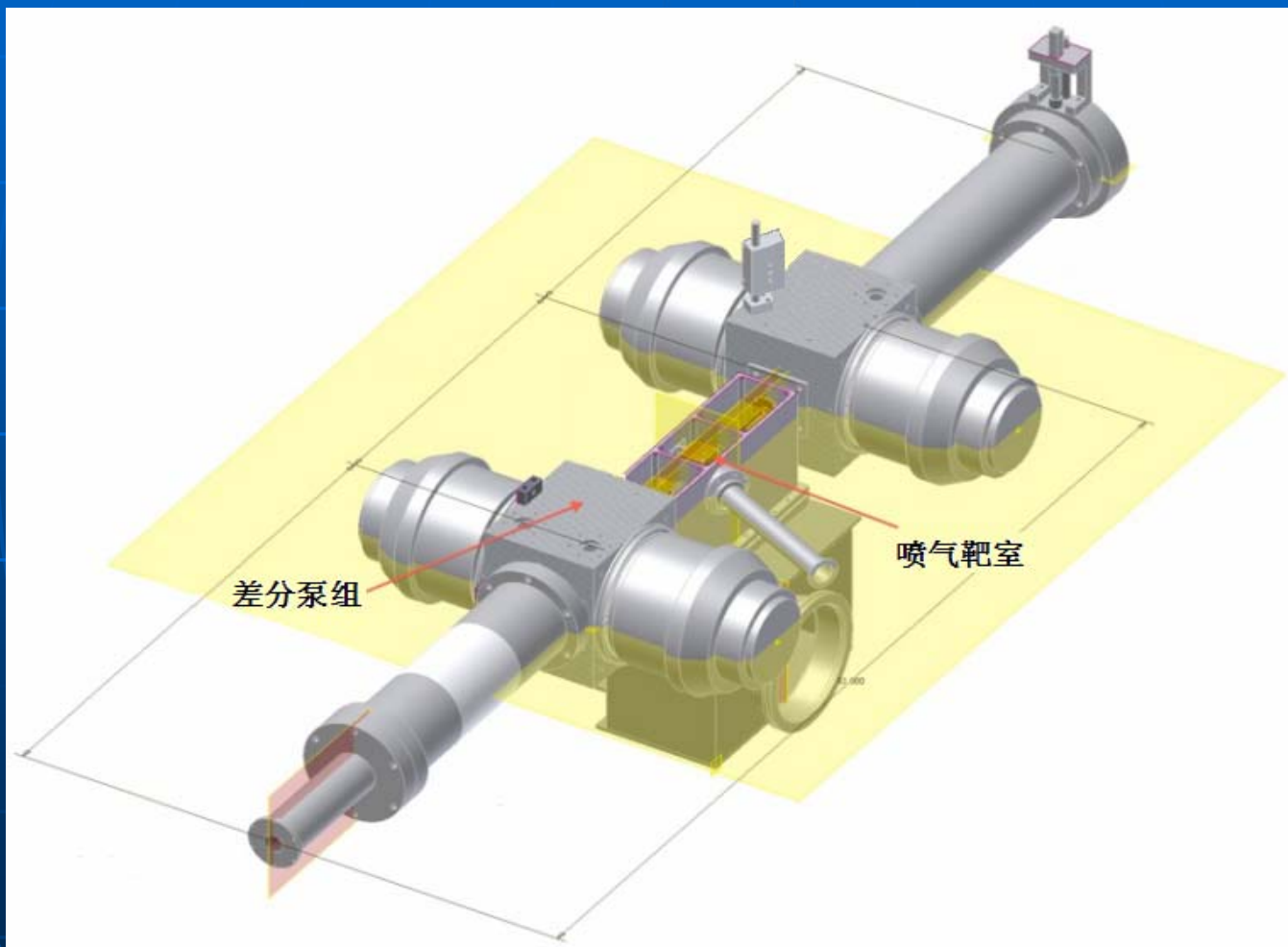
无窗喷射气体靶初步设计

难点一：气体喷嘴设计



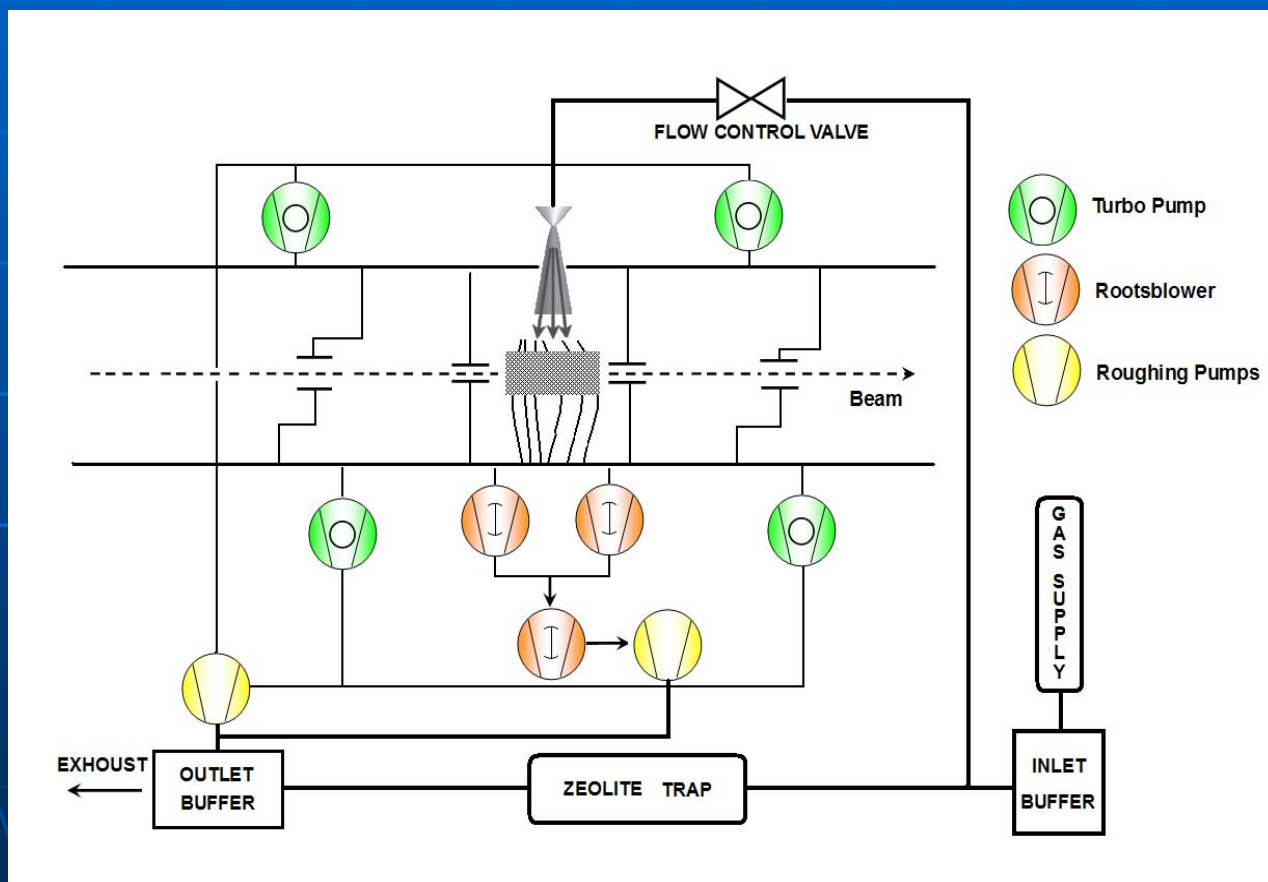
无窗喷射气体靶初步设计

难点二：气体靶泵组空间安排



无窗喷射气体靶初步设计

难点三：循环气路设计



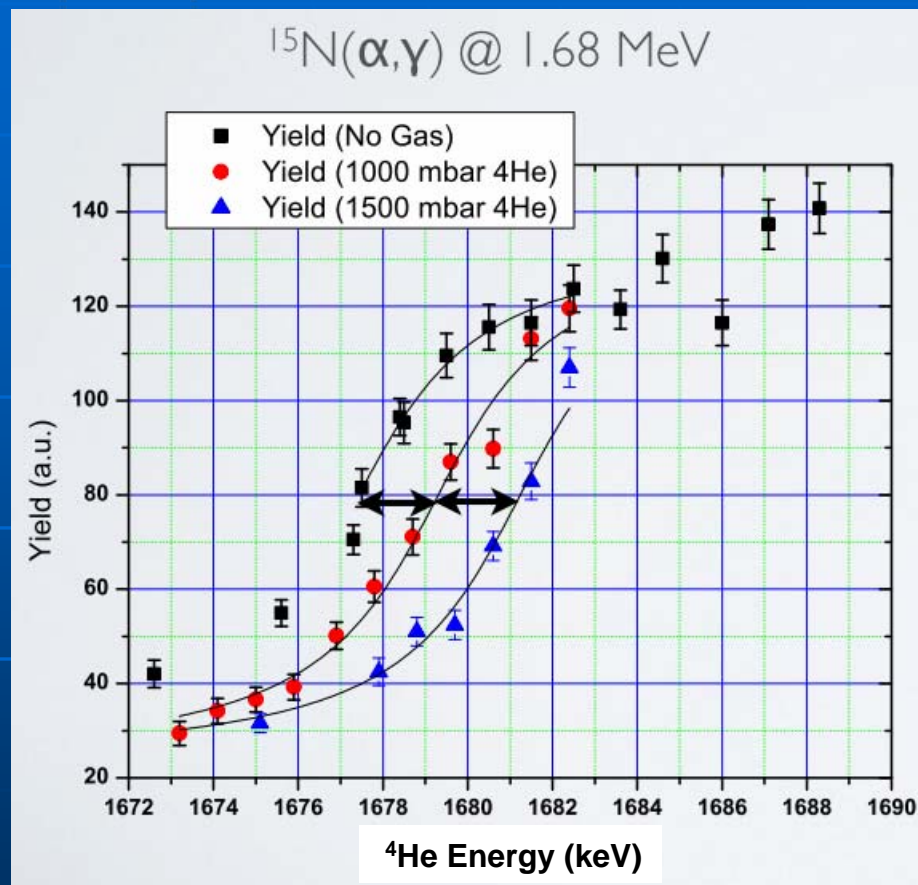
无窗喷射气体靶初步设计

难点四：靶厚精确测量

➤ Elastic scattering Method

➤ Energy Loss Method

Measurement of the excitation curve of a resonance with and without gas



University of Notre Dame
Joint Institute for Nuclear Astrophysics

无窗喷射气体靶初步设计

➤ A total of 6 pumping stages

4 Turbo-molecular pumps & 4 Roots Blowers

➤ Compact design

Allowing for gamma ray detection set-up in close geometry

➤ Designed jet thickness

$10^{17} \sim 10^{18}$ atoms/cm² @ Helium 1500 mbar

5-10% of target thickness uncertainty

The plan for 2012

➤ ~ 2011.12

To nail down the task of WorkPackages.

➤ 2012.1 ~ 2012.6

According to the LUNA-MV project,
making detailed design of the windowless gas jet target

➤ 2012.7 ~ 2012.12

Fabricating the gas jet target in CIAE
including the **gas cell**, the **jet system** and **remote control**

经费预算

项目	内容	预计费用（万）
差分泵组	包括：4组罗茨泵、4组分子泵、3组前级泵及相应的自动控制系统	150
稳流装置	气体稳流装置和安全保护系统	25
靶室	靶室、气嘴、气阻、气动阀门及相应的控制系统	30
国际合作	参加国际会议、LUNA实验、协调工作进度	15
其他	气体靶设计、测试实验、靶厚测量	25
合计		245

仪器基金申请

.....申请者为积累了多年的实验经验，申请书中对于仪器的方案、设想、调试等都比较详细，比较切实可行。主要的问题是申请的仪器项目将配置在国外的加速器实验装置中，以往也有类似的项目归属于国际合作项目中，本人认为，**此类项目因属于国际合作项目的范围，所以建议这里不予资助。**

.....本项目提出的研究无窗喷射气体吧，具有重要的应用价值，特别对于低能核反应实验。提出的方案经过详细调研分析，具有较好的可行性。但目标是用于参与国际深地实验合作，**似乎申请重大国际合作项目更合适。**

.....研制目标明确，有一定难度，可为今后国际合作开展天体物理相关的 α 核反应截面测量创造条件。该国际合作项目本人不了解，但从申请书内容看，意方已与原子能院签订合作意向协议，**说明从其他渠道是可以得到经费支持的。综上，建议不予资助。**

总结：

- **LUNA** 唯一的地下核天体物理实验室
- 新的**MV**计划将拓展**LUNA**的研究范围
- 借助创新群体平台参与**LUNA-MV**计划：
开展合作研究的良机
- 其他基金的支持

Thanks !