Introduction

Simone Donati

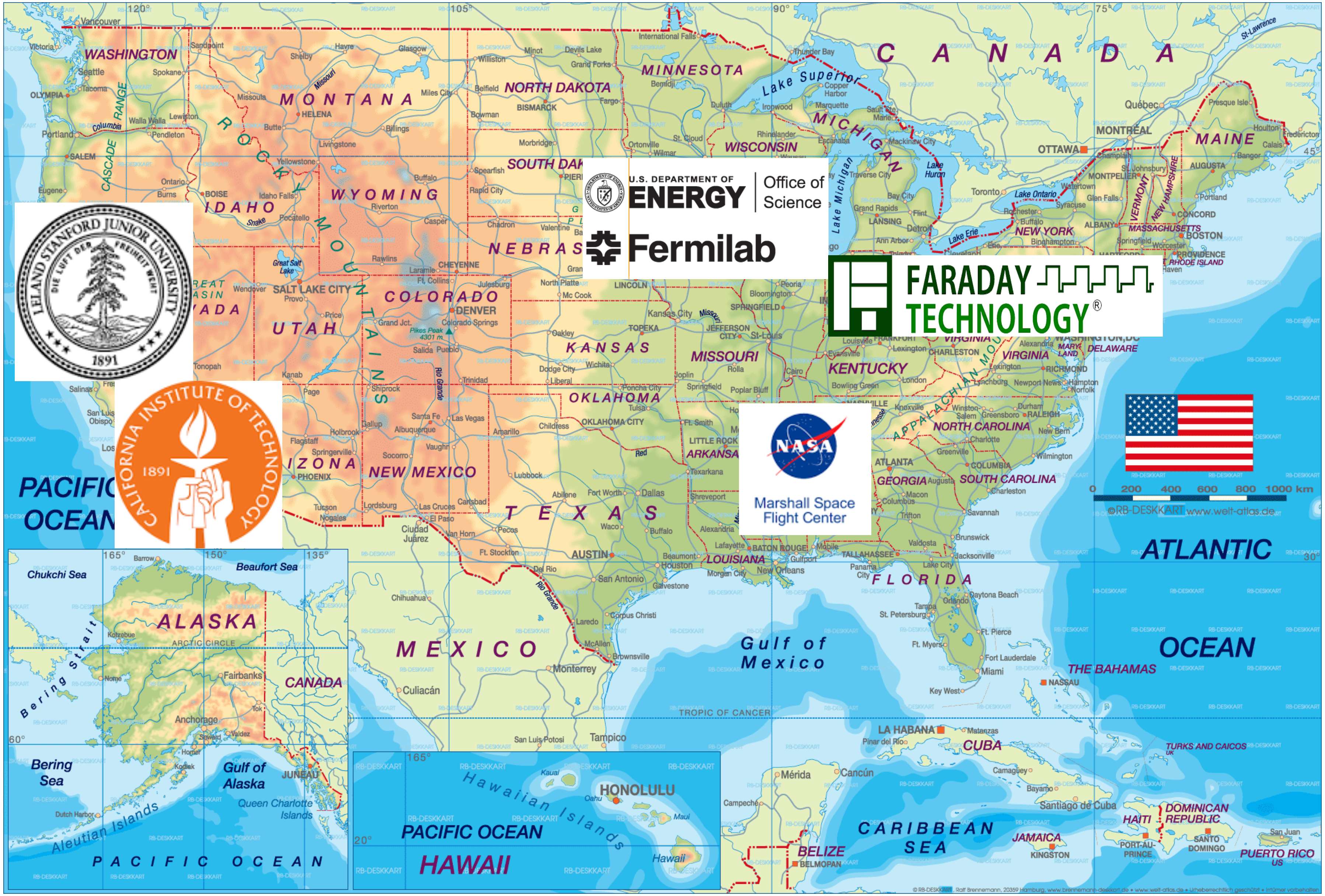
MidTerm Review, Pisa, March 4-5, 2019

Web site: risenews.df.unipi.it

European Commission

Trilateral EU-US-Japan collaboration (EU)

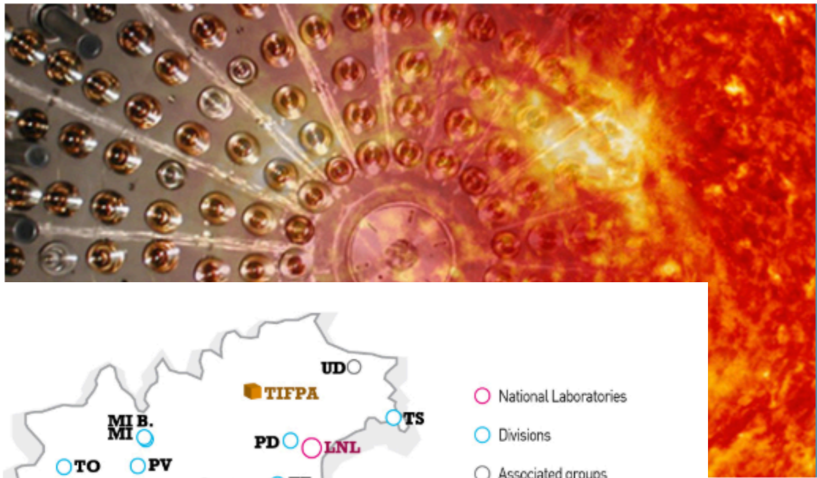
Trilateral EU-US-Japan collaboration (US)



Trilateral EU-US-Japan collaboration (J)

National Institute for Nuclear Physics

HOME THE INSTITUTE STRUCTURE EXPERIMENTS PROJECTS COMMUNICATION & OUTREACH CAREERS



PRESS RELEASE 2018

1 2 3 4

OVER 10 YEARS OF SCIENTIFIC SUCCESSES: THANKS TO BOREXINO TODAY WE KNOW THE SUN WITH UNPRECEDENTED DETAIL

After more than ten years from the beginning of its scientific activity focused on the internal structure of the Sun, which gave an understanding of the power mechanism of our star with unprecedented detail, the Borexino experiment at the INFN Gran Sasso National Laboratories publishes on October 25th on Nature...

Read more

LINES OF RESEARCH

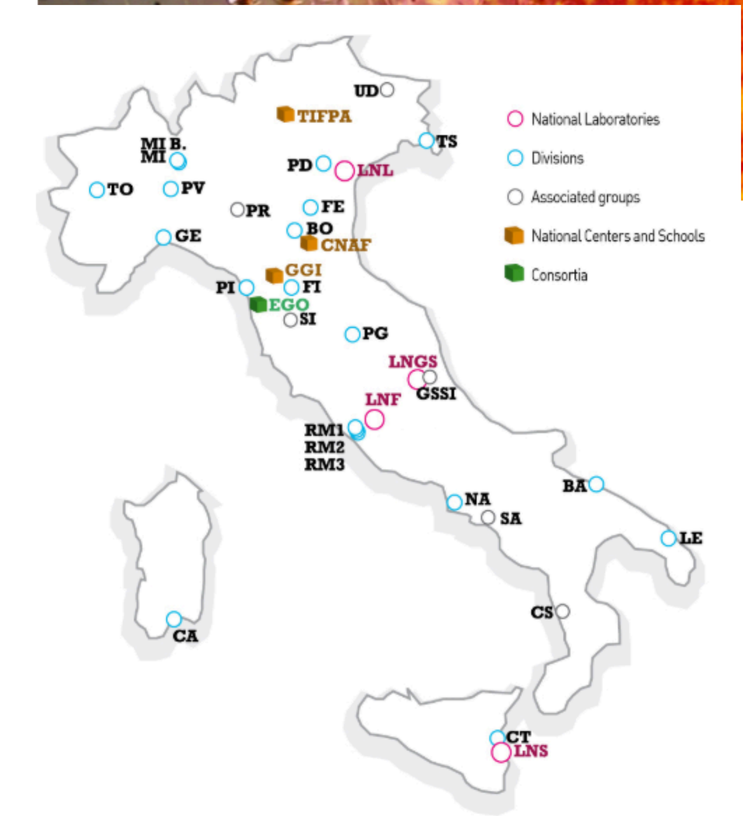
1 PARTICLE physics

2 ASTROPARTICLE physics

3 NUCLEAR physics

4 THEORETICAL physics

5 TECHNOLOGICAL physics



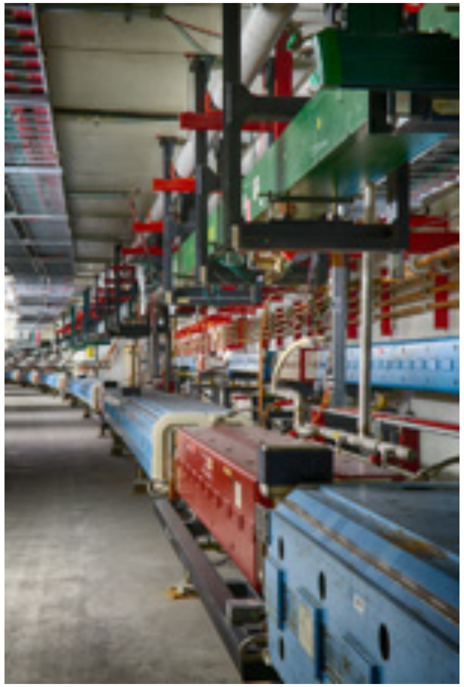
Facilities in Italy

The INFN carries out research activities at two complementary types of facilities: divisions and national laboratories. The four national laboratories, based in Catania, Frascati, Legnaro and Gran Sasso, house large equipment and infrastructures available for use by the national and international scientific community. Each of the 20 divisions and the 6 groups linked to the divisions or laboratories are based at different university physics departments and guarantee close collaboration between the INFN and the academic world.

NEWS: NEw WindowS on the universe and technological advancements from trilateral EU-US-Japan collaboration

Gravitational wave physics

Astroparticle & Astrophysics

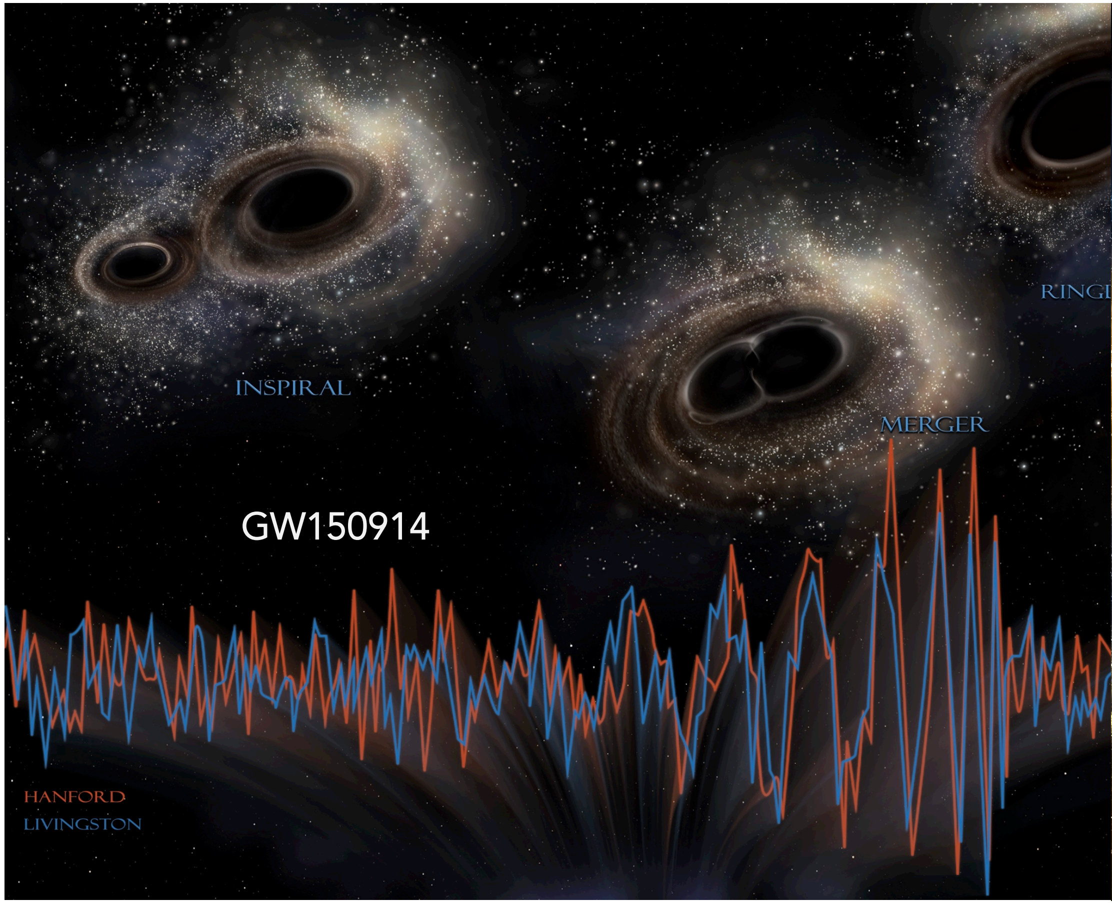


Particle physics at accelerators

Technology, Technology,
and more Technology

Will hear more from the WP co-leaders

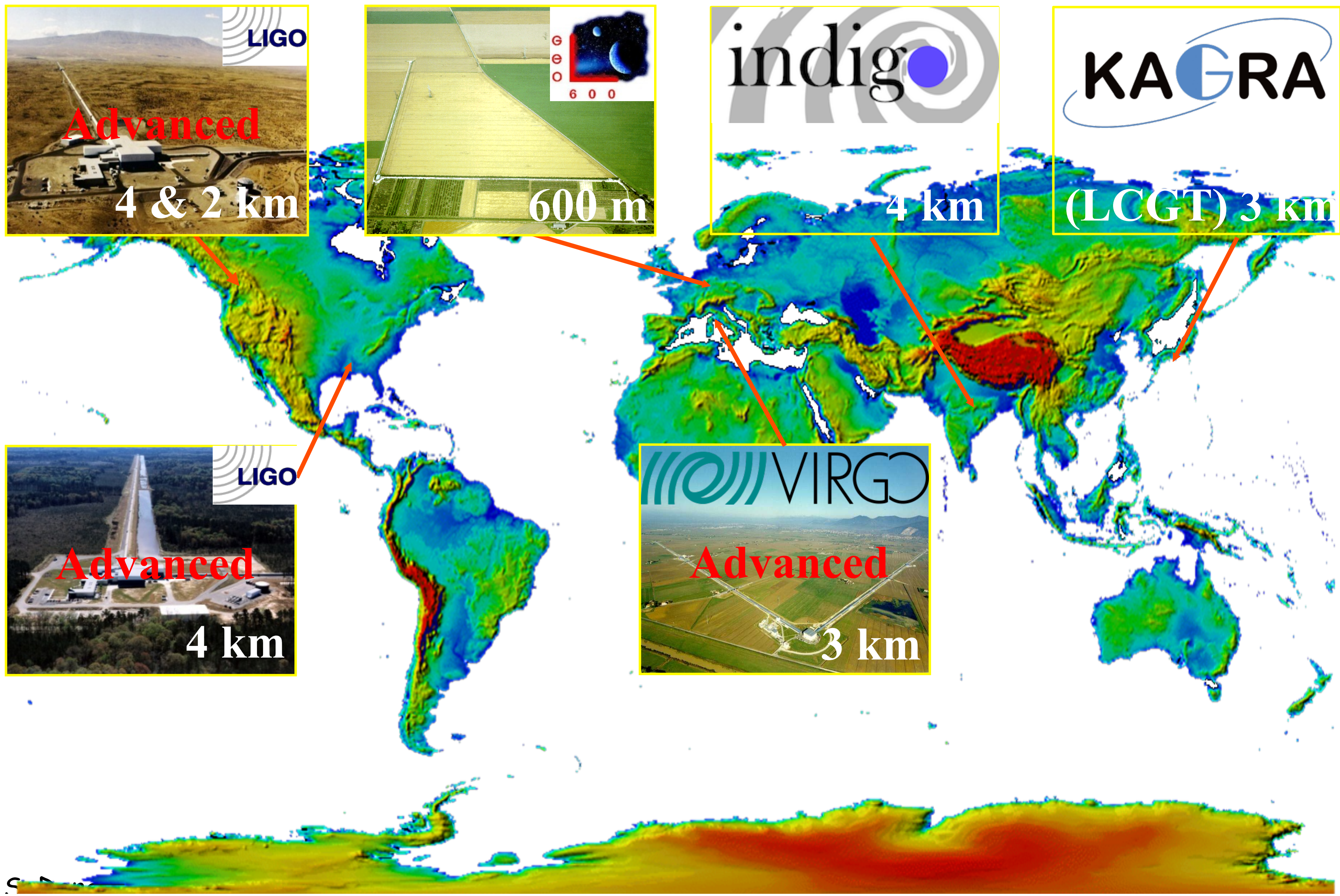
TWO GROUND-BREAKING DISCOVERIES A NEW ERA IN THE OBSERVATION OF THE UNIVERSE



Two merging black holes

Two merging neutron stars

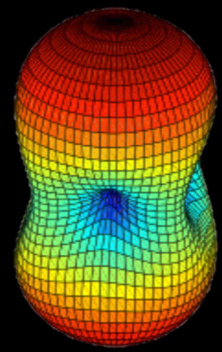
Ground-based interferometric detectors



1989: there was a long-term vision there…

2007: LSC-Virgo MoU

2007: LSC-VIRGO MoU for a "SINGLE MACHINE"
A MAJOR STEP TOWARDS GW ASTRONOMY



Memorandum of Understanding

between

VIRGO

on one side

and the

Laser Interferometer Gravitational Wave Observatory (LIGO)

on the other side

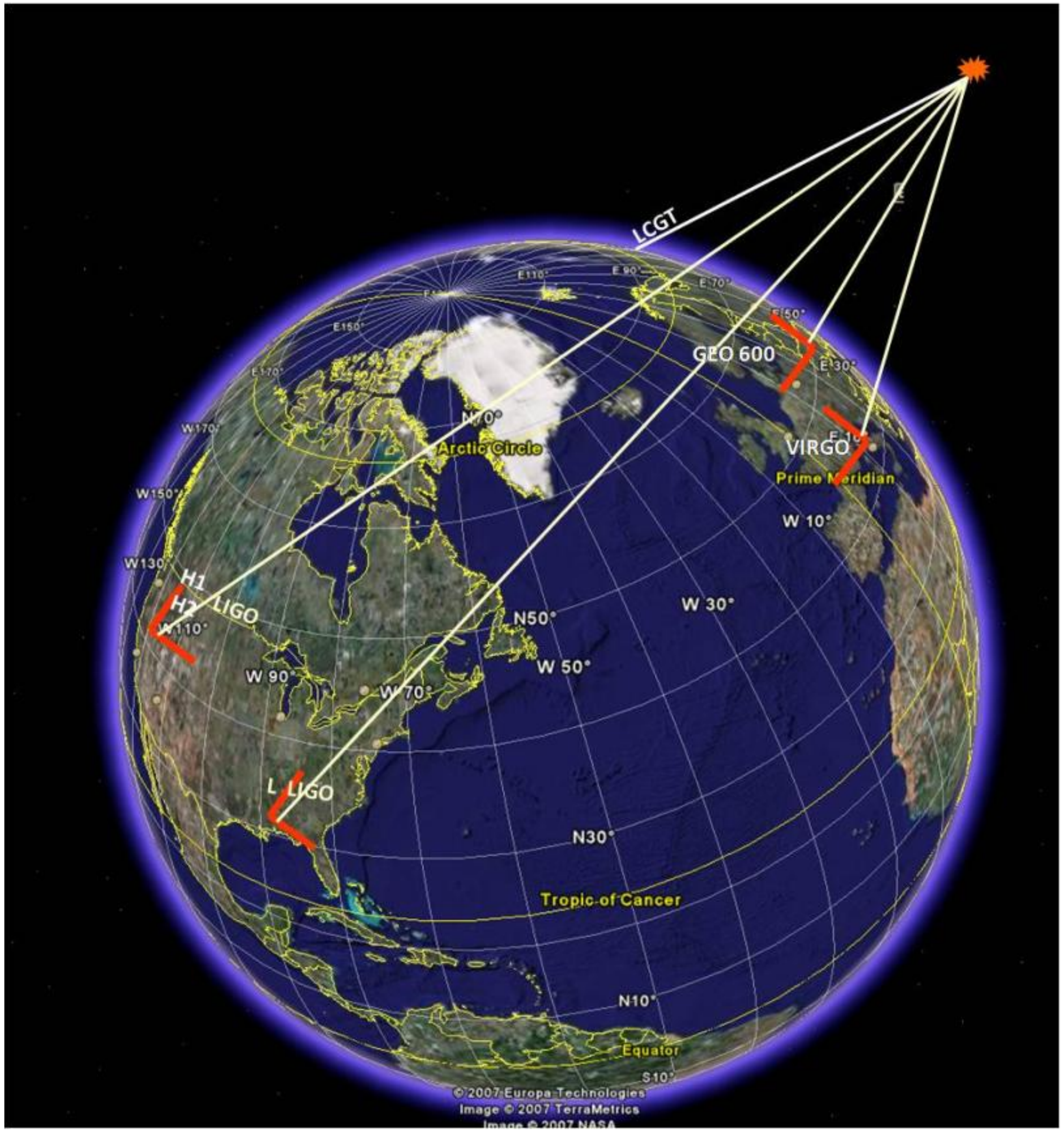
Purpose of agreement:

The purpose of this Memorandum of Understanding (MOU) is to establish and define a collaborative relationship between VIRGO on the one hand and the Laser Interferometer Gravitational Wave Observatory (LIGO) on the other hand in the use of the VIRGO, LIGO and GEO detectors based on laser interferometry to measure the distortions of the space between free masses induced by passing gravitational waves.

AFT

IMPROVING EVENT SIGNIFICANCE AND LOCALIZATION, SKY AND TIME COVERAGE

Network of ground-based detectors



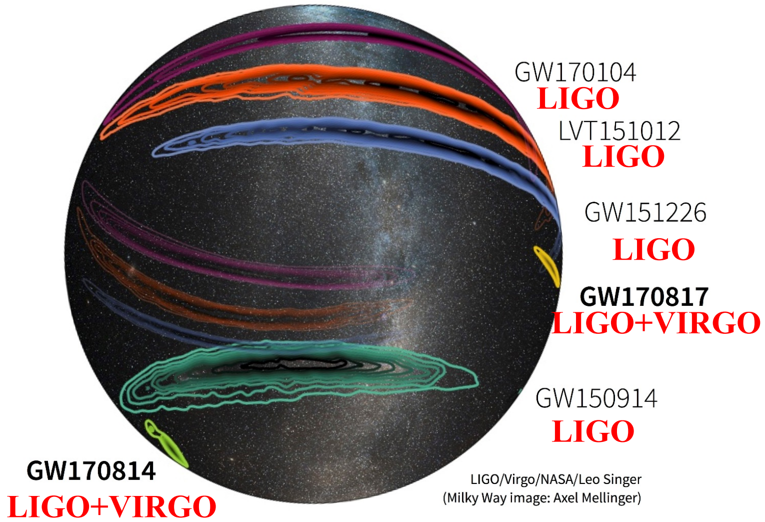
Advantages:

Improve event reconstruction

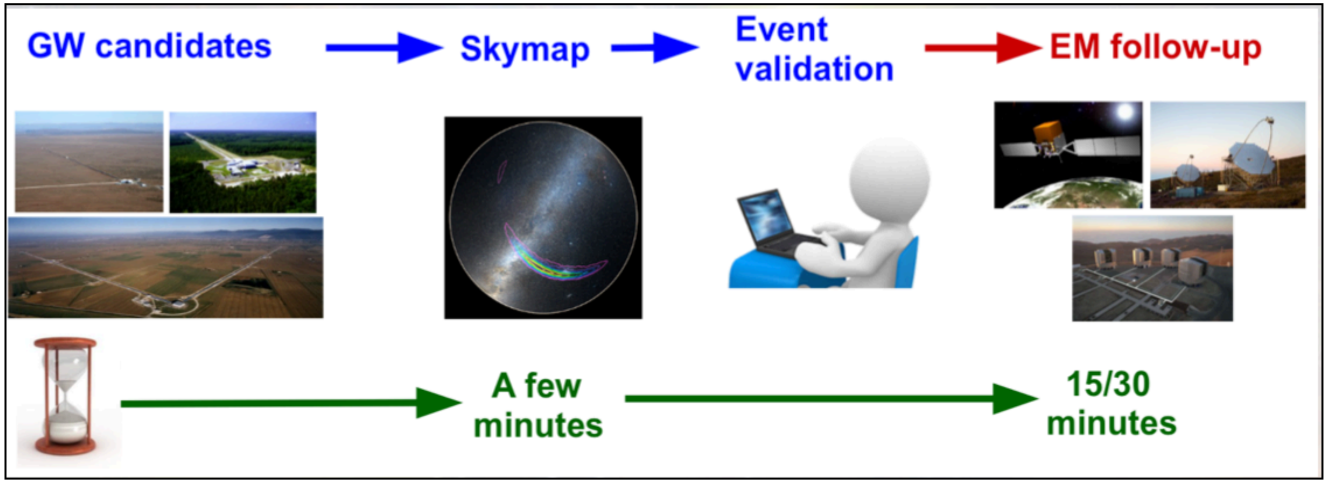
Increase detection probability

Increase significance of each detected event

Increase sky coverage

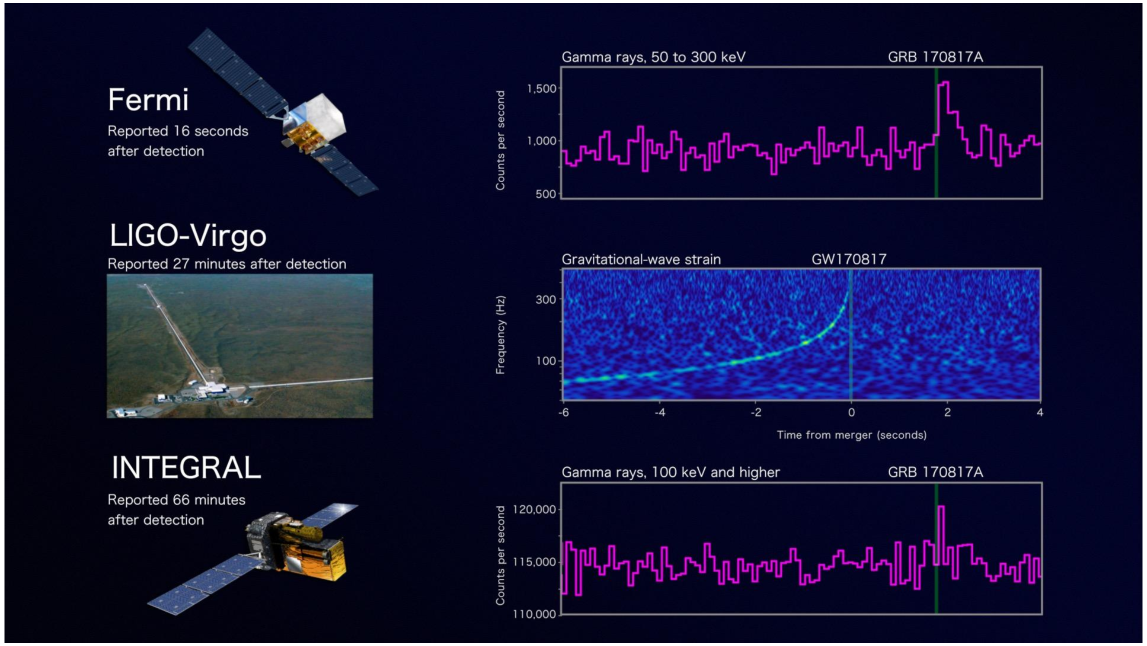


The Multi-Messenger network



Combine GW and light emission as a unique probe to astrophysics sources and fundamental Physics

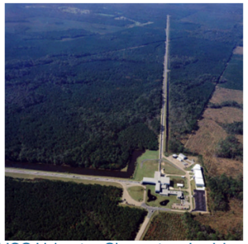
Virgo and Fermi crucial for the development of the Multi-Messenger approach



Gravitational Wave Open Science Center

- Getting Started
- Data
  - Catalogs
  - Bulk Data
- Tutorials
- Software
- Detector Status
- Timelines
- My Sources
- GPS ↔ UTC
- About the detectors
- Projects
- Acknowledge GWOSC

LIGO Hanford Observatory, Washington
(Credits: C. Gray)



LIGO Livingston Observatory, Louisiana
(Credits: J. Giaime)

Virgo detector, Italy
(Credits: Virgo Collaboration)

The Gravitational Wave Open Science Center provides data from gravitational-wave observatories, along with access to tutorials and software tools.

Get started!

Download data

GWTC-1: Catalog of Compact Binary Mergers

Join the email list

Attend an open data workshop

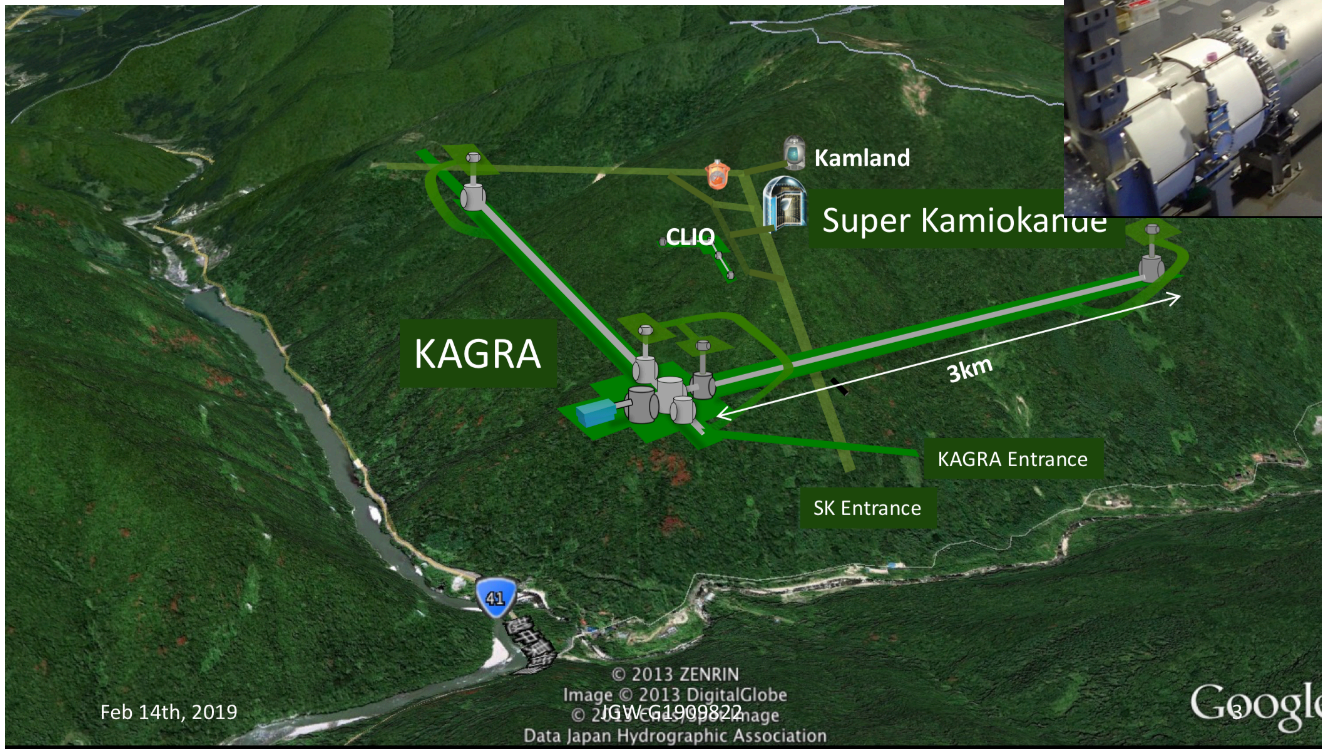
Login Acknowledge Privacy Contact

https://www.gw-openscience.org/about/

KAGRA, 2.5 Generation detector and beyond

Underground, cryogenics (2.5G)

First steps towards 3G (ET)



The Fermi Large Area Telescope (Fermi-LAT)

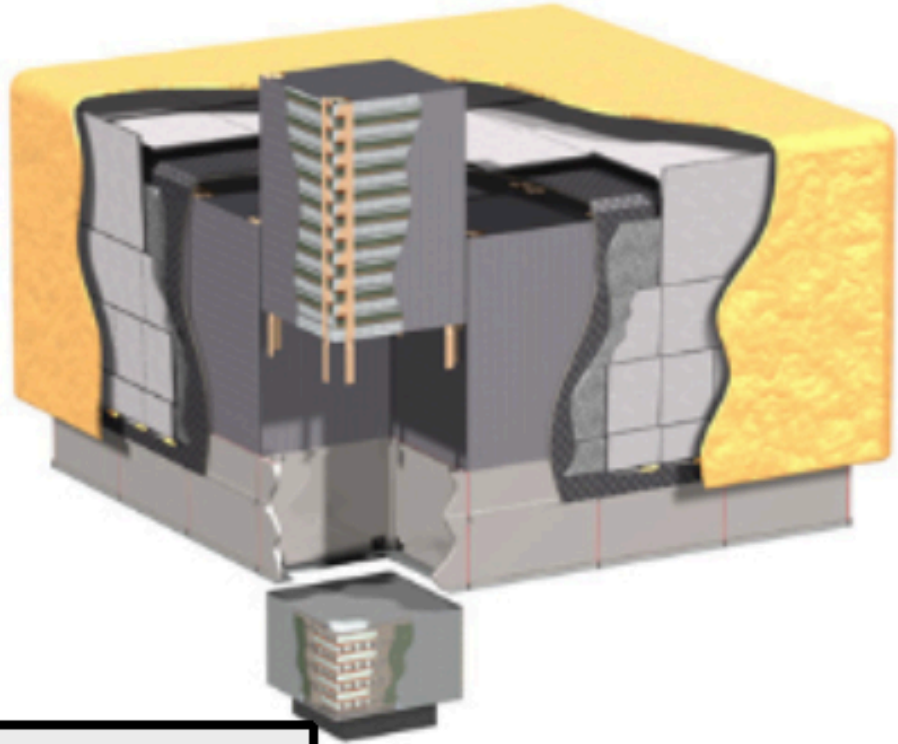
Sky Survey:
LAT sees ~1/5 of sky at once
Whole sky every 3 hours

***Fermi*-LAT Collaboration:**
~400 Scientific Members,
NASA / DOE & International Contributions

Large Area:
$A_{eff} > 0.9\ m^2$ on-axis,
~ $0.4\ m^2$ 60° off-axis

Huge Energy Band:
~30 to $2x10^6$ MeV

Almost 5 decades
(Visible light = ¼ decade)



Public data:
All photon data released to public within hours

LAT Highlights

Largest silicon Tracker operating in space (mostly Italian contribution)

- $93 m^2$ active surface, 900k channels, ~300 watt

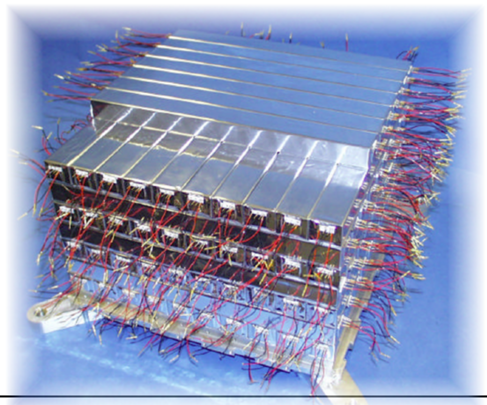
3D imaging calorimeter

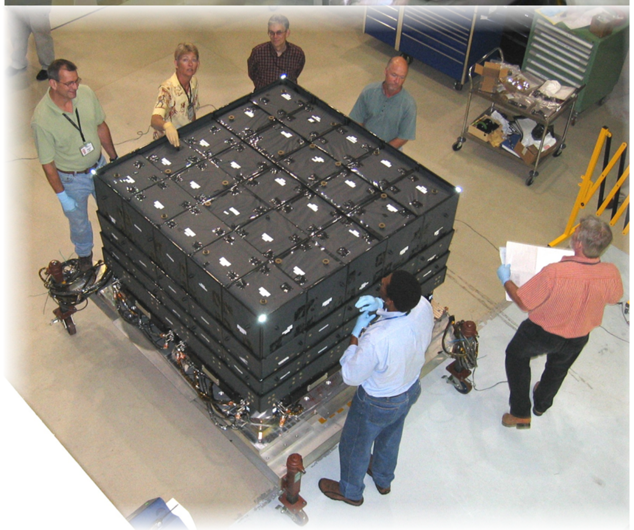
- 1536 CsI crystal logs in hodoscopic configuration

Efficient, hermetic Anticoincidence Detector

Flexible onboard software trigger

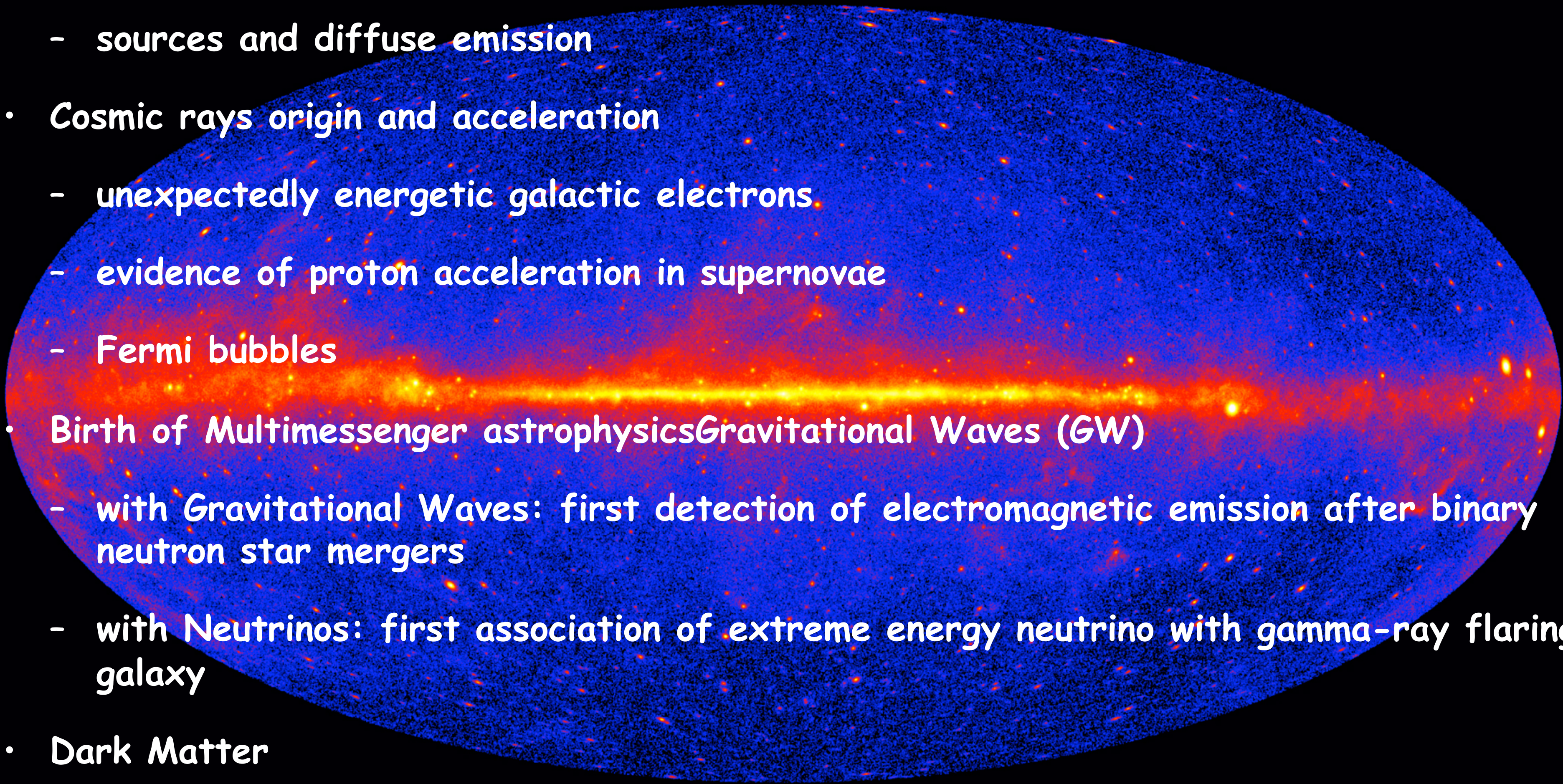
LAT Calibration through beam tests and simulations





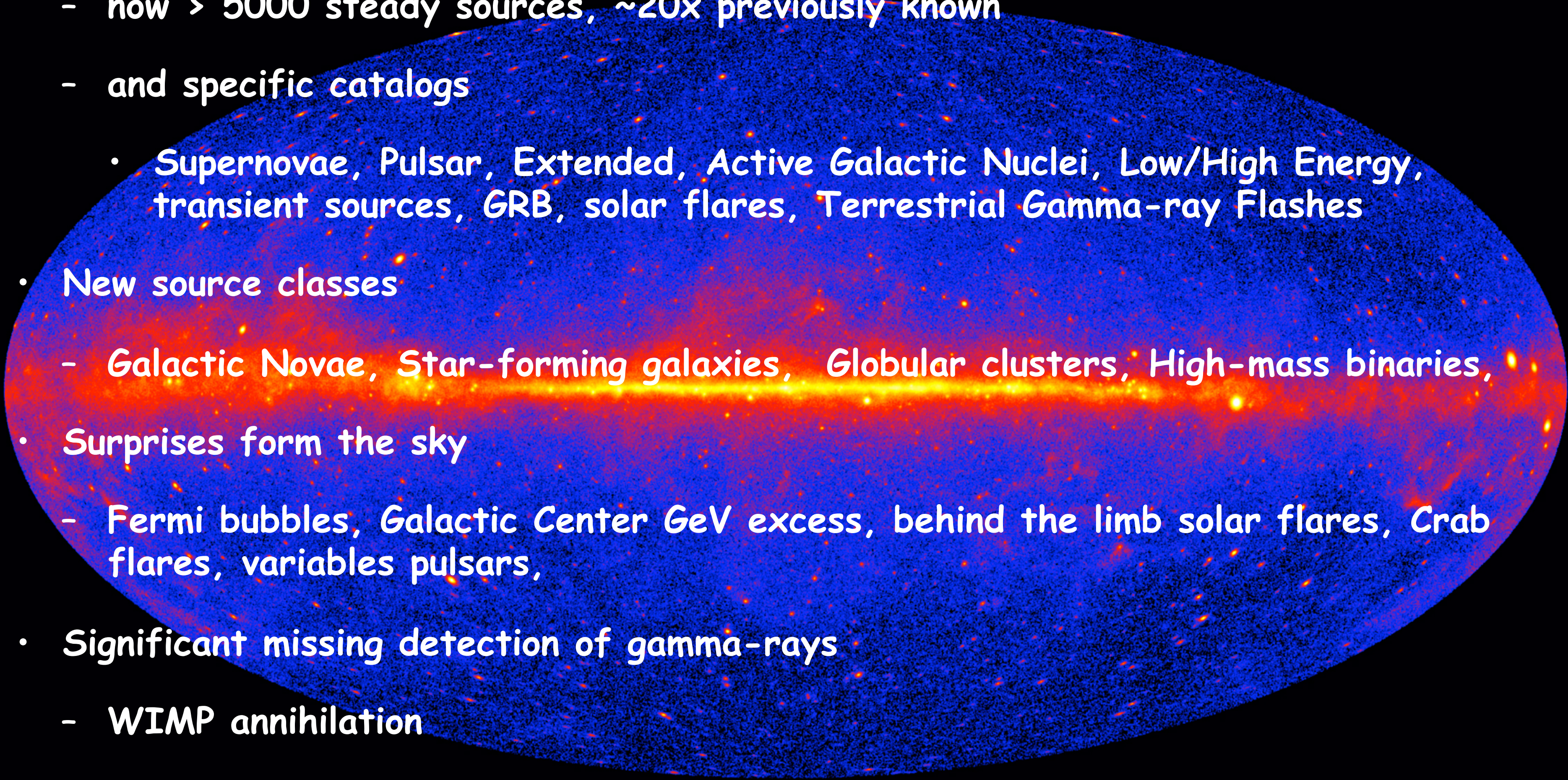
Launch: June 13^{th} 2008

Science Highlights



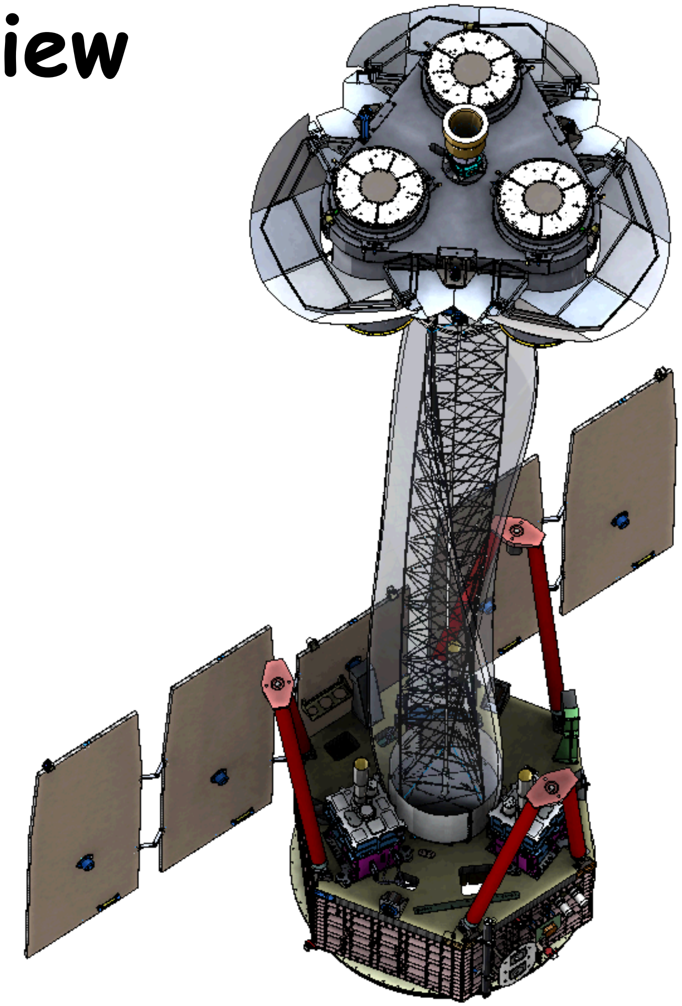
- Deep, high resolution, new view of the gamma-ray sky
  - sources and diffuse emission
- Cosmic rays origin and acceleration
  - unexpectedly energetic galactic electrons
  - evidence of proton acceleration in supernovae
  - Fermi bubbles
- Birth of Multimessenger astrophysicsGravitational Waves (GW)
  - with Gravitational Waves: first detection of electromagnetic emission after binary neutron star mergers
  - with Neutrinos: first association of extreme energy neutrino with gamma-ray flaring galaxy
- Dark Matter
  - most stringent limits on generic particle candidate (WIMP)

Confirmations and Revolutions



- Catalogs of gamma-ray sources - Fermi science bulk
  - now > 5000 steady sources, ~20x previously known
  - and specific catalogs
    - Supernovae, Pulsar, Extended, Active Galactic Nuclei, Low/High Energy, transient sources, GRB, solar flares, Terrestrial Gamma-ray Flashes
- New source classes
  - Galactic Novae, Star-forming galaxies, Globular clusters, High-mass binaries,
- Surprises form the sky
  - Fermi bubbles, Galactic Center GeV excess, behind the limb solar flares, Crab flares, variables pulsars,
- Significant missing detection of gamma-rays
  - WIMP annihilation
  - galaxy clusters
  - asteroid belt

IXPE Mission Overview



IXPE is a NASA SMEX mission:

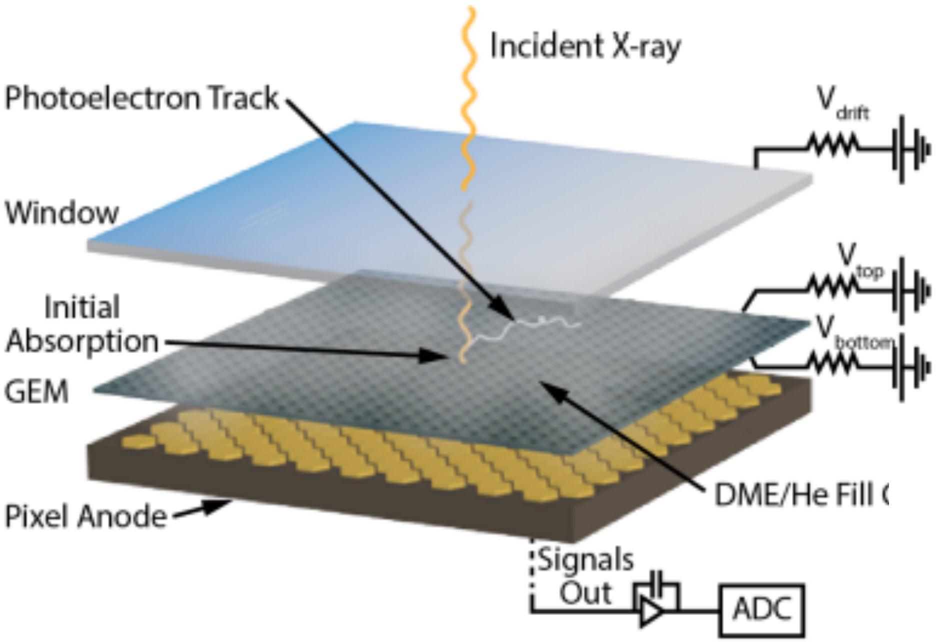
- Selected January 2017
- Italian contribution due December 2019
- Launch April 2021

No margin for schedule delays

Italian Contribution supported by ASI, INAF, INFN

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

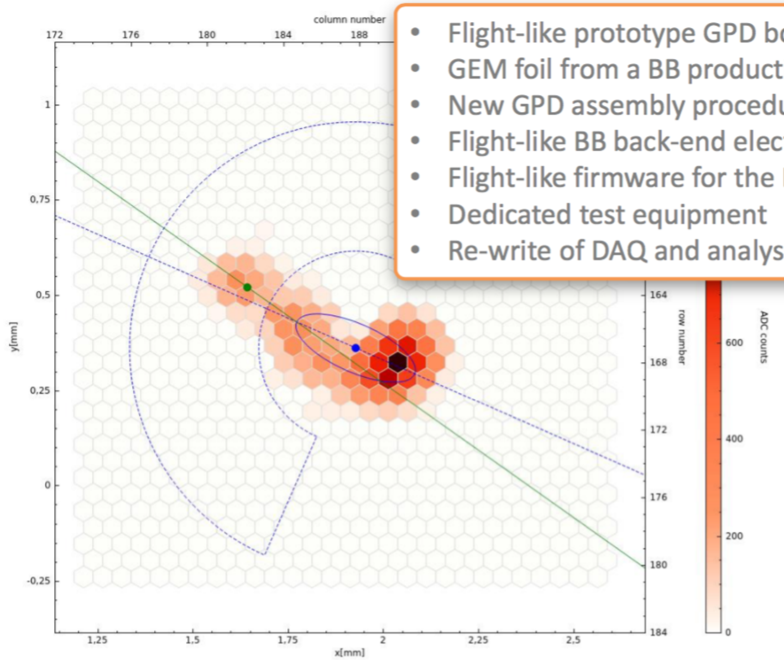
GPD Detector Overview



Detector breakout

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Event Reconstruction



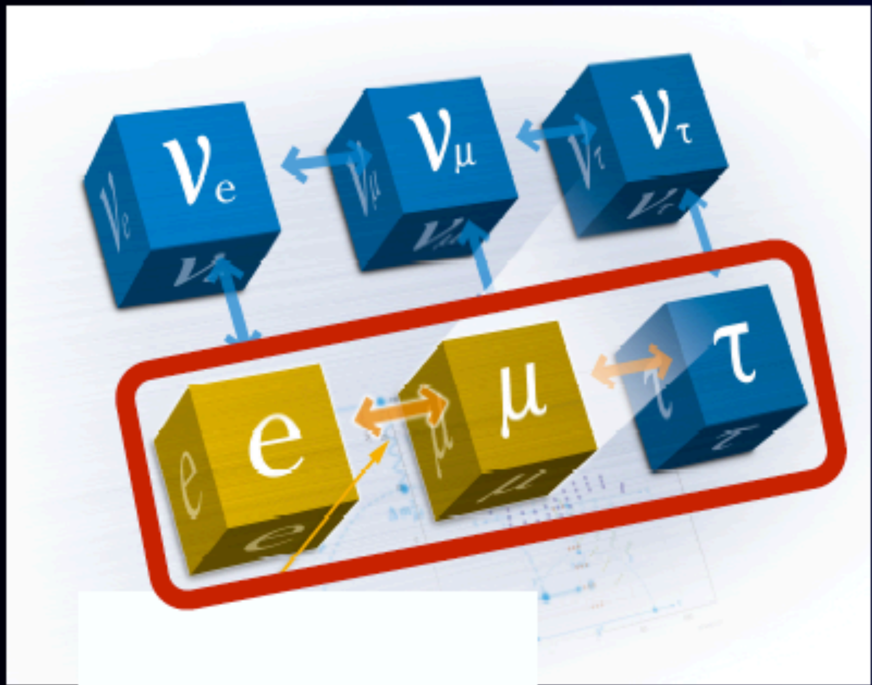
- Flight-like prototype GPD board
- GEM foil from a BB production run
- New GPD assembly procedure
- Flight-like BB back-end electronics
- Flight-like firmware for the DAQ board
- Dedicated test equipment
- Re-write of DAQ and analysis software

Quarks, Neutrinos, and Charged Leptons

Quarks

Quark mixing observed

Leptons



Neutrino mixing observed

Charged lepton mixing not observed.

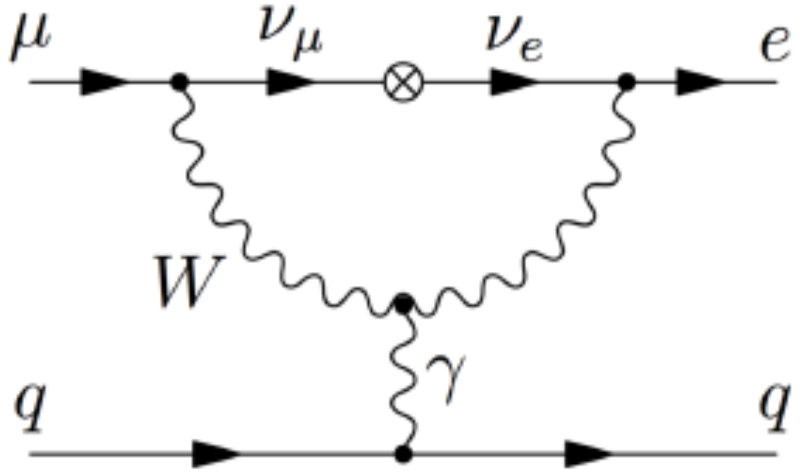
Fermilab Muon Campus experiments

Fermilab Muon Campus:

- Two new experimental halls and the associated beamlines
- Will produce world's highest intensity muon beams
- First beam delivered in 2017 (Muon g-2)

Charged Lepton Flavour Violation

- **CLFV forbidden in the Standard Model of particle physics**
- **μ conversion in the extended-SM introduced by ν masses and mixing at a negligible level ~10^{-52}**

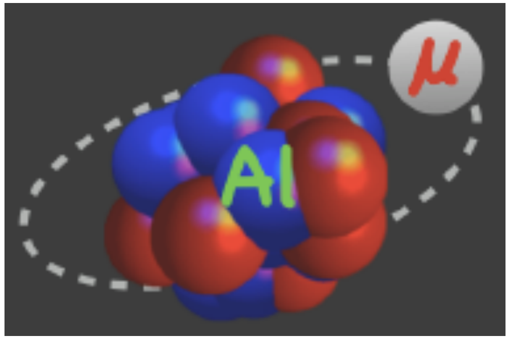


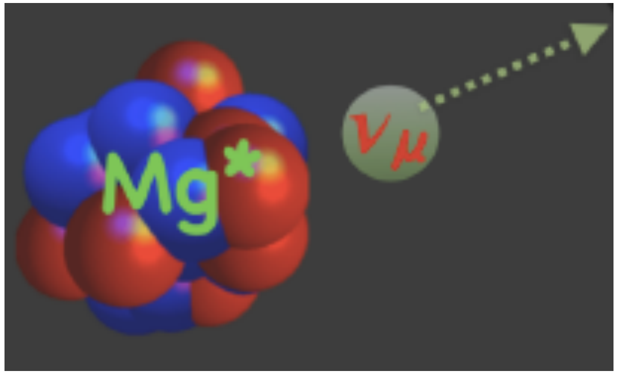
- **Many SM extensions enhance the rate through mixing in the high energy sector of the theory (other particles in the loop)**

Mu2e: search for μ+Al $\rightarrow$ e+Al

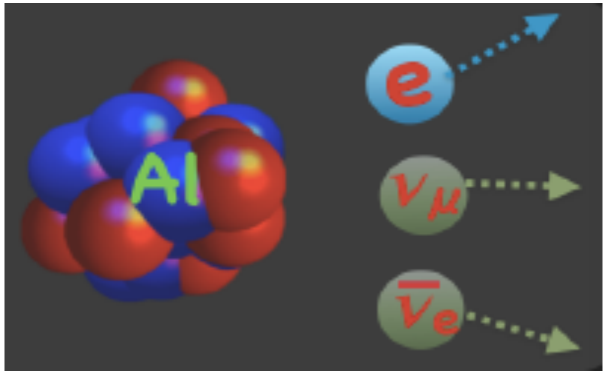
Experimental technique:

- Produce high intensity μ beam
- Stop μ in Al target
- Trap μ in orbit around Al nucleus



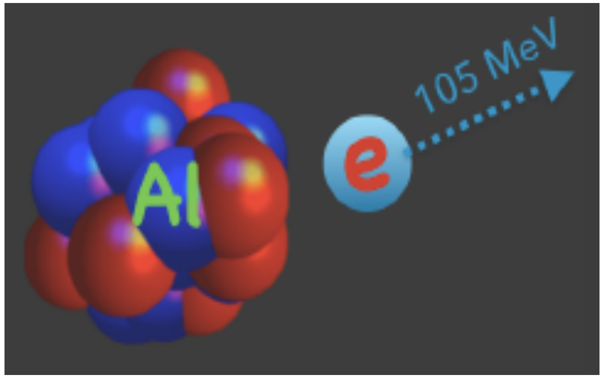


Nuclear capture ~ 61%
(used as normalization factor)



Decay In Orbit ~ 39%
(Dominant background)

Conversion < 10^{-12}
(Signal)



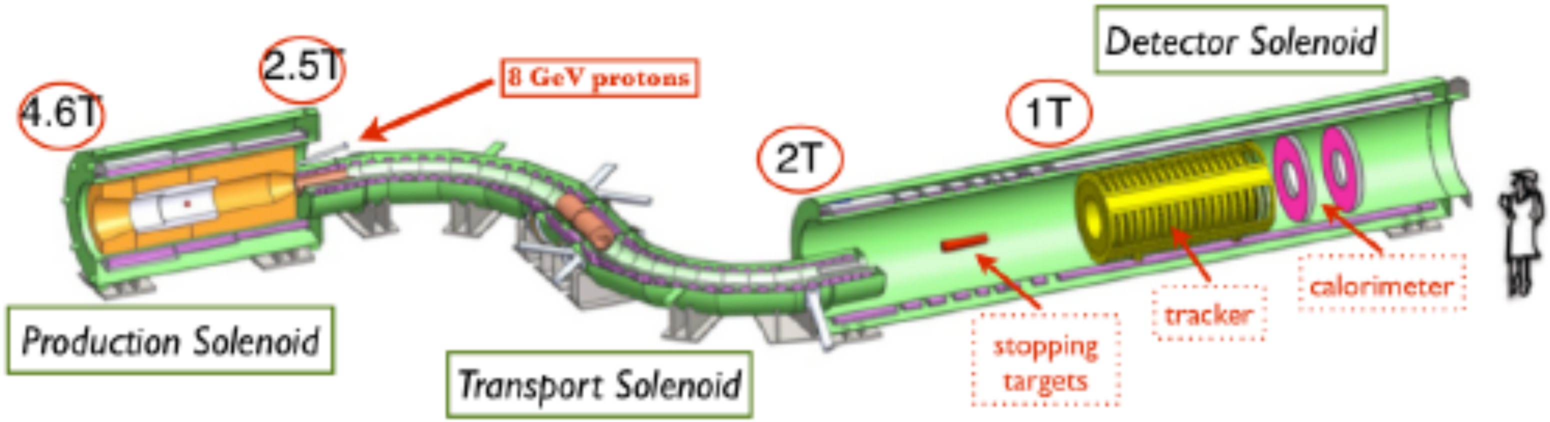
Mu2e experimental setup

- ***Production Solenoid:***

➡ Proton beam strikes target, producing mostly π
➡ Graded magnetic field contains backwards π/μ and reflects slow forward π/μ

- ***Detector Solenoid:***

➡ Capture muons on Al target
➡ Measure momentum in tracker and energy in calorimeter
➡ Graded field "focuses" e- in tracker fiducial

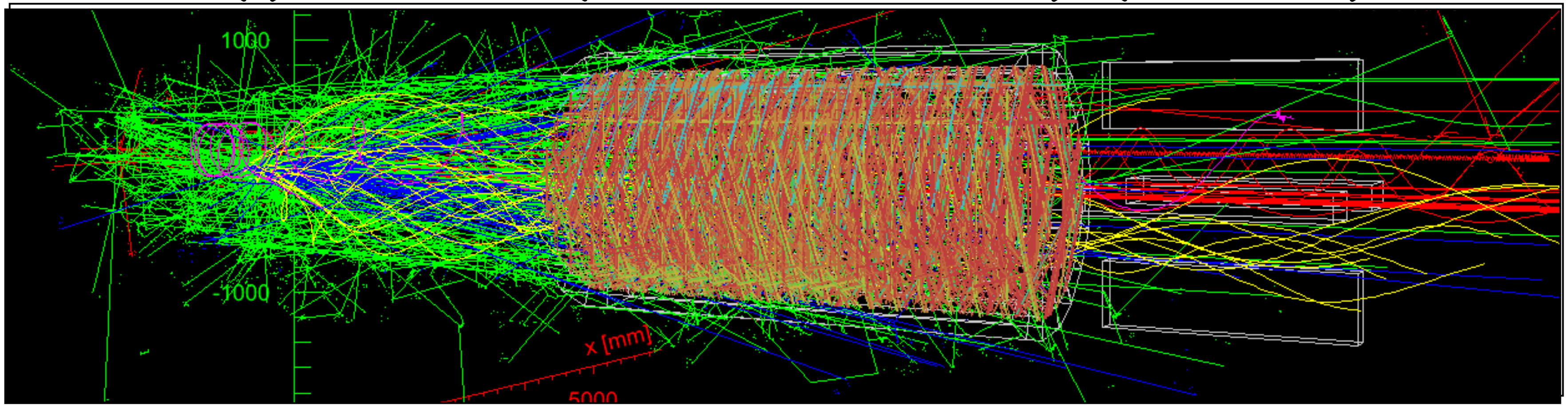


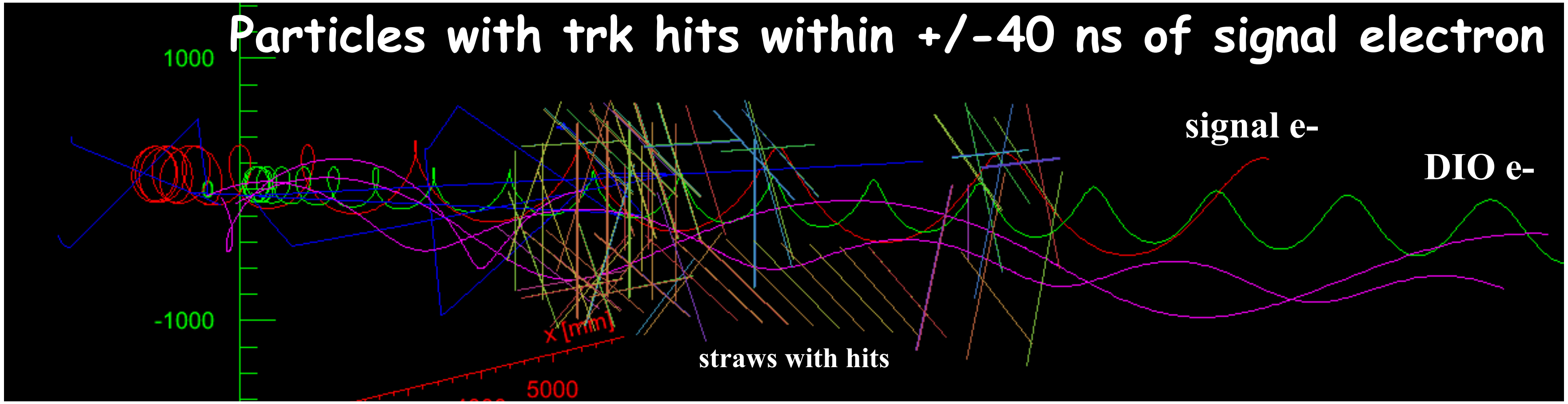
- ***Transport Solenoid:***

➡ Select low momentum, negative muons
➡ Antiproton absorber in the mid-section

Mu2e signal event (simulation)

Signal electron, with all the other "stuff" occurring simultaneously



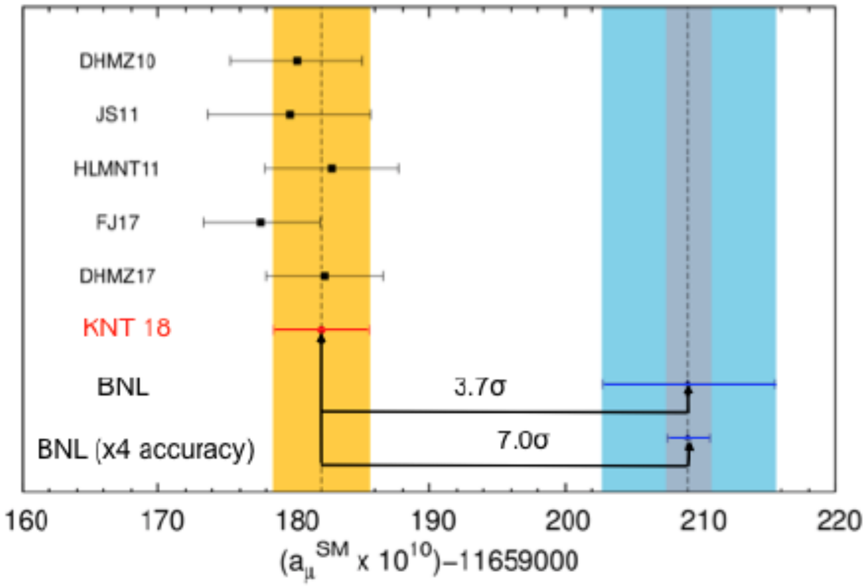


Mu2e Collaboration

Argonne National Laboratory, Boston University, Brookhaven National Laboratory
University of California, Berkeley, University of California, Irvine, California Institute of Technology, City University of New York, Joint Institute for Nuclear Research, Dubna, Duke University, Fermi National Accelerator Laboratory, Laboratori Nazionali di Frascati, Helmholtz-Zentrum Dresden-Rossendorf, University of Houston, University of Illinois, INFN Genova, Kansas State University, Lawrence Berkeley National Laboratory, INFN Lecce and Università del Salento, Lewis University, University of Louisville, Laboratori Nazionali di Frascati and Università Marconi Roma, University of Minnesota, Muons Inc., Northern Illinois University, Northwestern University, Novosibirsk State University/Budker Institute of Nuclear Physics, Institute for Nuclear Research, Moscow, INFN Pisa, Purdue University, Rice University, University of South Alabama, Sun Yat Sen University, University of Virginia, University of Washington, Yale University

FNAL Muon (g-2) experiment

Comparison of the measurement to the calculaton
Of $a_\mu = (g_\mu - 2)/2$ allows for precise test of SM



arXiv:1802.02995v1 [hep-ph]

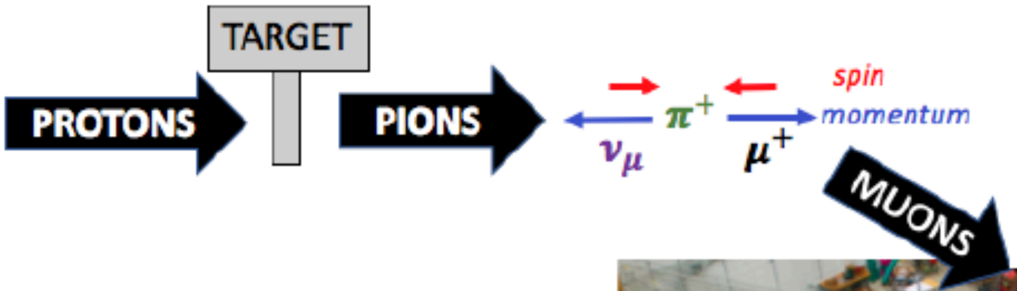
BNL *g*-2 experiment (E821) found a 3σ discrepancy

FNAL *g*-2 experiment (E989) will reduce uncertainty by a factor of 4

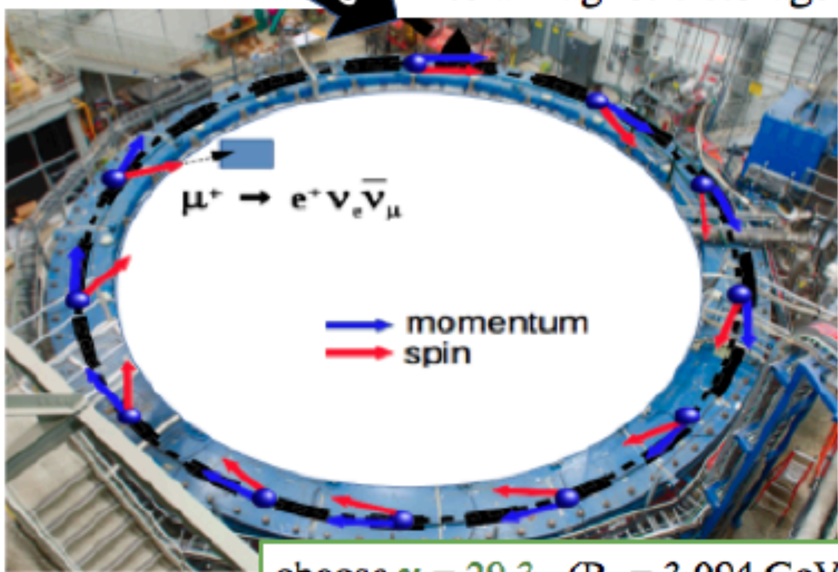
If the a_μ value is confirmed, the new *g*-2 results has the potential to confirm discrepancy and claim discovery

Muon (g-2) experimental technique

1. Muon production



2. Polarized muons are injected into a magnetic storage ring



3. Measure B and the "anomalous precession frequency" *i.e.*, the Spin precession frequency relative to the Cyclotron frequency:

choose $\gamma = 29.3$ ($P_\mu = 3.094$ GeV/c)

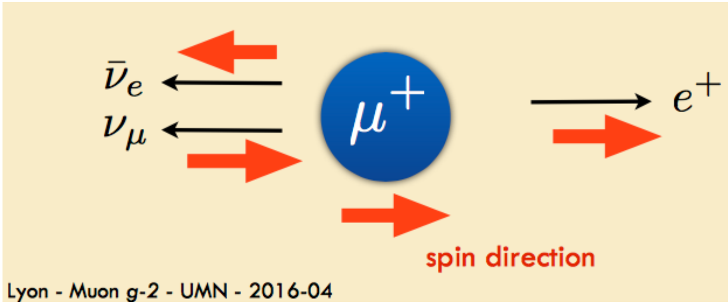
$$\vec{\omega}_a = \vec{\omega}_S - \vec{\omega}_C = -\frac{e}{m}\left[a_\mu \vec{B} - \left(a_\mu - \frac{1}{\gamma^2 - 1}\right)\frac{\vec{\beta} \times \vec{E}}{c}\right]$$

Measure these

Journey of the storage ring: from BNL to FNAL

How ω_a is measured

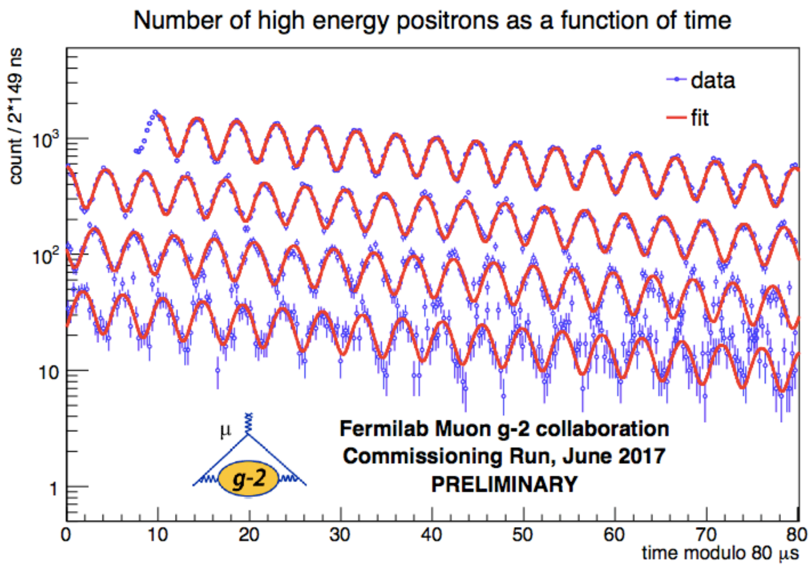
Injected polarised muons decay: $\mu^+ \rightarrow e^+ + \nu_e + \nu_\mu$



High energy e^+ emitted preferentially with momentum direction strongly correlated with μ^+ spin (parity violation)

Wiggle plot: count the number of e^+ with $E > E_{thr}$ as a function of t

The goal:
Publish analysis results in 2019



Muon (g-2) Collaboration

US Universities
- Boston
- Cornell
- Illinois
- James Madison
- Kentucky
- Massachusetts
- Michigan
- Michigan State
- Mississippi
- Northern Illinois
- Regis
- Texas
- Virginia
- Washington

National Labs
- Argonne
- Brookhaven
- Fermilab

Italy
- INFN
  - LNF Frascati,
  - Naples
  - Pisa
  - Roma 2
  - Trieste
  - Lecce
- Udine
- Naples
- Trieste
- Rjeka
- Molise
- SNS Pisa

China
- Shanghai

The Netherlands
- Groningen

Germany
- Dresden (thy)

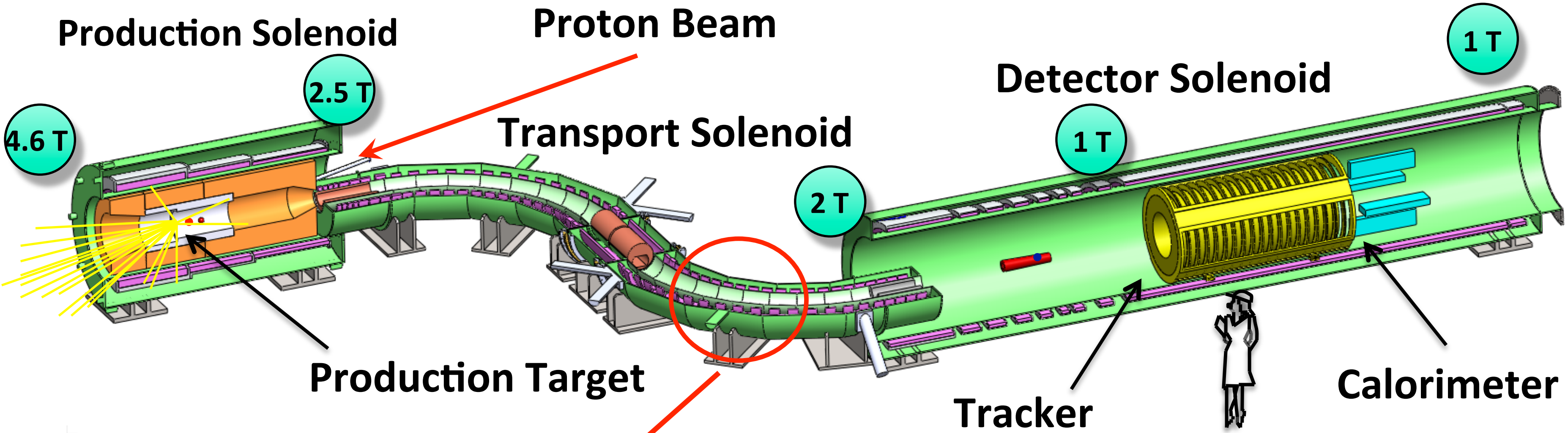
England
Cockroft Institute
Lancaster
Liverpool
University College London

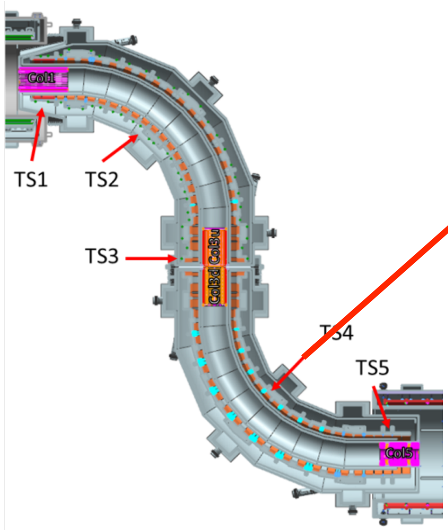
Korea
KAIST
CAPP

Russia
Dubna
Novosibirsk

Superconductors for particle accelerators

Mu2e TS solenoid: 52 superconducting coils integrated into 27 modules constituting the TS serpentine.

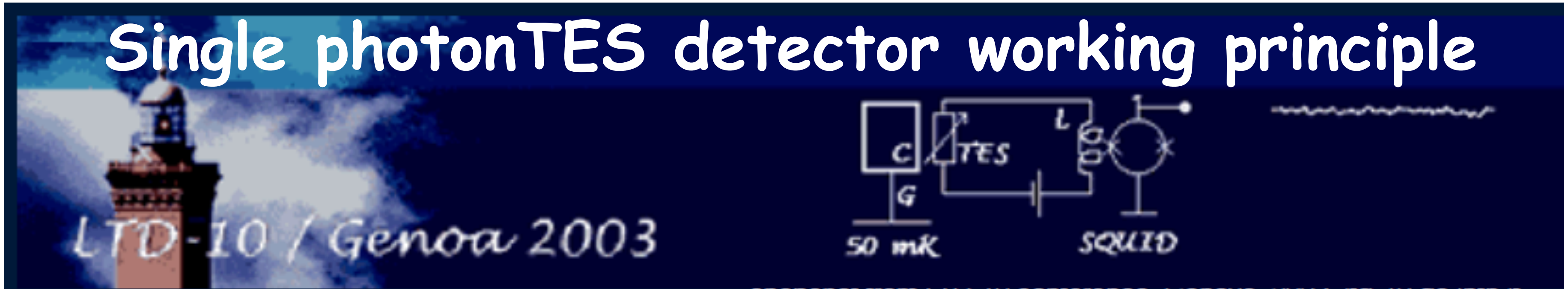




The TS module design was validated through prototype module development in the framework of a collaboration FNAL-INFN.

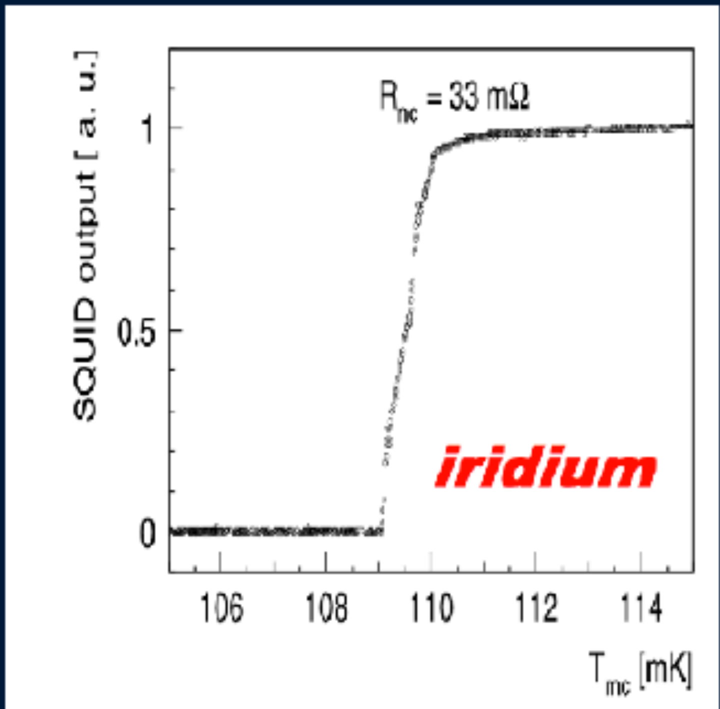
Superconductors for particle detectors

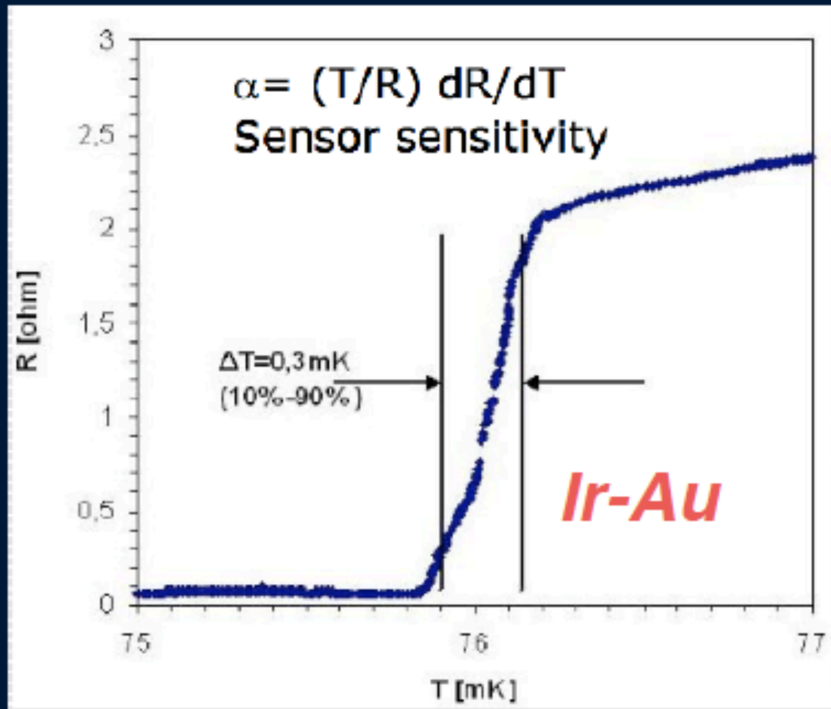
Single photonTES detector working principle



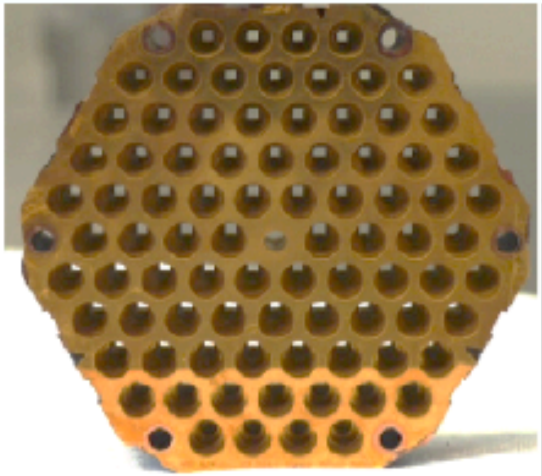
snapshot from LTD-10 conference, Genova, 2003. ltd-10.ge.infn.it

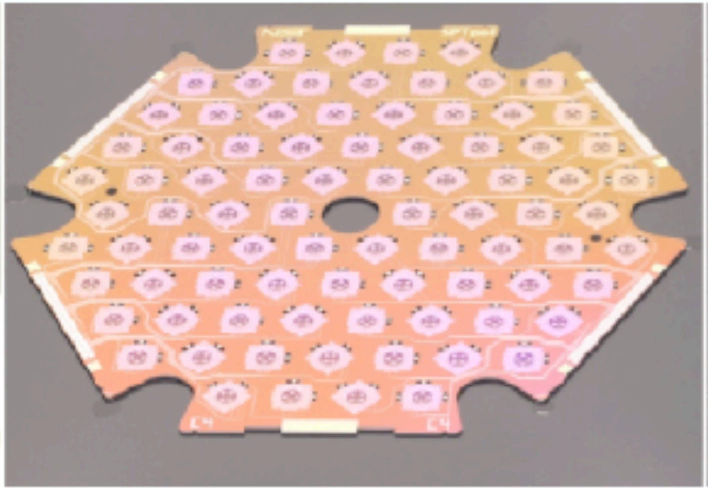
High quality film with steep superconducting to normal transition

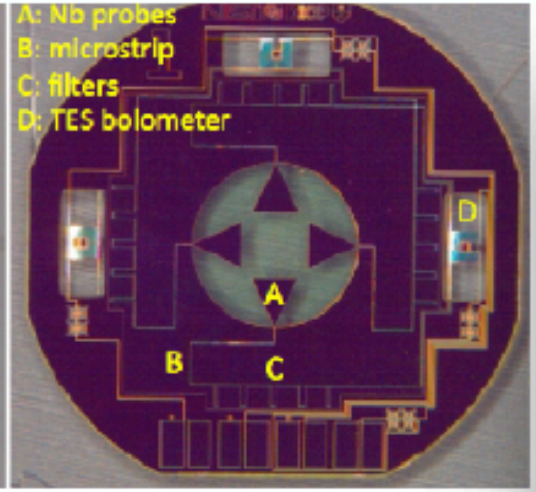


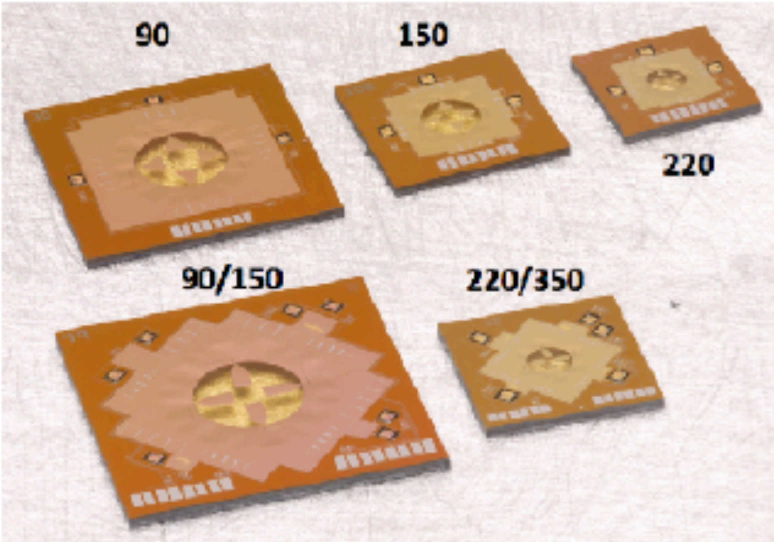


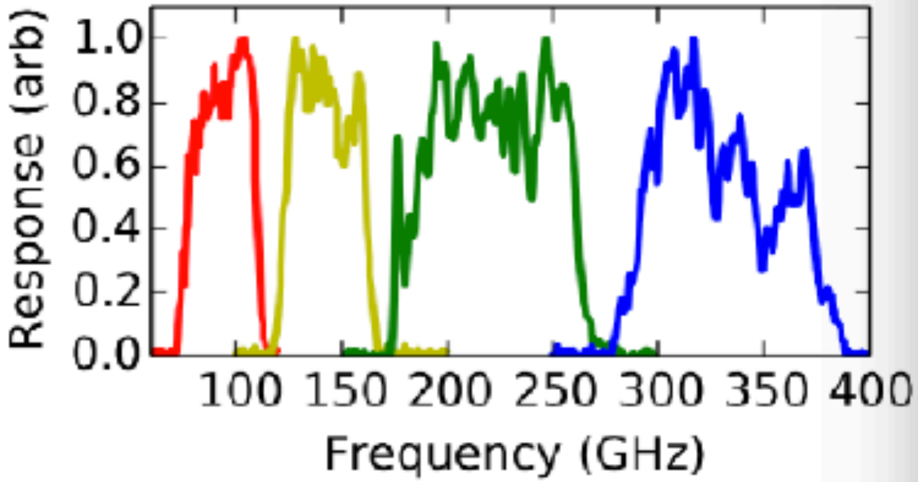
Microwave Antenna Coupled Bolometer











Continuous Transfer of Knowledge

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INFN Istituto Nazionale di Fisica Nucleare

CLEVER OPERATION®

HZDR HELMHOLTZ ZENTRUM DRESDEN ROSSENDORF

KTH VETENSKAP OCH KONST

UNIVERSITÀ DI PISA

impex high tech

POLITECNICO MILANO 1863

Stockholm University

SAPIENZA UNIVERSITÀ DI ROMA

cnrs

Fermilab

EGO - Virgo

ICRR Institute for Cosmic Ray Research University of Tokyo

DALARNA UNIVERSITY

NASA

UNIVERSITÀ DEGLI STUDI DI GENOVA

NINS National Institutes of Natural Sciences

CALIFORNIA INSTITUTE OF TECHNOLOGY 1891

Outreach towards general public

NEWS implementation

WP #	WP Name	Lead Beneficiary	Co-Leader
1	Ethics requirements	INFN	S. Donati (INFN)
2	Gravitational Wave Physics	INFN	M.Razzano (Unipi), E.Majorana (INFN), N. Robertson (Caltech)
3	Gravitational Wave Detectors	UNIPG	H.Vocca (Unipg), E. Calloni (Unina)
4	Fermi-LAT data analysis	INFN	S.Cutini (INFN), M.Pesce-Rollins (INFN), S.Digel (Stanford)
5	X-Ray Polarimetry	UNIPI	L.Baldini (Unipi), L. Latronico (INFN), B.Ramsey (Marshall)
6	FNAL Muon Campus Experiments	INFN	I. Sarra (INFN), V.Giusti (Unipi),S. Di Falco (INFN)
7	Supercondctors for accelerators	POLIMI	S.Franz (Polimi), S. Farinon (INFN), E.Barzi (FNAL)
8	Superconductors for detectors	UNIGE	F.Gattti (Unige), M.DeGerone (INFN), E.Barzi (FNAL)
9	Dissemination and Outreach	UNIPG	F.Cottone (Unipg), C.Oppedisano (INFN). C.Luongo (INFN)
10	Transfer of Knowledge	UNINA	R.DeRosa (Unina), E.Pedreschi (INFN). R.Sia (Clever)
11	Management	INFN	S.Giovannella (INFN), M.Punturo (INFN), S.Donati (INFN)

Scientific Board Chair: Luca Latronico INFN

MidTerm Review Agenda

Monday, March 4, 2019

S. Donati, “Introduction”
M. Razzano, WP2 “Gravitational Wave Physics”
E. Calloni, WP3 “Gravitational Wave Detectors”
M. Pesce-Rollins, WP4 “Fermi-LAT Data Analysis”

Coffee Break

L. Baldini, WP5 “X-ray Polarimetry”
S. Di Falco, WP6 “FNAL Muon Campus Experiments”
E. Barzi, WP7 “Superconductors for Particle Accelerators”

Lunch

MidTerm Review Agenda

F. Gatti, WP8 “Superconductors for Particle Detectors”
C. Oppedisano, WP9 “Outreach and Dissemination”
G. Bellettini (on behalf of C. Luongo)
“The Italian Summer Students Program at FNAL and other US Laboratories”
Tea Break

R. Sia, WP10 “Transfer of Knowledge (I)”
E. Pedreschi, WP10 “Transfer of Knowledge (II)”
S. Donati, WP11 “Management”

Report from Seconded Researchers

Social Dinner