INFN
LNGS
Istituto Nazionale di Fisica Nucleare
Laboratori Nazionali del Gran Sasso

HAMMER

LSC
Laboratorio Subterráneo de Canfranc

The most modern mechanical technologies and cutting edge radio-analytical techniques merged for extremely low background achievement

S.Nisi, Chemistry Department, Gran Sasso National Laboratory, INFN

D. Orlandi, Advanced Mechanics Service, Gran Sasso National Laboratory, INFN

On behalf of collaboration

Low
Radioactivity
Techniques

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OUTLINE

Why Low Radioactivity Techniques (LRTs) ?

Additive Manufacturing technologies (AM="3D printing")

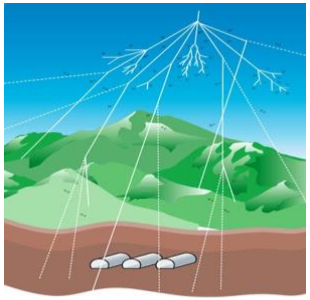
Aim of this work: new LB Cu components production process

LRTs: tools to ensure the quality control

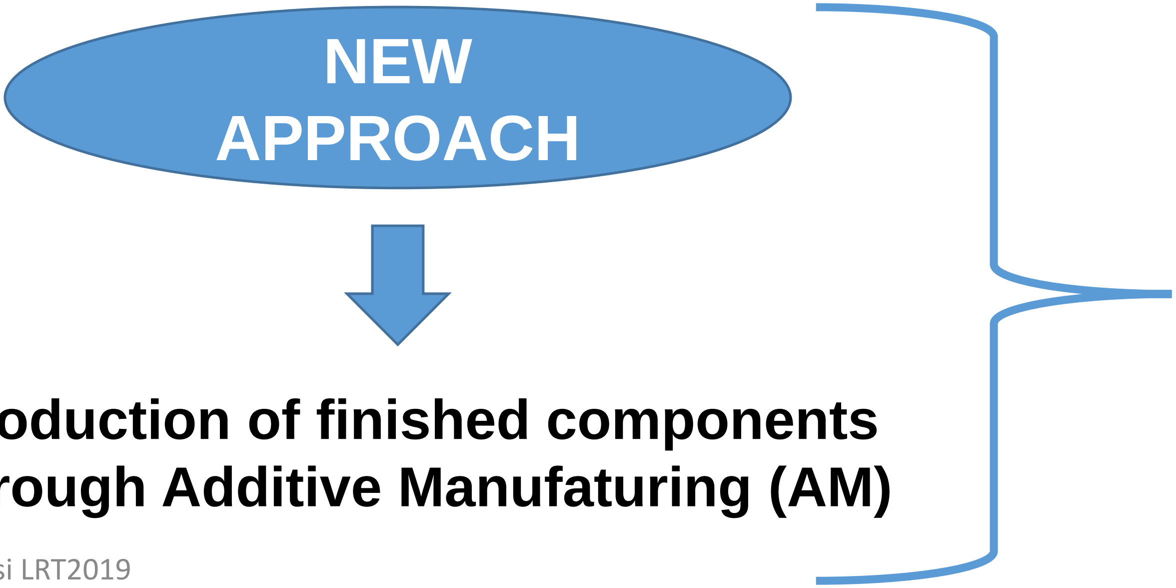
Conclusions

Why Low Radioactivity Technique (LRT) ?

Low Radioactive Techniques are essential **to select** the materials needed for assembling Low Background (LB) apparata



- They are used for screening of semi-finished metal/plastic materials
- The final component realization often requires heavy machining
- Surface contamination is very critical (often dominant) for LB
- Components need final surface treatment and cleaning



NEW APPROACH

Production of finished components through Additive Manufaturing (AM)

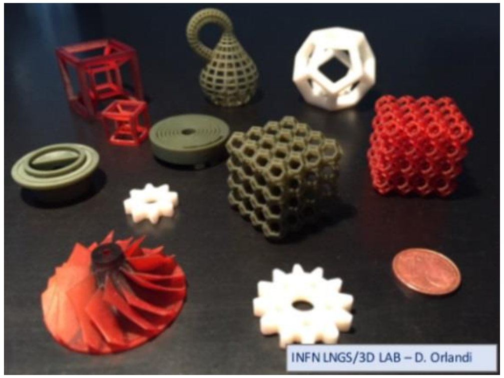
LRTs play a fundamental role for production process monitoring

S. Nisi LRT2019

Additive Manufacturing at LNGS

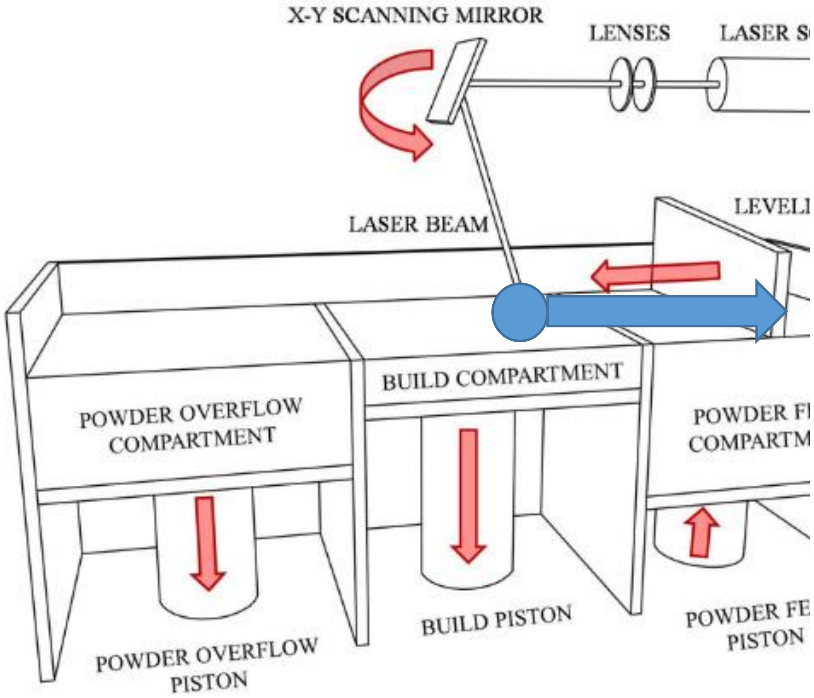
For several years now the Mechanical Workshop is operating 3D printing devices to realize pieces with **photo-polymeric** and MultiJet Hi-performance **thermoplastic resins**

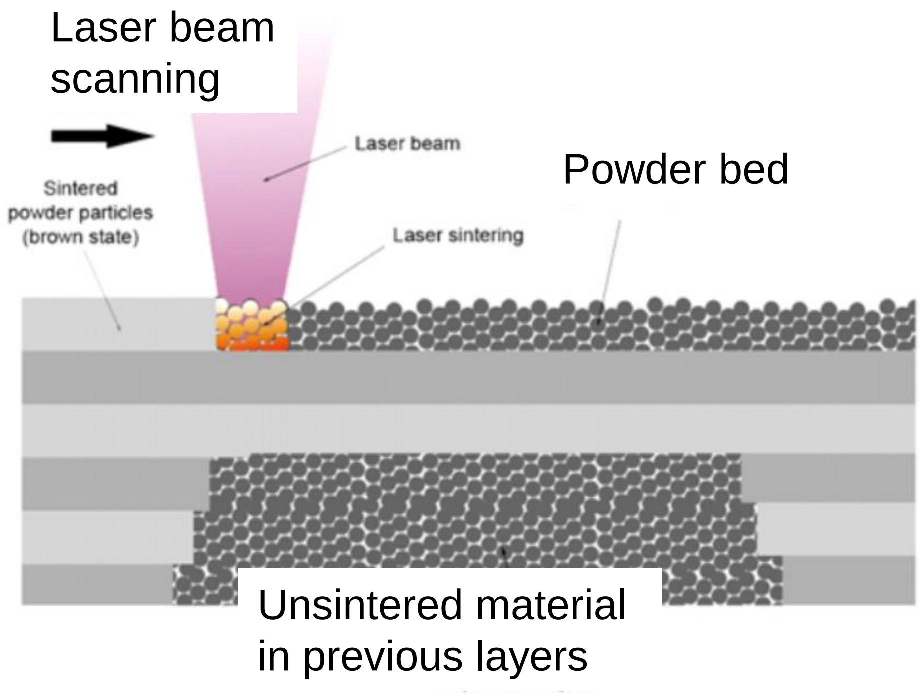
Carbon PEEK 3D printing is coming soon



The facility is equipped with a stereoscopic Hi-Res 3D scanning station for quality analysis and reverse engineering

AM: Laser **Metal** Fusion Technology





Laser beam scanning

Powder bed

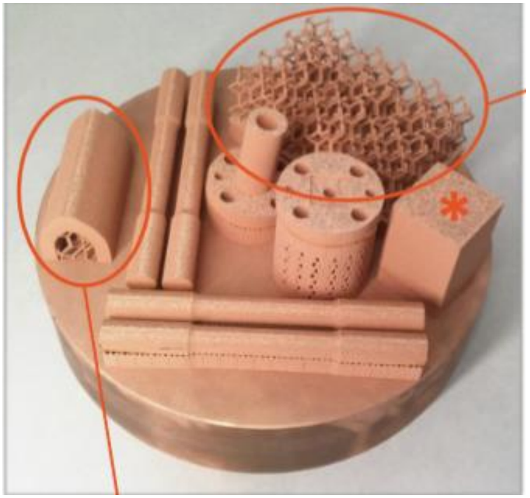
Unsintered material in previous layers

Technical Data - Dati Tecnici	mysint100PM
Building volume - Volume di lavoro	ø 100x80 63,5x80 34,5x80 mm (interchangeable - intercambiabili)
Laser Source - Sorgente laser	Fiber Laser 200 W
Precision Optics - Ottiche di precisione	Quartz F-Theta Lens
Laser spot diameter - Diametro spot laser	30 µm
Typical layer thickness (adjustable) - Spessore tipico layer (regolabile)	20-40 µm
Inert gas - Gas inerti	Nitrogen, Argon - Azoto, Argon

Additive Manufacturing: Future Outlook in Designing **Pure Copper** Components for particle detectors

AM allows to produce parts:

- complex geometries
- high Resolution
- hollow components
- w/o final traditional machining
- w/o surface cleaning
- mass savings with a factor ≈ 2-3
- reduction of number of components



Crystal Holder

Traditional CNC
mass=27g

M/3 !

AM same support
mass=11g

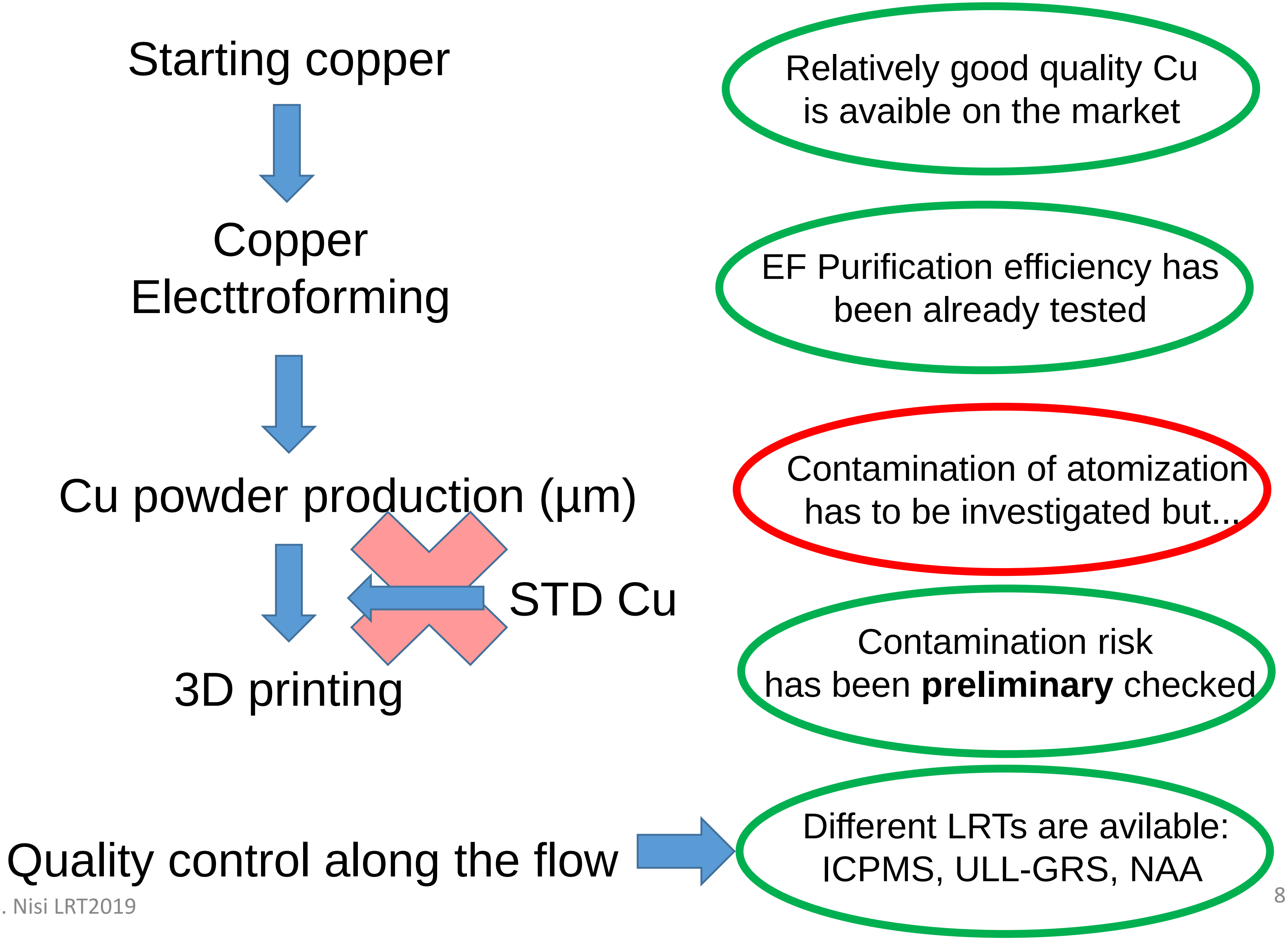
AM new design
mass=9g

Mechanical and physical properties of pure copper components obtained trough AM

		Raw Cu	Cu AD/Cu Raw
Density (porosity)	gcm^{-3}	8.93	95-97%
Resolution (grain size, laser spot size)	µm	---	5-25 µm
Roughness	µm	---	5-25 µm
Thermal conductivity Low Temperature	$Wm^{-1}k^{-1}$	390	70%
Yield Strengt $\sigma_{0.2}$	MPa	80-120	80%

Special post production thermal treatment (HIP:ing at 1000bars at 1150 °C for 120 min) changes the grain size and it enhances the quality of Cu from the mechanical and physical point of view.

Ultrapure Copper component production process



Starting copper

Copper Electtroforming

Cu powder production (µm)

STD Cu

3D printing

Quality control along the flow

Relatively good quality Cu is avaible on the market

EF Purification efficiency has been already tested

Contamination of atomization has to be investigated but...

Contamination risk has been **preliminary** checked

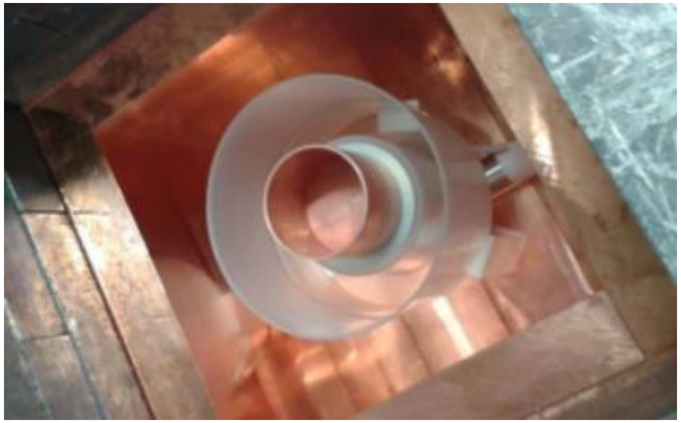
Different LRTs are avilable: ICPMS, ULL-GRS, NAA

Copper Electroforming facilitiy at LSC

Cu Electroforming allows to produce clean pieces, but relatively simple geometries, it's time consuming, it needs intermediate and/or final mechanical machining and surface cleaning

EF copper over the mandrel after the first mechanization treatment (left) and the final part (on the right)

EF copper piece over a Marinelli container in the sample cavity a HPGe (GeOroel at LSC)

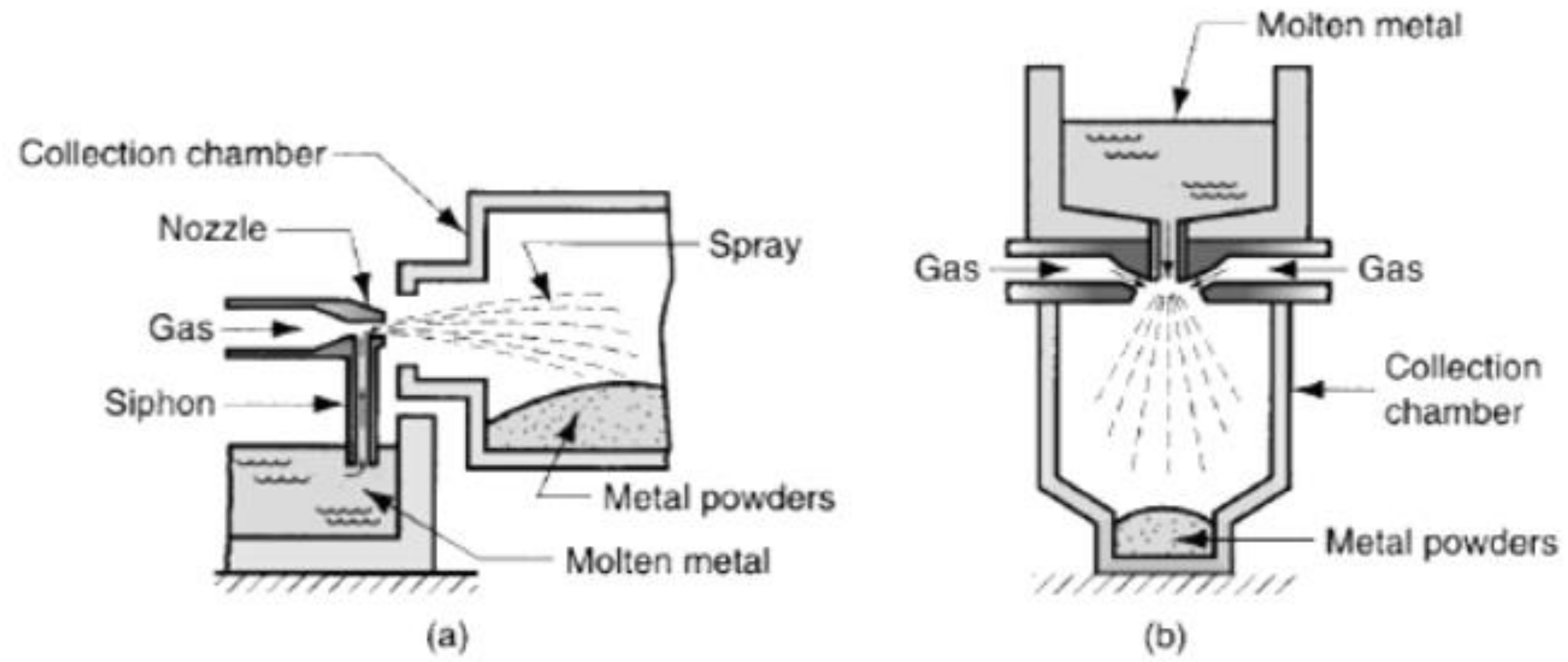


Purification efficiency of EF at LSC

			CURAW2ET.D		CUEF2ET.D		Removal efficiency	
Element	Mass		[ng/g]		[ng/g]		[%]	
Mn	55	ppb	21		<10		>	52.38
Fe	57	ppb	13,000		<3000		>	76.92
Co	59	ppb	1,600		<1		>	99.94
Ni	60	ppb	26,000		<10		>	99.96
Zn	68	ppb	70,000		<10		>	99.99
Ge	72	ppb	5.6		<1		>	82.14
As	75	ppb	1,300		<100		>	92.31
Ag	107	ppb	1,000		240			76.00
Cd	110	ppb	520		<5		>	99.04
In	115	ppb	75		<2		>	97.33
Sn	118	ppb	19,000		<5		>	99.97
Sb	121	ppb	1,900		<5		>	99.74
Te	125	ppb	66		<5		>	92.42
Pb	208	ppb	49,000		<50		>	99.90
Bi	209	ppb	180		<5		>	97.22
Th	232	ppb	<0.010		<0.001			
U	238	ppb	<0.005		<0.001			

Bulk !

Production of ultrapure Cu powder by mean atomization technology



Gas technique atomization methods

Atomizer is very expensive → outsourcing, but using dedicated pure Cu line

Ultra-low level radioactivity counting facilities

STELLA SubTErranean Low Level Assay

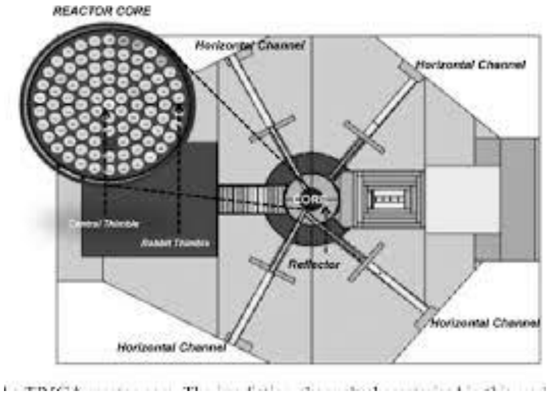
- Ƴ spectrtometry High-Purity Ge Detectors (HPGE)
- α spectrometry Silicon PIPS detectors
- Liquid scintillation counters

ICP-Mass Spectrometry

- Quadrupole and double focusing ICPMS
- ISO 6 Clean room
- Regents purification systems
- Sample treatment device

Neutron Attivation Anlysis (NAA) Pavia

- TRIGA Mark II reactor Pavia University
- Radio-Chemical Lab
- HPGE at Milan INFN&Univerity



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LRTs performances comparison

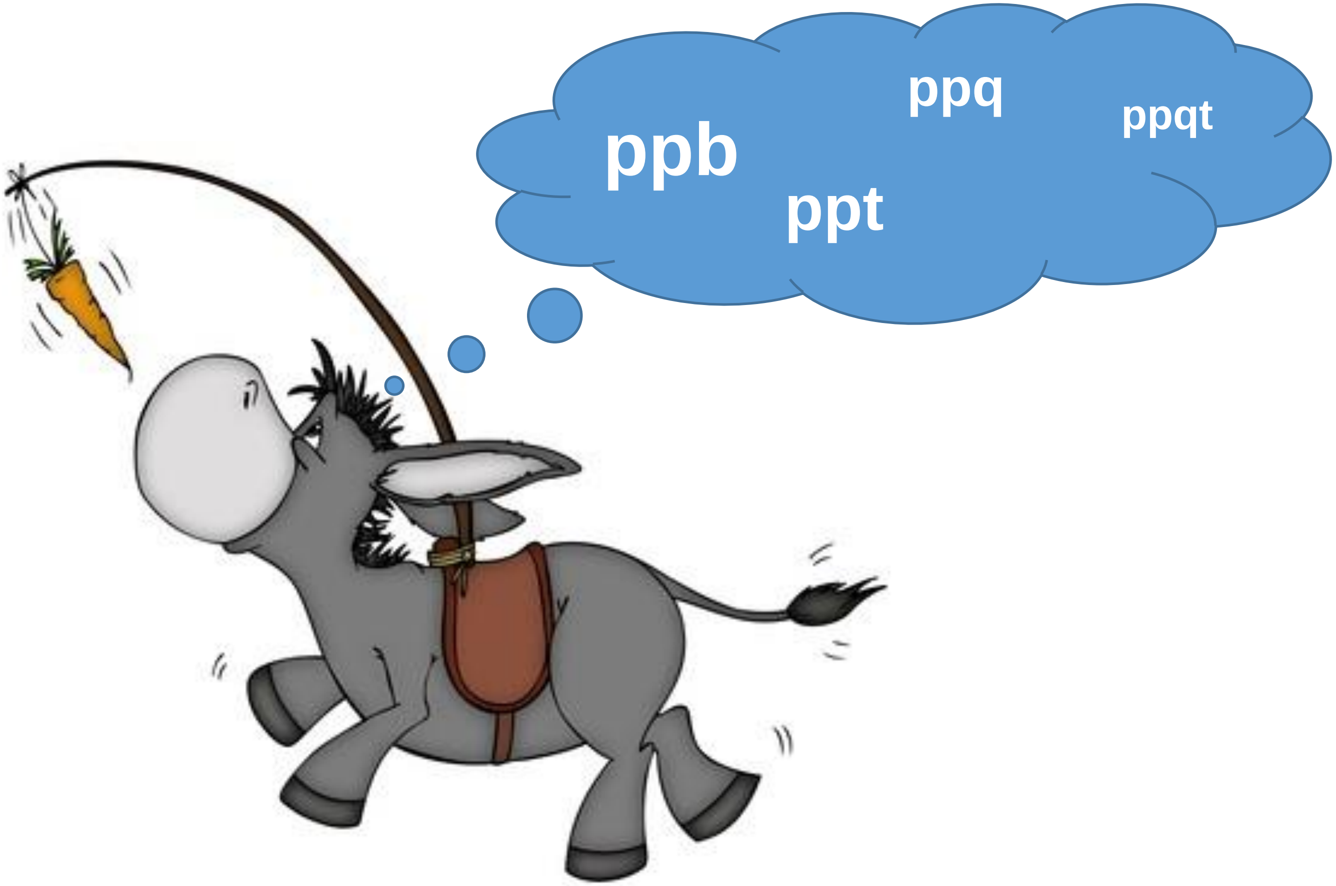
		ICPMS LNGS (LSC)	**ULL GRS LNGS (LSC)**	**ULLGS+NAA Milano-Pavia**
		Primordial parents	ϒ emitters	Primordial parents
		Surface/bulk	Bulk	Surface/bulk
Destructive		Yes	No	Yes
DL	[10^{-12}g/g]	Th=0.5 U=0.5	Th= 10-20 U= 10-20	Th(^{233}Pa)= 0.5 U(^{239}Np)= 3-5
Sample size	[g]	0.1-10	1-10000	200
Sample treatment		Contamination **risk not negligible**	Almost free	**Hot sample handling Low cont risk**
Analysis Time		Days	Weeks	Days-week

R&MS are often applied both to check for secular equilibrium of decay chain ICP-MS allows to perform the quality control of each single part (or lot).

Conclusion

- AM is a suitable technology to produce complex mechanical components **reducing their mass (and background!) up to 70%**
- AM reduces the risk of contamination during the production process
- The purity of Cu powder should improve supplying the atomizer with EF copper
- **Mechanical and physical properties** of the components obtained trough AM **are acceptable** but they can be improved optimizing the process parameters and applying special post production thermal treatment
- **The LRTs** applied during the production process **allow the quality control at sub ppt level (Th, U)**
- **Their sensitivity needs to be further enhanced** in order to certify cleaner and cleaner radio-pure material…

... this is the NeverEnding Story (Luckily!)



Thank you for your attention !

Abstract

The sensitivity of the experiments, searching for rare and low energy processes which could explain the most fascinating open questions of the modern physic, is limited by the radioactive background of the whole experimental apparatus. Radiometric and non-radiometric cutting edge analytical techniques have already been widely applied for the screening of the materials available on the market. Likely the new frontier of low background experiments requires new materials development, suitably studied, in order to match the thermal, mechanical and radio-purity performances needed in this field of physic.
The recent and rapid diffusion of 3D printing technologies allows producing plastic and metal parts characterized by complex geometry and reduced weight in comparison to the same structural parts obtained by traditional machining. In this project 3D printing, supported by high sensitivity analytical techniques such as ICPMS, ULL-GRS and NAA, will help the achievement of very low background conditions. The monitoring of the purity of the material during the production starting by the metal or polymer to the finished object will be discussed.

HAMMER Hub for Additive Manufacturing, Materials Engineering & Research

Donato Orlandi (INFN LNGS) - Valerio Pettinacci (INFN Rome) - Stefano Nisi (INFN LNGS) - Matthias Laubenstein (INFN LNGS)