ESFRI

Einstein Telescope
a work of Art

BND school
Sept 6, 2024

Nick van Remortel
Universiteit Antwerpen

www.et-gw.eu/
www.einsteintelescope.be
www.etpathfinder.eu
www.etest-emr.eu
et2smes.eu/

Photo: courtesy M. Kraan, NIKHEF, Amsterdam

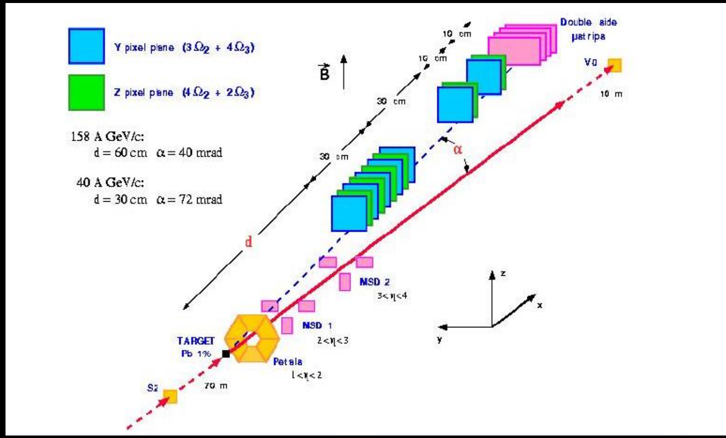
Einstein Telescope / NL / BE / D /

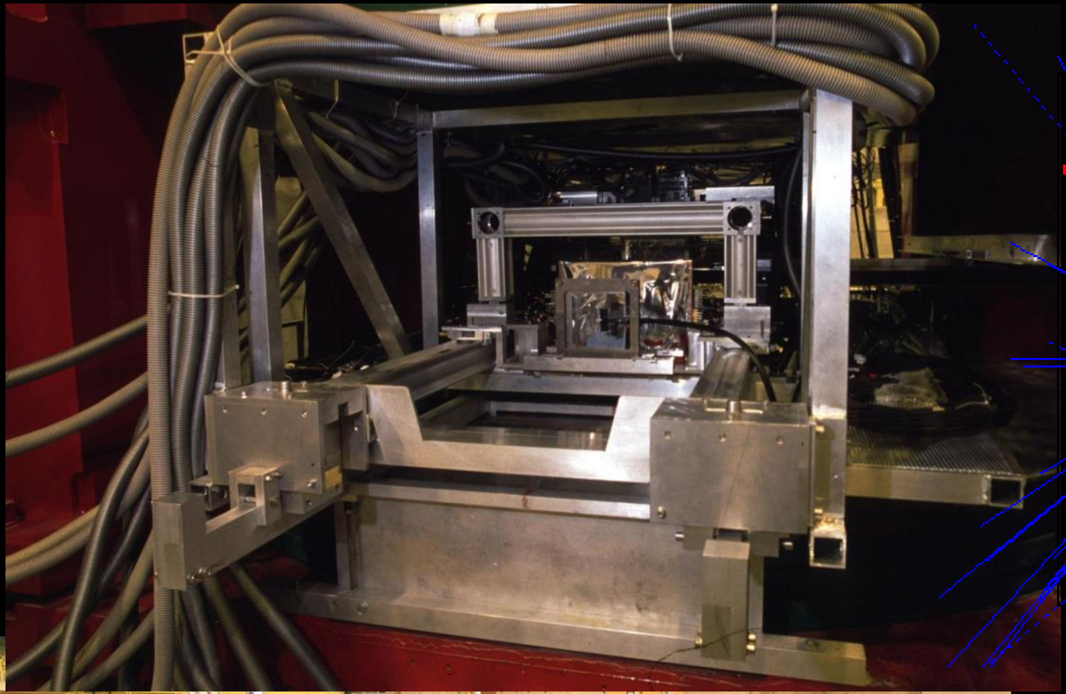
ET EINSTEIN TELESCOPE

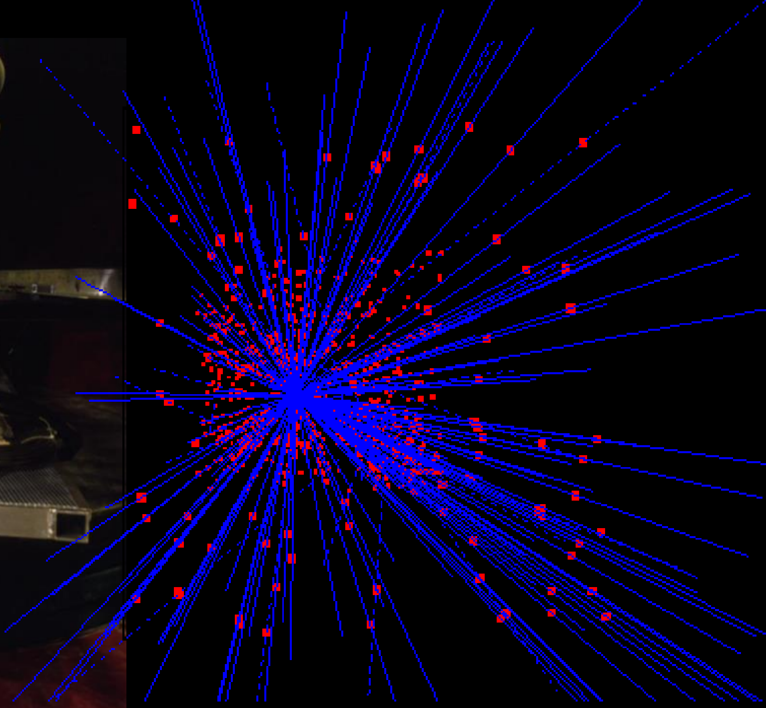
My Journey through HEP: 1997

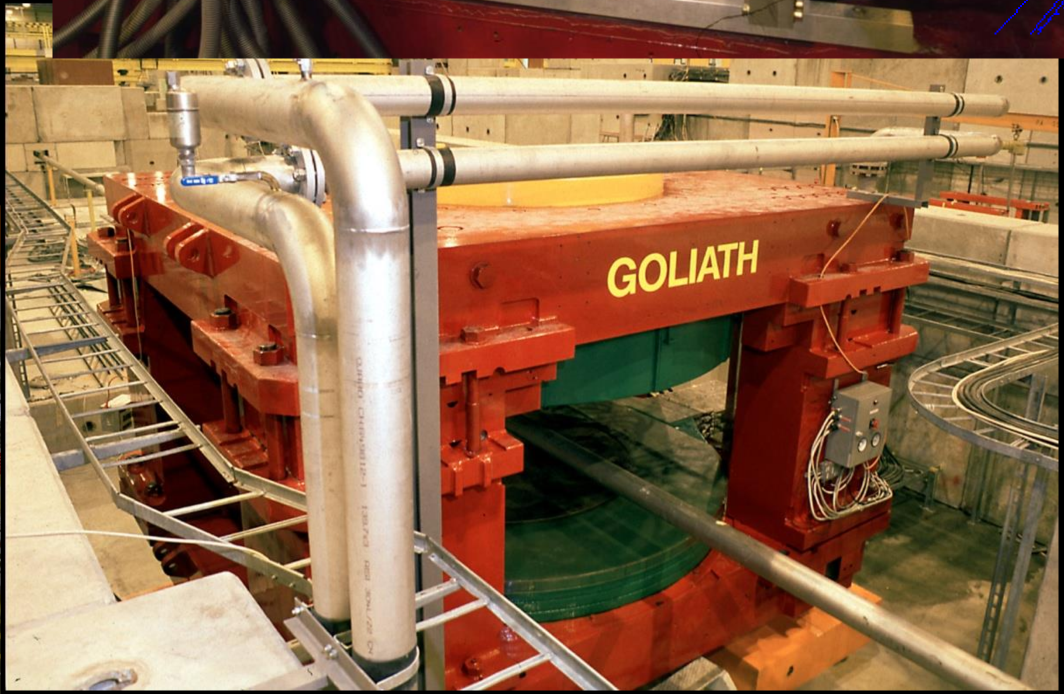
NA27 at the SPS

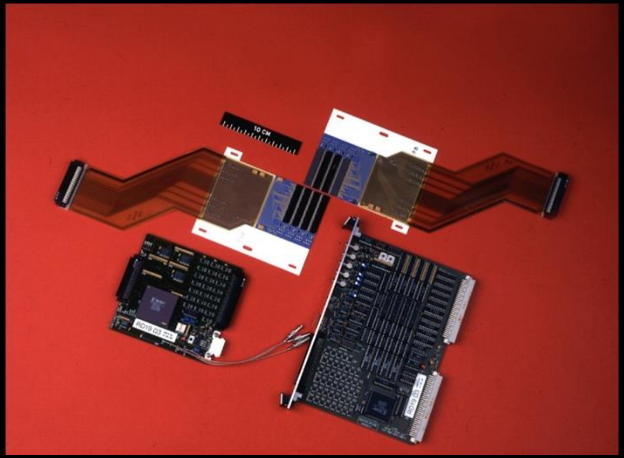
Existence of QGP confirmed at RHIC in 2005



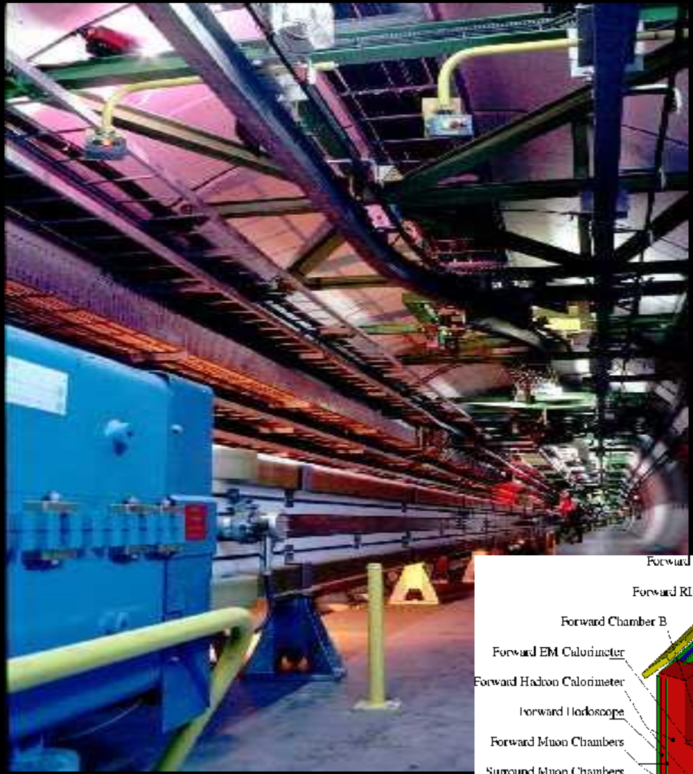


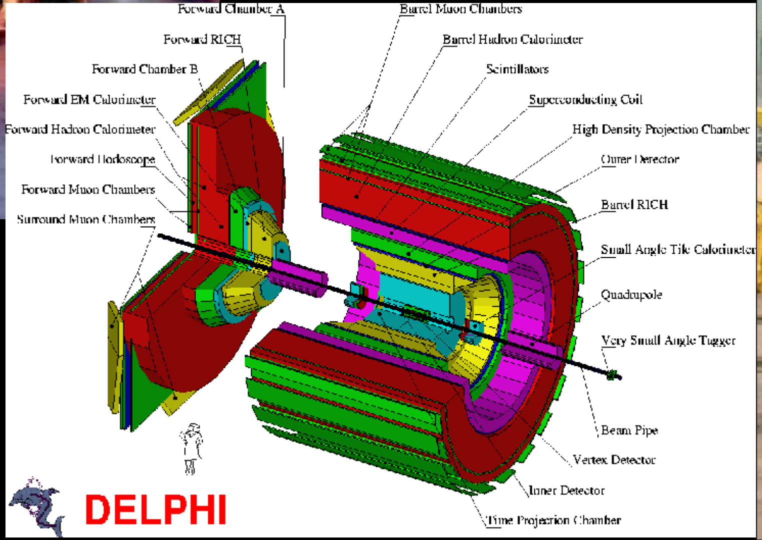


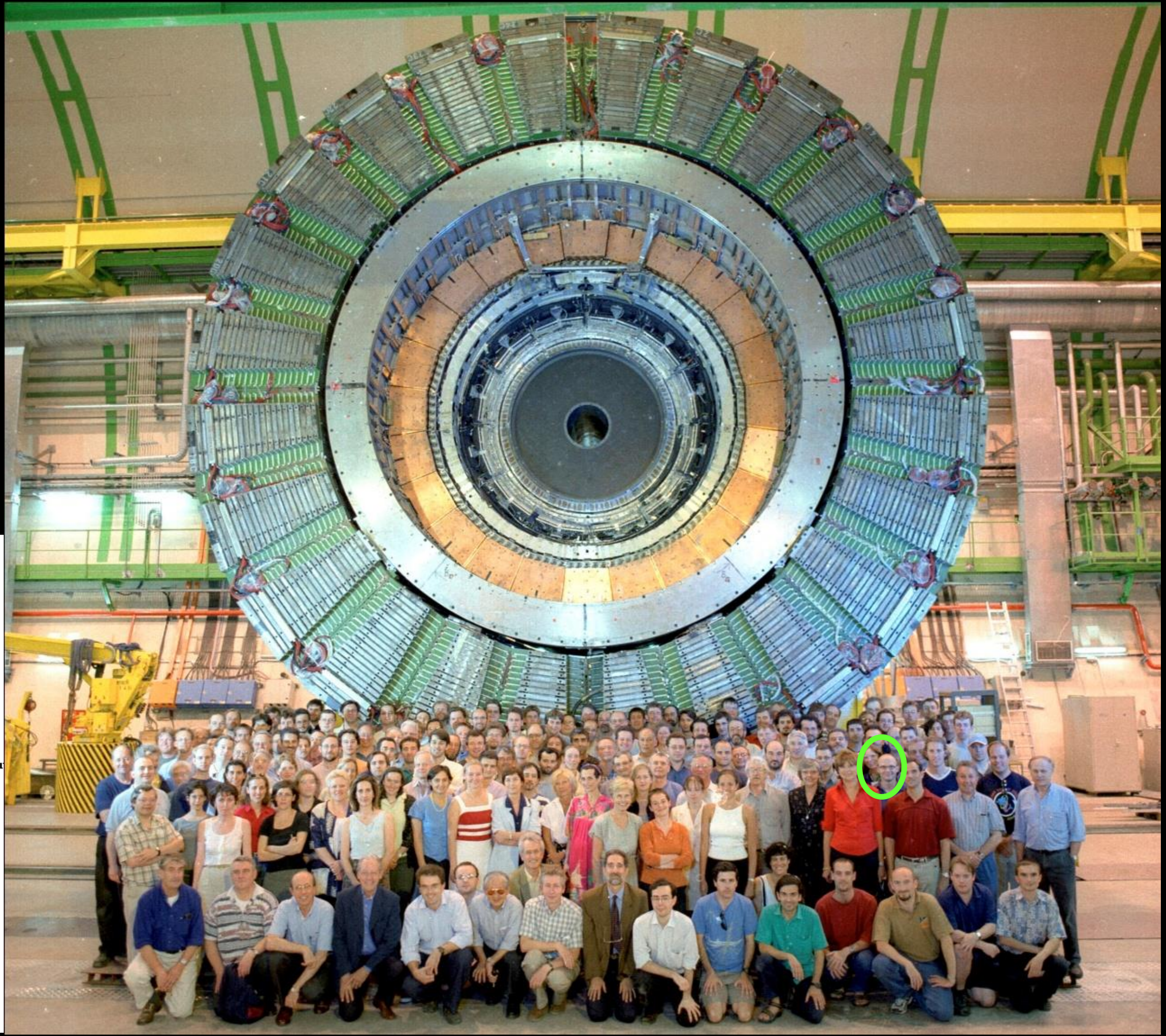


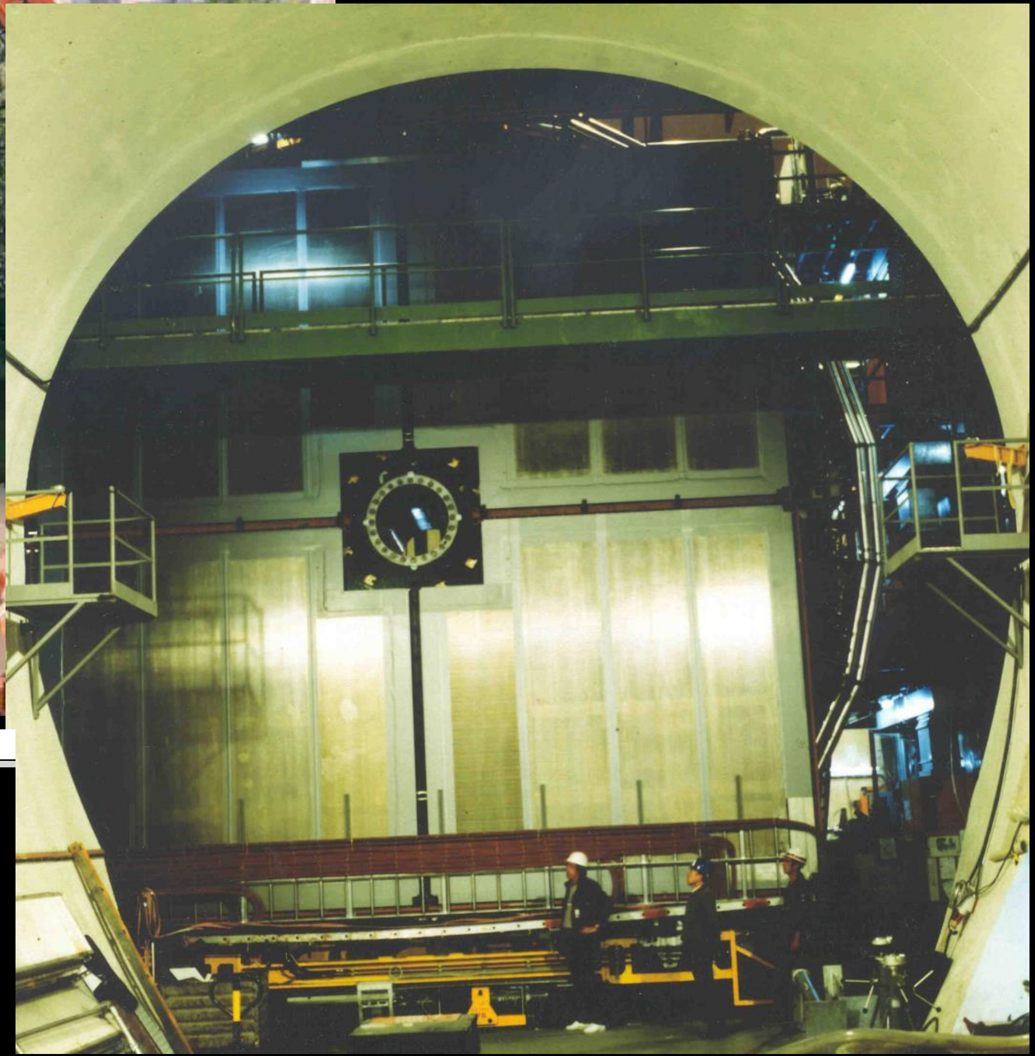


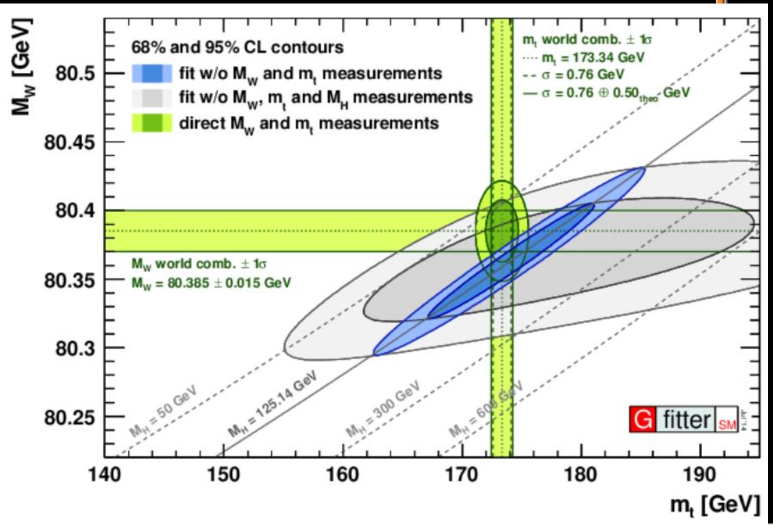
1998-2001: LEP2 ($\sqrt{s} \leq 209$ GeV)

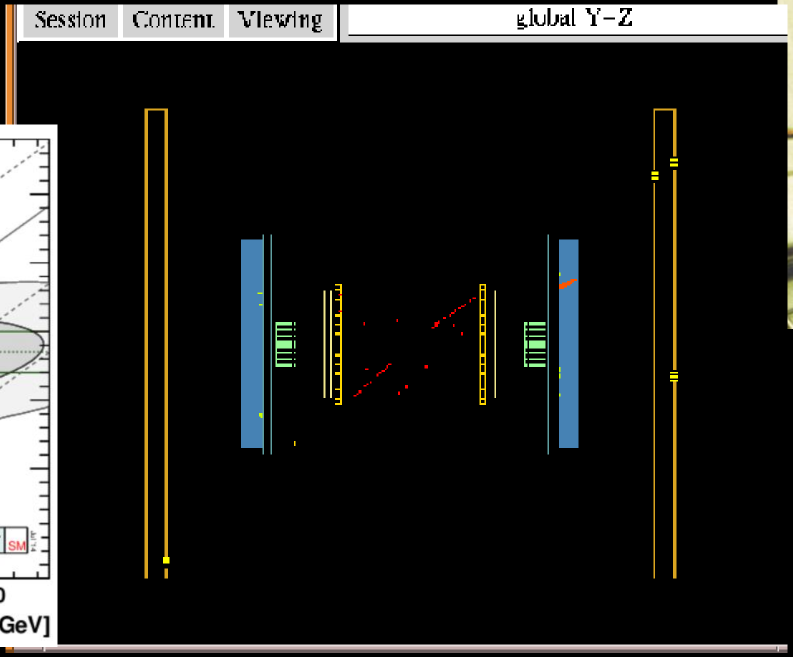






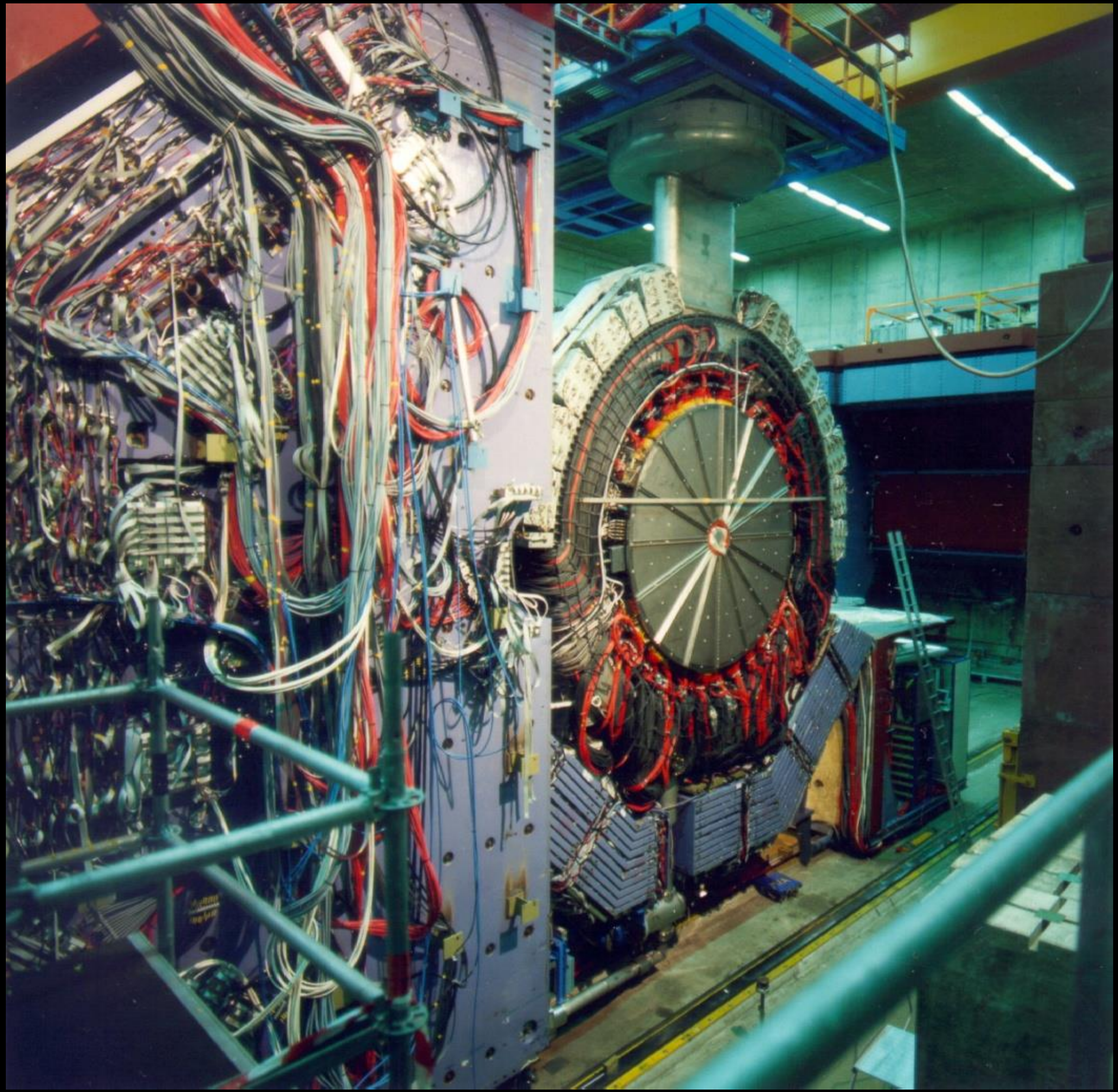


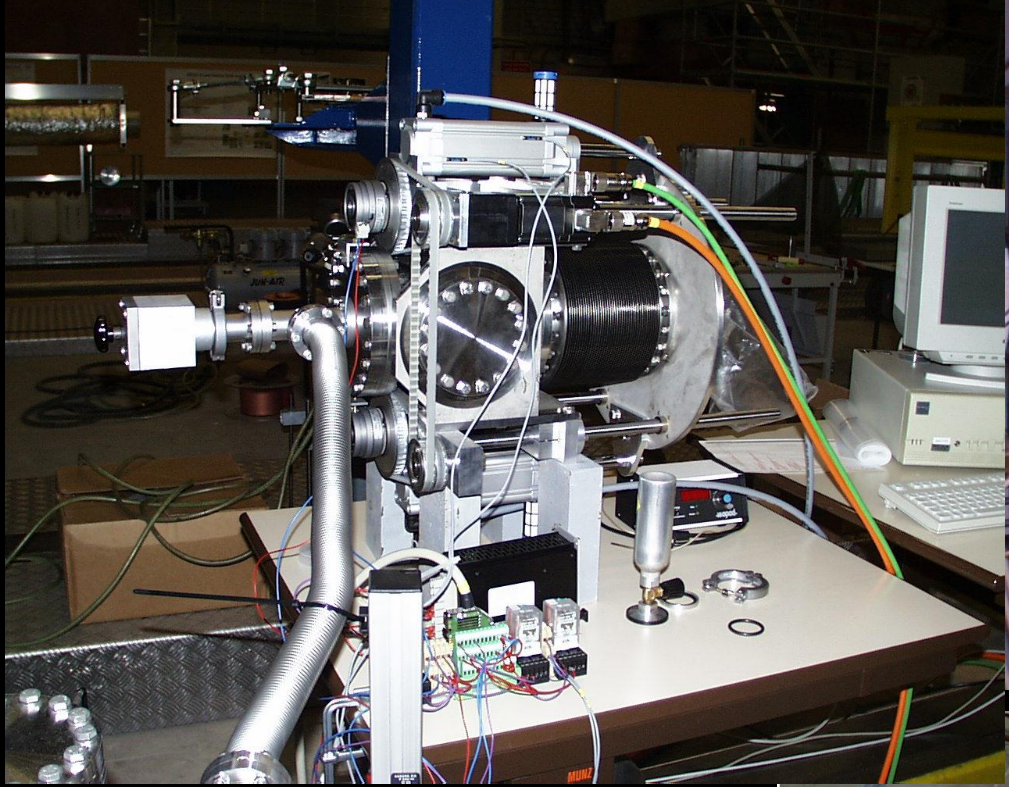


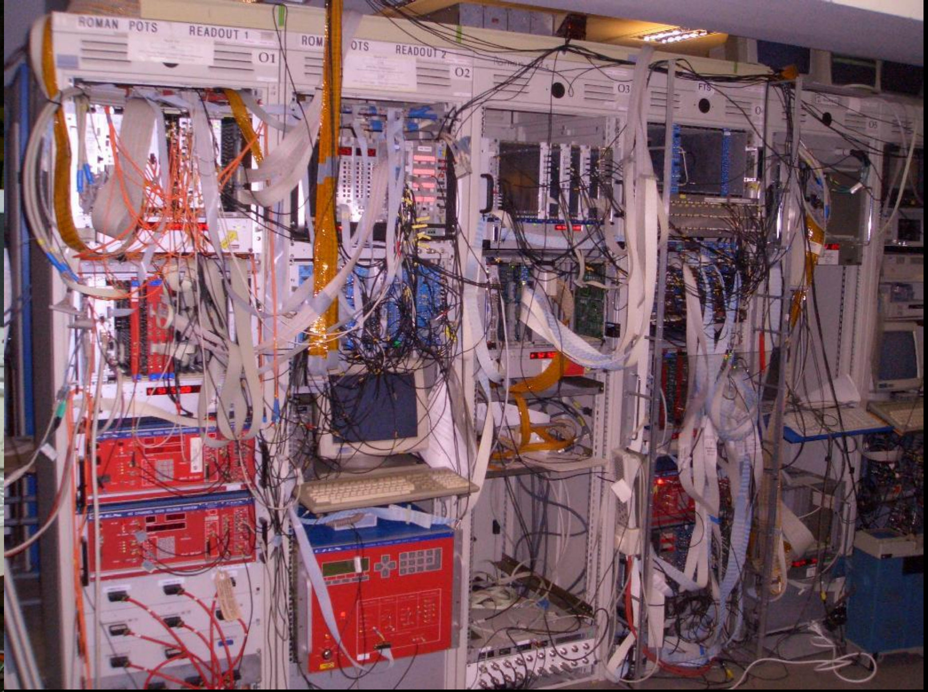


The Forward Muon system: MUF

H1 at HERA: 2003-2004



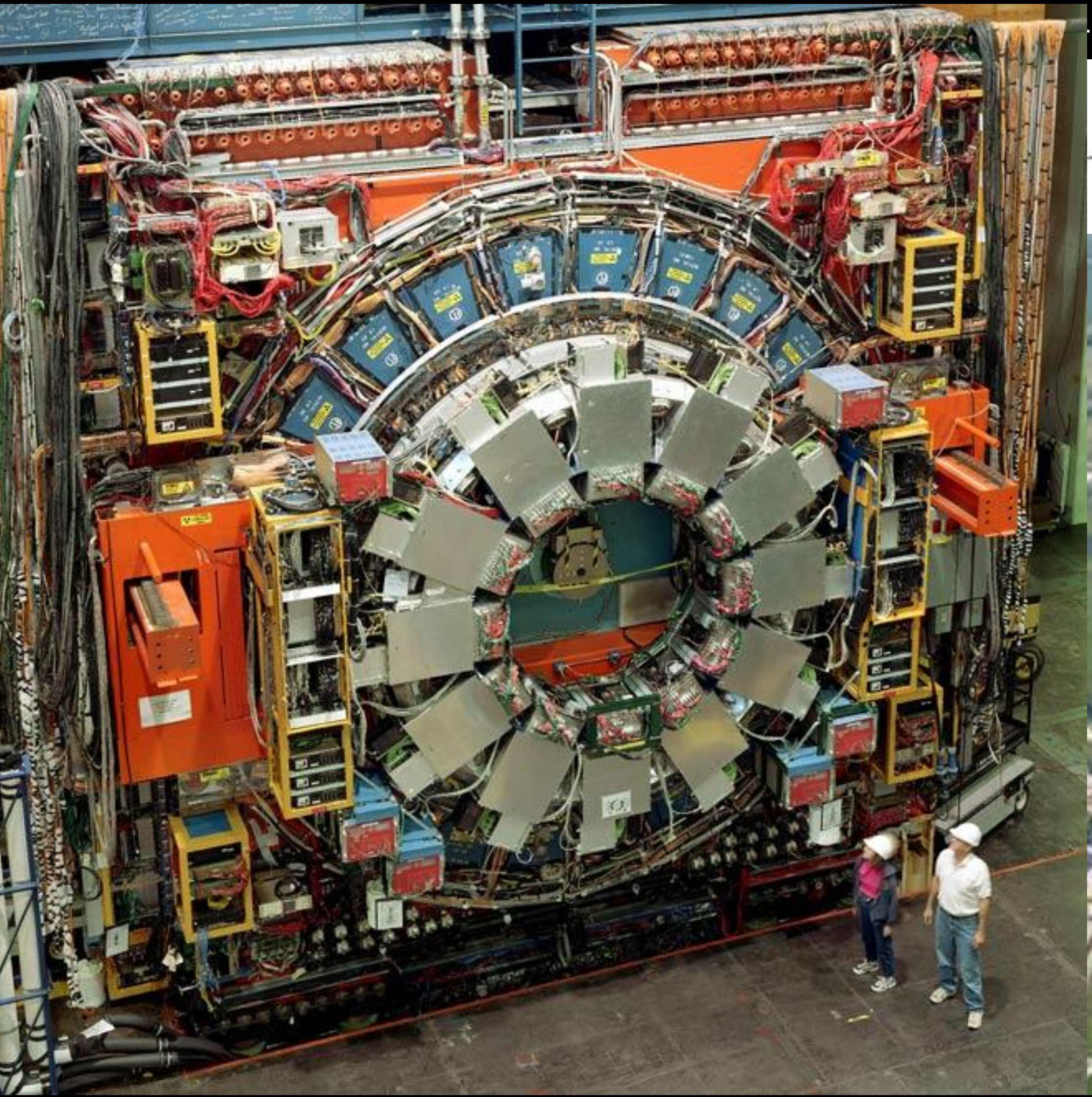



ROMAN POTS
READOUT 1
READOUT 2


Vision_1: VFPS
Shift
Plots
PC
Beam
Temperatures
Setting
Shift Mode
FPS/VFPS Slow Control
FPS-63H
WAIT
Waiting
Calculating
Position 619290
Out
In
Rate 48293
Low
High
FPS-80H
In
In
Rate limit
Position 507306
Out
In
Rate 49714
Low
High
FPS-81V
In
- In -
Position 600271
Out
In
Rate 5311
Low
High
FPS-90V
In
- In -
Position 400839
Out
In
Rate 5257
Low
High
VFPS-1
Moving In
Position 1053419
Out
In
Rate 100
Low
High
VFPS-2
Moving In
Position 1101094
Out
In
Rate 169
Low
High
Action on all Pots:
Move In
Retract
Logbook
All
Warnings
Alarms
Archives
09-Mar 01:08:39: Move IN Pots: VFPS-1
09-Mar 01:08:41: Move IN Pots: VFPS-2
09-Mar 01:08:49: Moving Pot VFPS:220 Moving In
09-Mar 01:08:49: Moving Pot VFPS:220 Moving In
09-Mar 01:08:53: Moving Pot VFPS:224 Moving In
09-Mar 01:08:53: Moving Pot VFPS:224 Moving In
Alarms
FPS
63H
80H
81V
90V
VFPS
1
2
TCP
HV
Motors
Reject
Low V
Others


Proton beam
Electron beam
VFPS2
VFPS1

CDF at the Tevatron 2004-2008



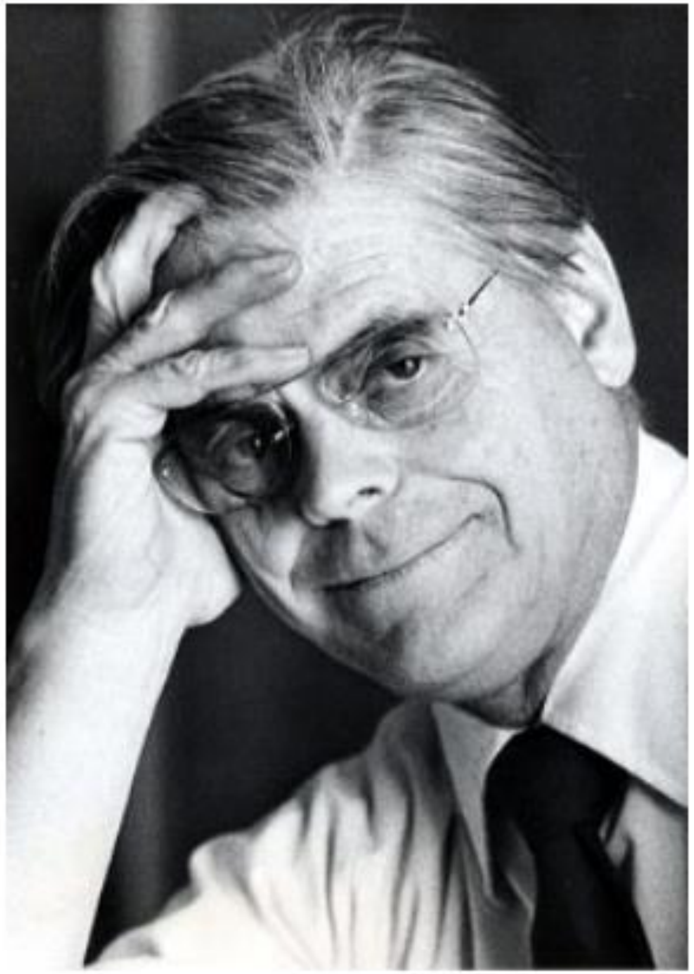
ABOUT 1,000 PHYSICISTS and uncounted technicians contributed to the CDF and DØ collaborations' efforts to find the top quark. The first pages of their respective papers reporting the discovery consist entirely of names.

'Acqua alle funi'

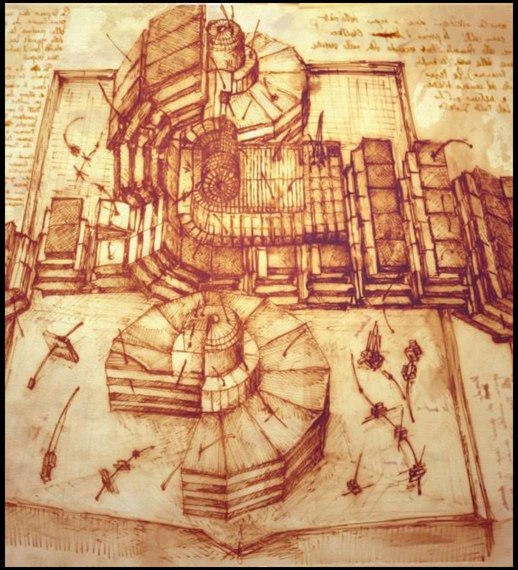
Robert Rathbun Wilson (Director from 1967 - 1978)

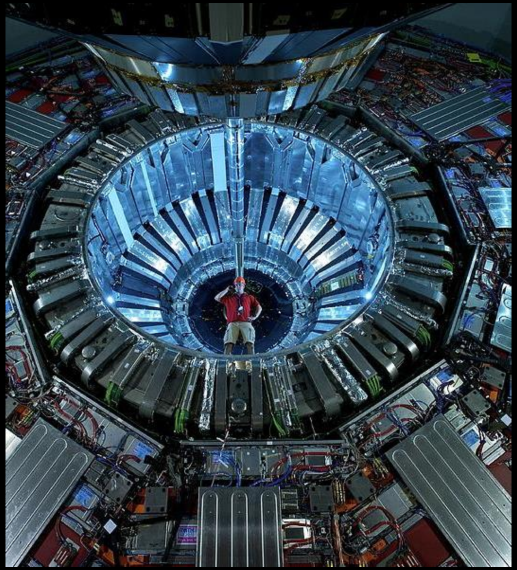
"It only has to do with the respect with which we regard one another, the dignity of men, our love of culture. It has to do with those things. It has to do with, are we good painters, good sculptors, great poets? I mean all the things that we really venerate and honor in our country and are patriotic about. It has nothing to do directly with defending our country except to help make it worth defending."

— Robert R. Wilson, answering Congress' question on how the new accelerator will affect the nation's security.

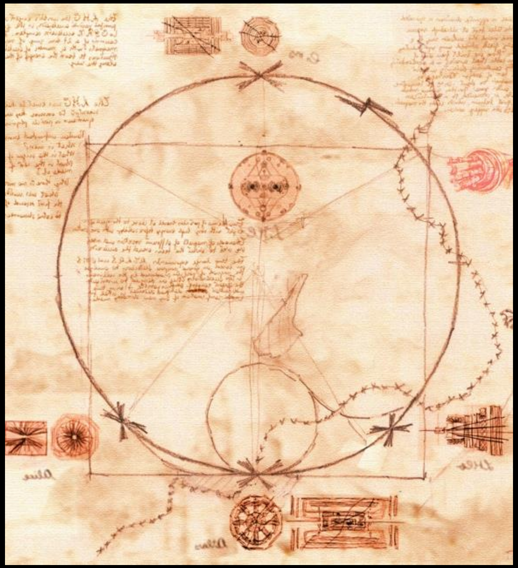


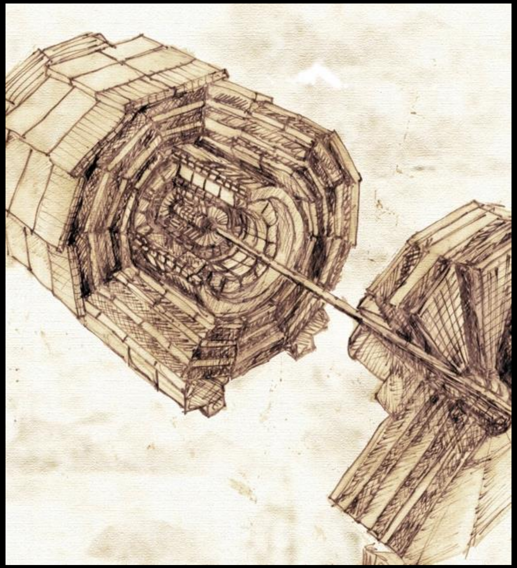
The Robert R. Wilson Collection contains the written and audio-visual records of the personal history (1914-2000) and professional history (1967-1978) of Fermilab's first director. Wilson's western roots and Berkeley training prepared him for his frontier work on the Manhattan Project and pioneering developments at Cornell University's Newman Laboratory for Nuclear Studies. In 1967 he was selected to create the National Accelerator

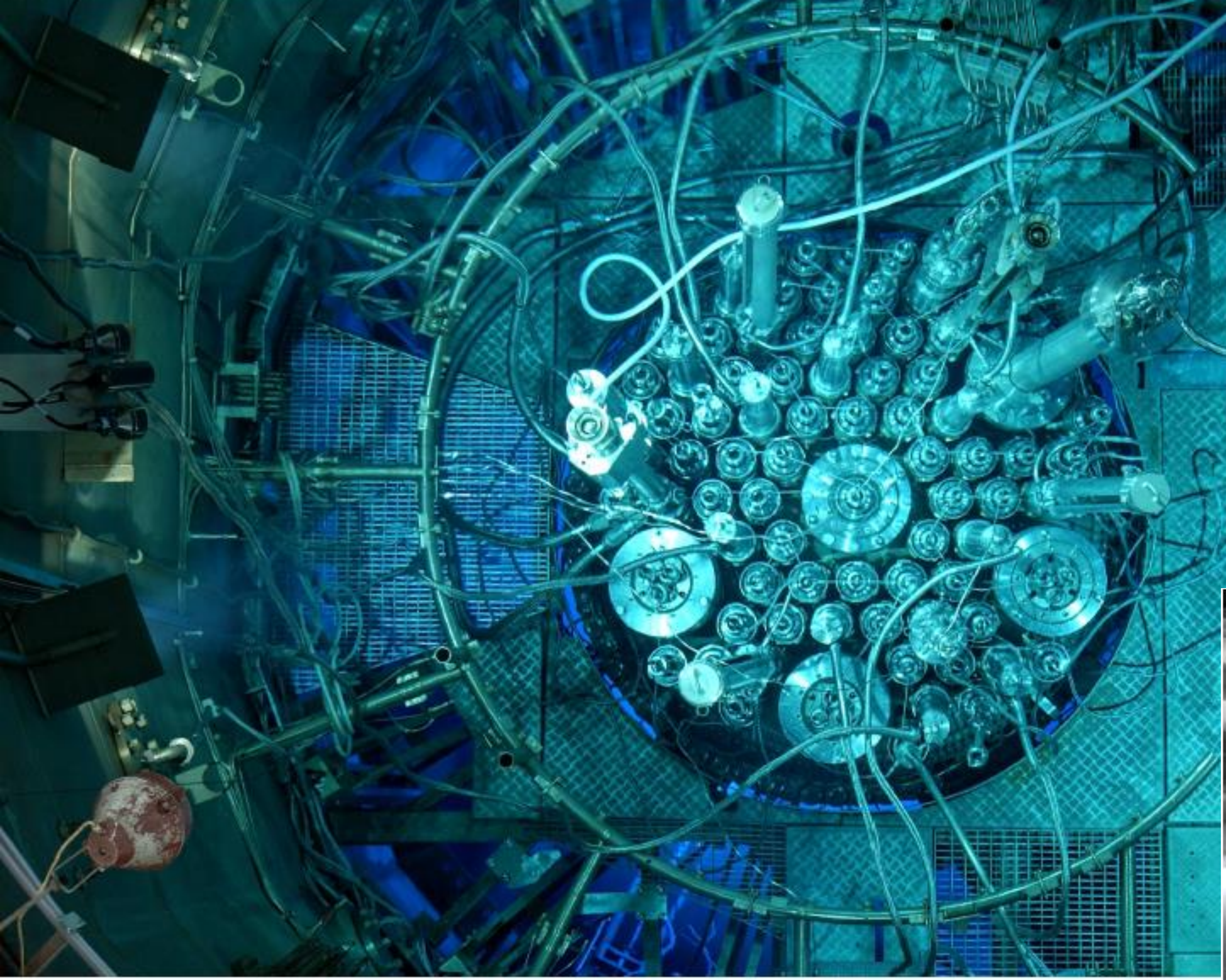




CMS at LHC: 2008 - 2017







SoLid at BR2 Belgium: 2014-2024

07.14382v1 [hep-ex] 19 Jul 2024

Search for Very-Short-Baseline Oscillations of Reactor Antineutrinos with the SoLid Detector

Y. Abreu,[1] Y. Amhis,[2] L. Arnold,[3] W. Beaumont,[1] I. Bolognino,[4] M. Bongrand,[2] D. Boursette,[2] V. Buridon,[5] H. Chanal,[6] B. Coupé,[7] P. Crochet,[6] D. Cussans,[3] J. D'Hondt,[8] D. Durand,[5] M. Fallot,[9] D. Galbinski,[5,*] S. Gallego,[10] L. Ghys,[7] L. Giot,[9] K. Graves,[11] B. Guillon,[5] S. Hayashida,[12] D. Henaff,[9] B. Hosseini,[11] S. Kalcheva,[7] L. N. Kalousis,[8] R. Keloth,[8] L. Koch,[10] M. Labare,[13] G. Lehaut,[5,†] S. Manley,[3] L. Manzanillas,[2] J. Mermans,[7] I. Michiels,[13] S. Monteil,[6] C. Moortgat,[13] D. Newbold,[14] V. Pestel,[5] K. Petridis,[3] I. Piñera,[6] A. de Roeck,[1] N. Roy,[2] D. Ryckbosch,[13] N. Ryder,[15] D. Saunders,[3] M. H. Schune,[2] M. Settimo,[9] H. Rejeb Sfar,[1] L. Simard,[2] A. Vacheret,[5,‡] S. Van Dyck,[7] P. Van Mulders,[8] N. Van Remortel,[1] G. Vandierendonck,[13] S. Vercaemer,[1] M. Verstraeten,[16] B. Viaud,[9] A. Weber,[17,10] M. Yeresko,[6] and F. Yermia[9]

(SoLid Collaboration)

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[7] *SCK CEN, Belgian Nuclear Research Centre, Mol, Belgium*
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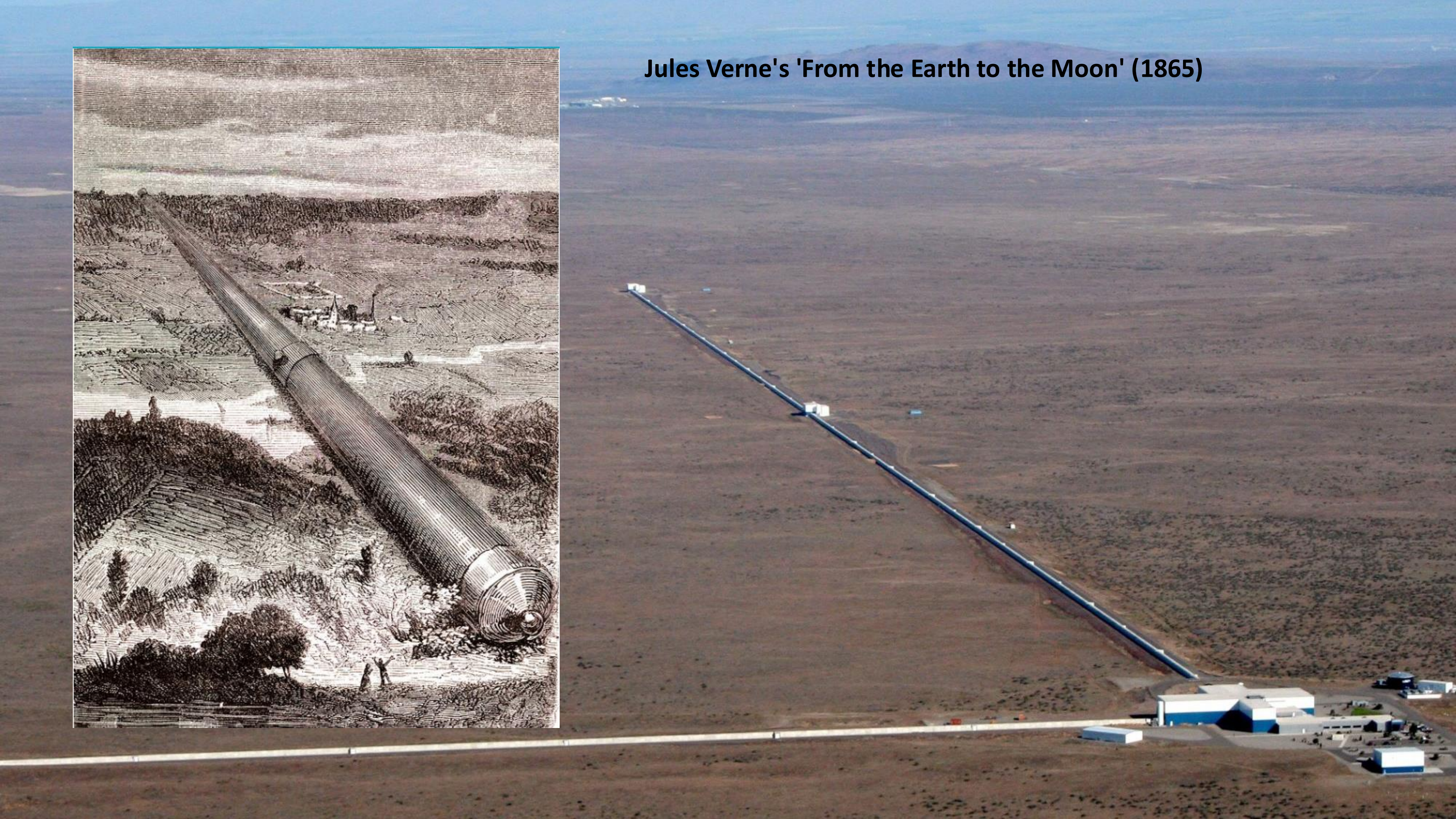
[17] *Fermi National Accelerator Laboratory, Batavia, USA*

(Dated: July 22, 2024)

In this letter we report the first scientific result based on antineutrinos emitted from the BR2 reactor at SCK CEN. The SoLid experiment uses a novel type of highly granular detector whose basic detection unit combines two scintillators, PVT and ^{6}LiF:ZnS(Ag), to measure antineutrinos via their inverse-beta-decay products. An advantage of PVT is its highly linear response as a function of deposited particle energy. The full-scale detector comprises 12 800 voxels and operates over a very short 6.3–8.9 m baseline from the reactor core. The detector segmentation and its 3D imaging capabilities facilitate the extraction of the positron energy from the rest of the visible energy, allowing the latter to be utilised for signal-background discrimination. We present a result based

LIGO-VIRGO: 2017 -

Jules Verne's 'From the Earth to the Moon' (1865)

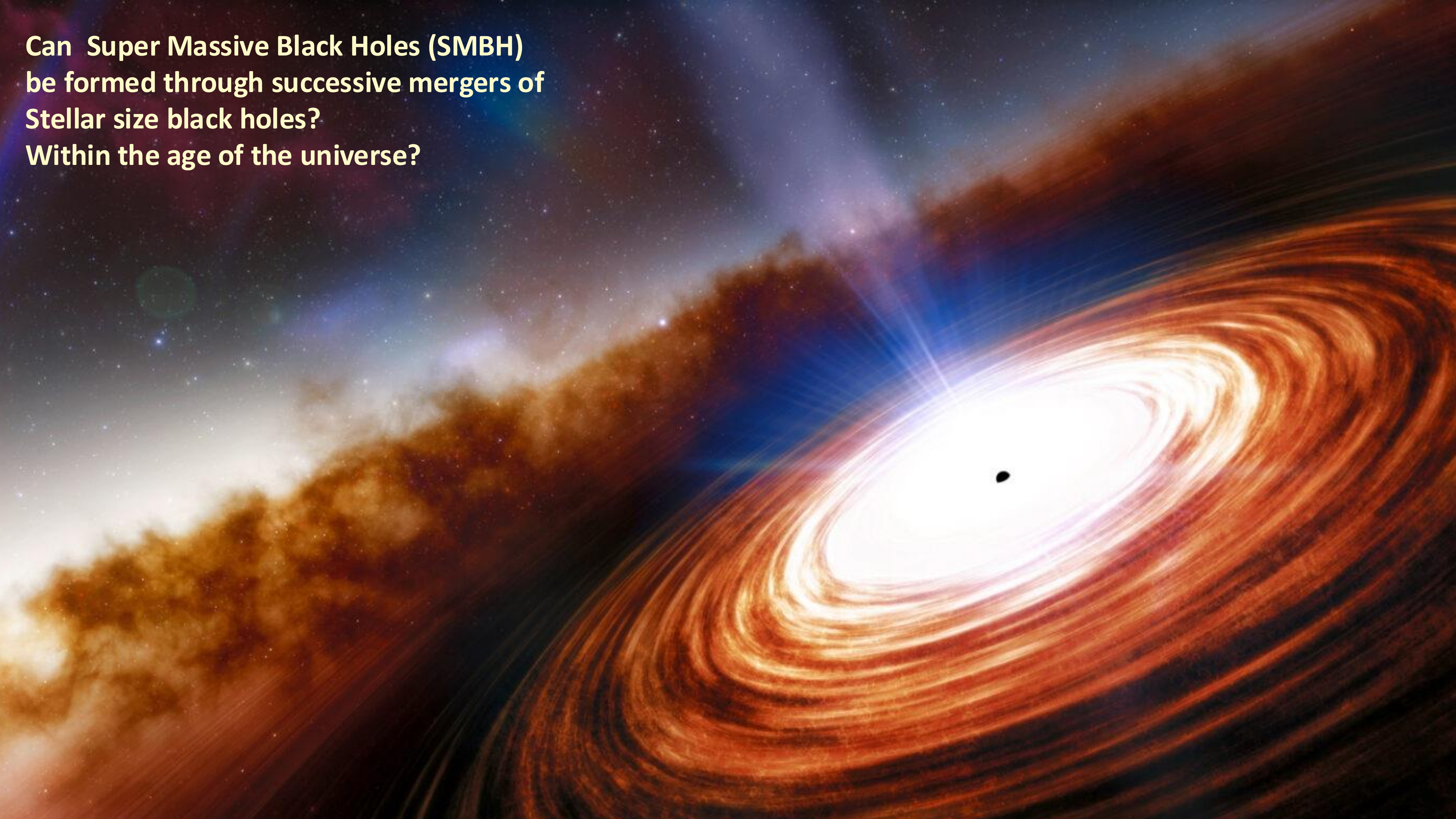


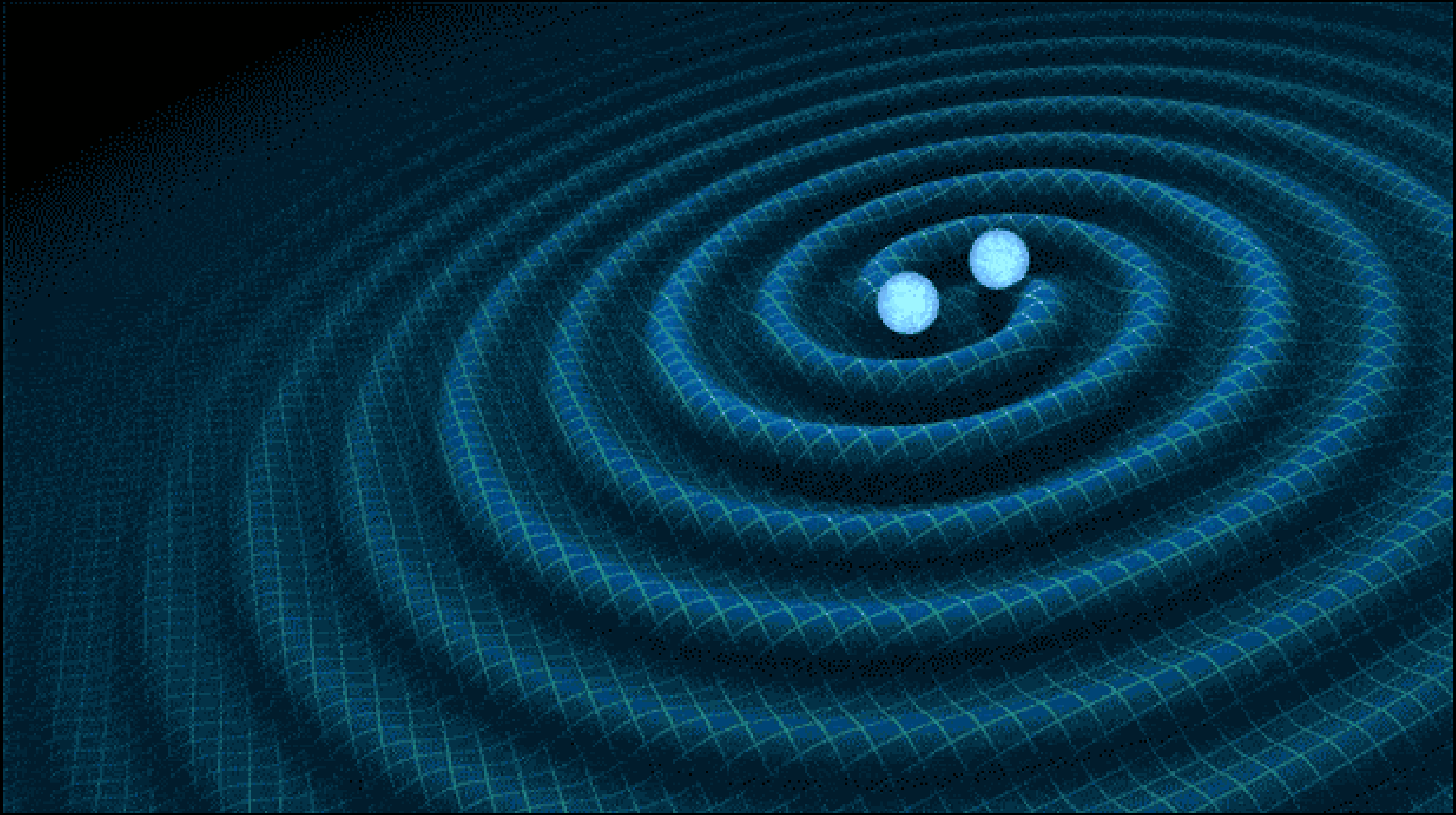

SHUMATE
HARLEY-DAVIDSON
INSTRUCTIONS

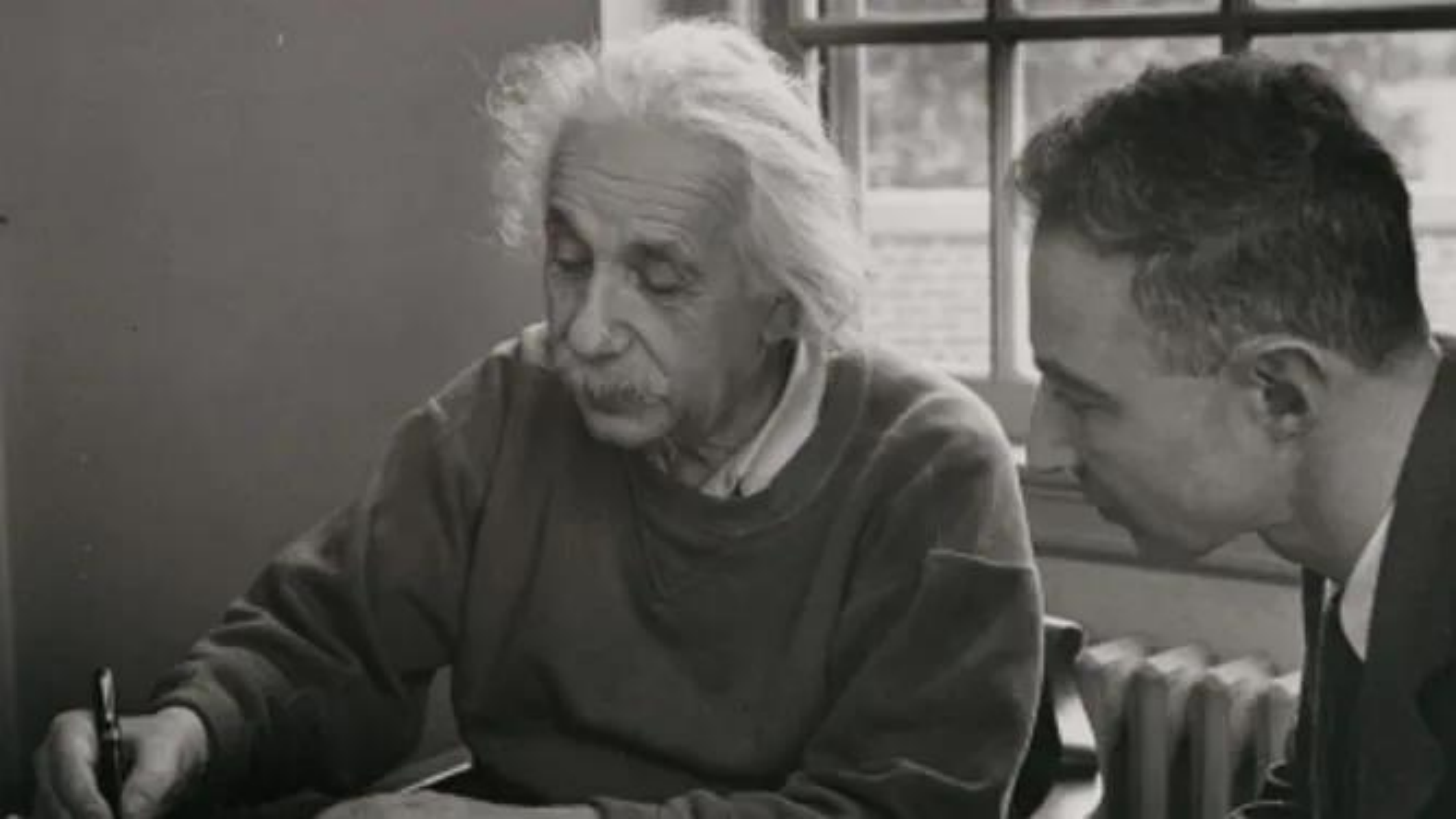

02 | MAR | 21

Pre-Flare
X-ray Image of Galactic Center
Flare
Post-Flare
Infrared View of Milky Way

Can Super Massive Black Holes (SMBH)
be formed through successive mergers of
Stellar size black holes?
Within the age of the universe?

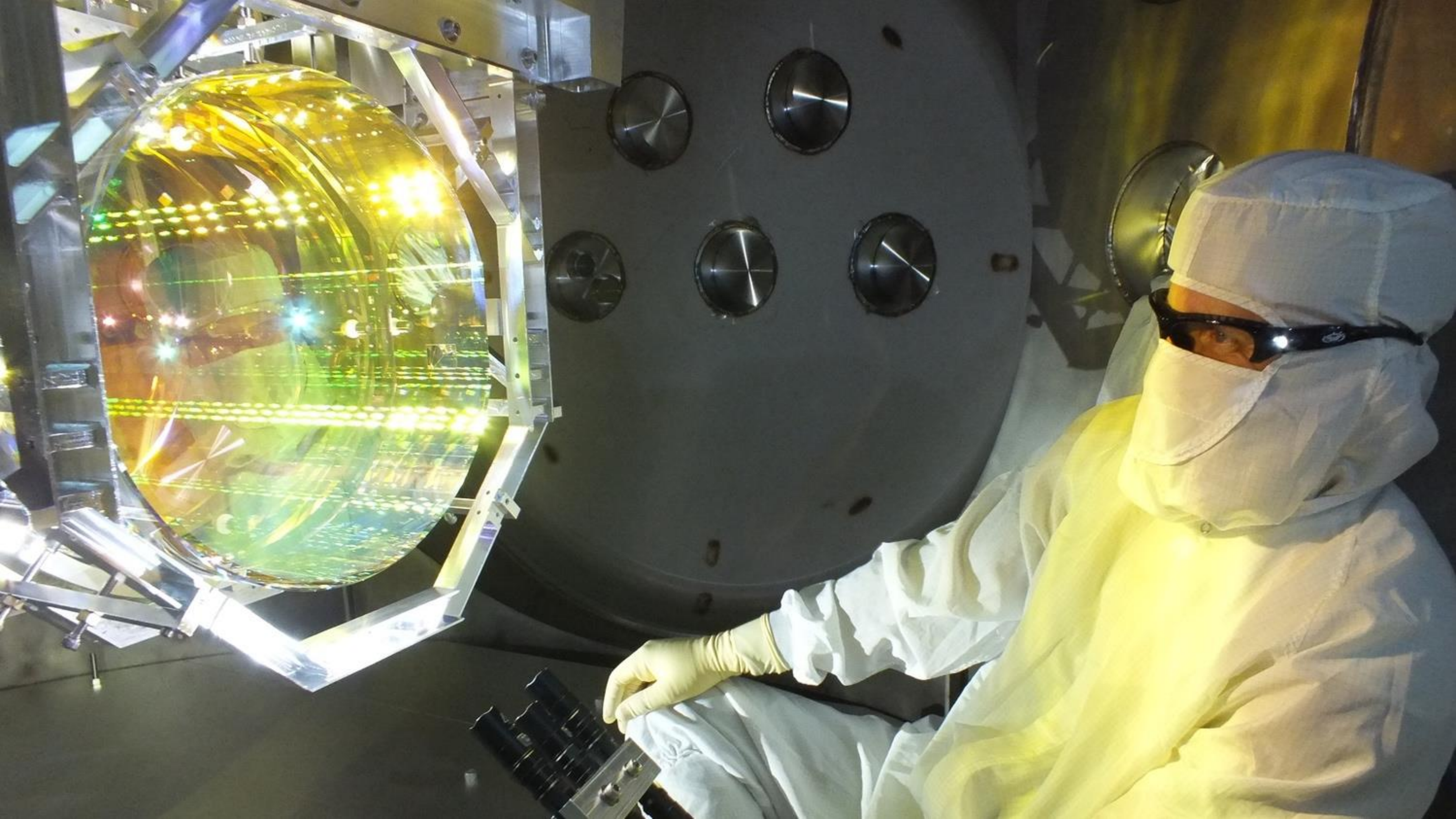




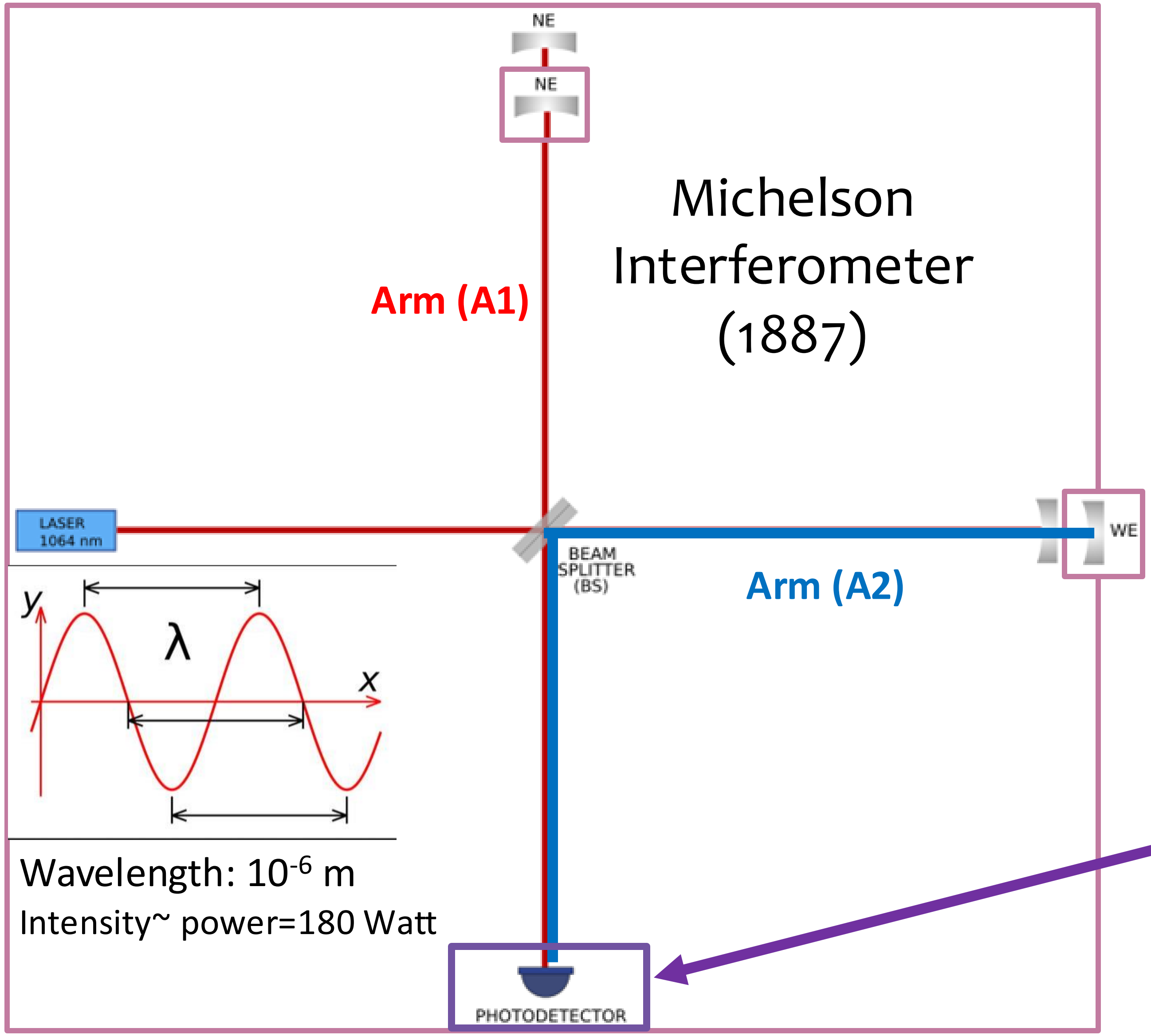


The current network of 2nd Gen detectors

Source: G. Gemme, XiV ET Symposiu
Maastricht, 6-10 May 2024

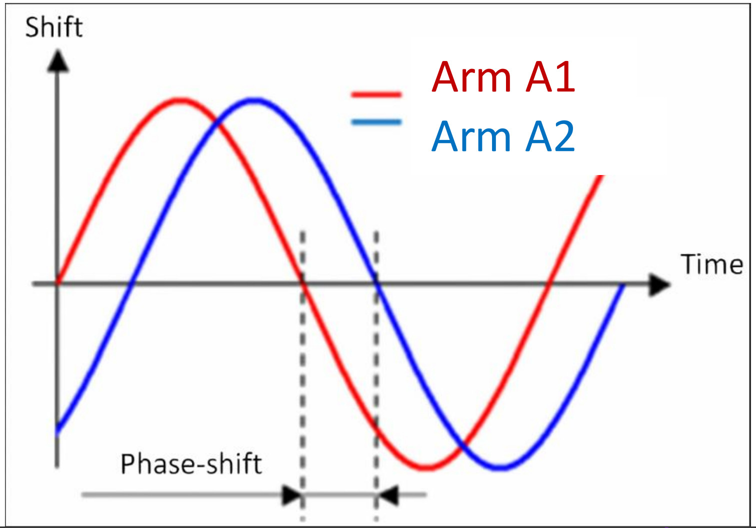


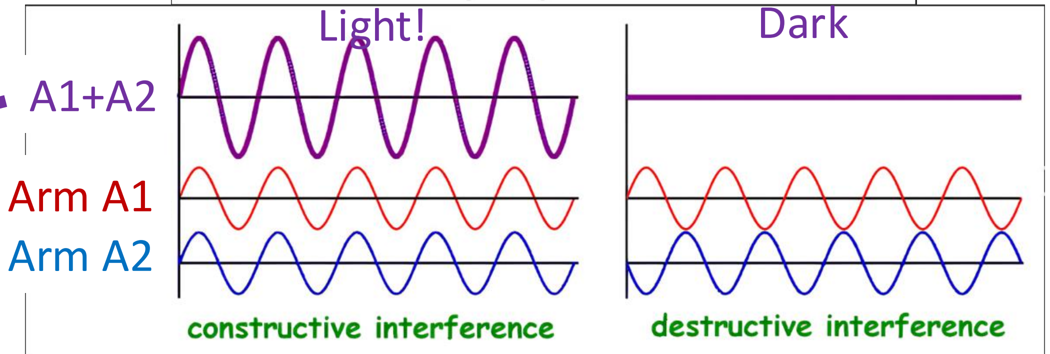
Gravitational wave detectors



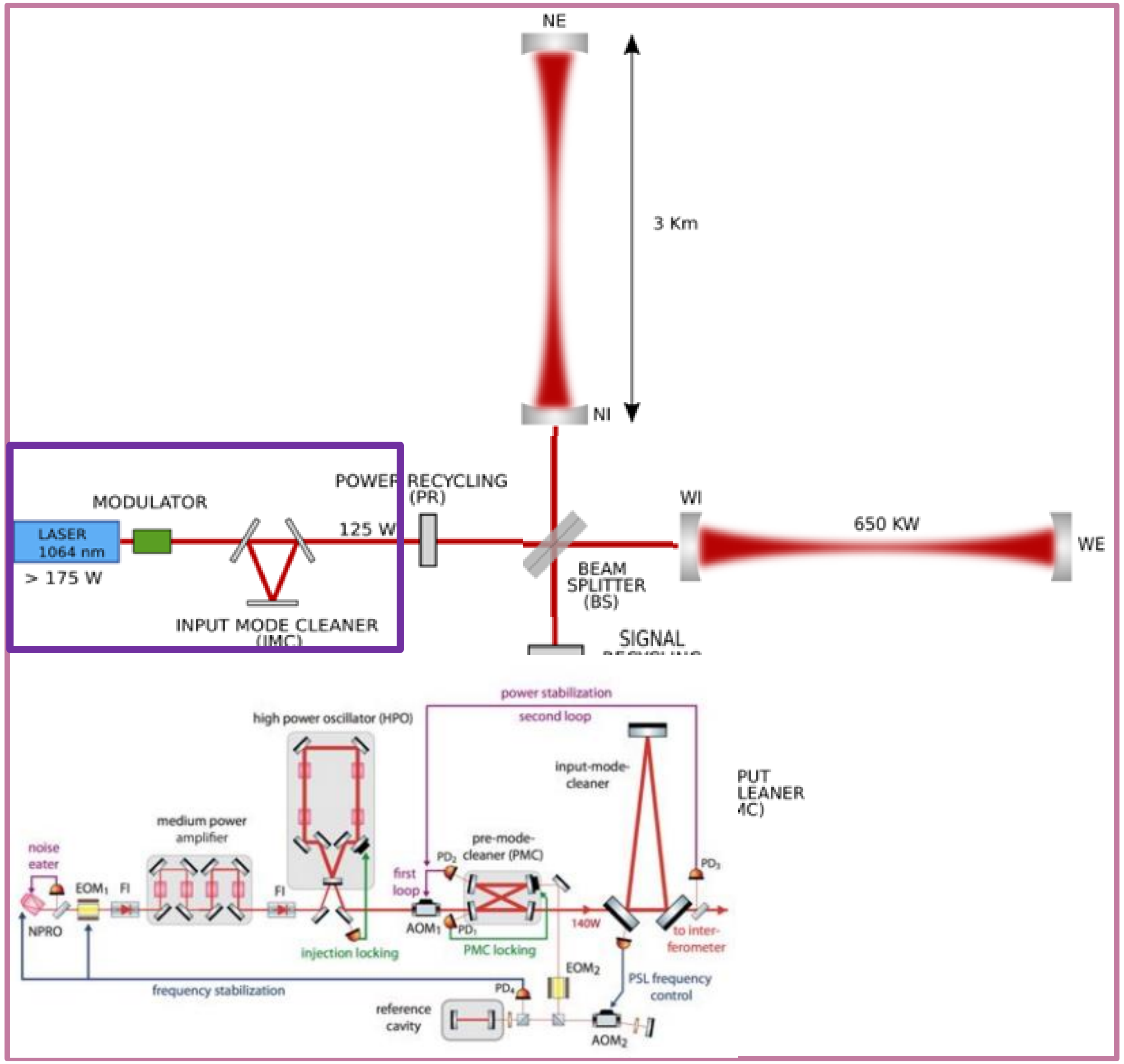
Gravitational waves cause changes **in length** ratio between arms A1>A2, A2>A1

Lichtwaves experience **change of phase**





Boosting the signal via optics, resonance & feedback



Fabry-Perot cavities:
Stabilizing arm length
Effective arm length increases by x400
Boosing the optical power

Optical modulation:
Stabilizing arm length
Measurement and control network
Via sensors and actuators

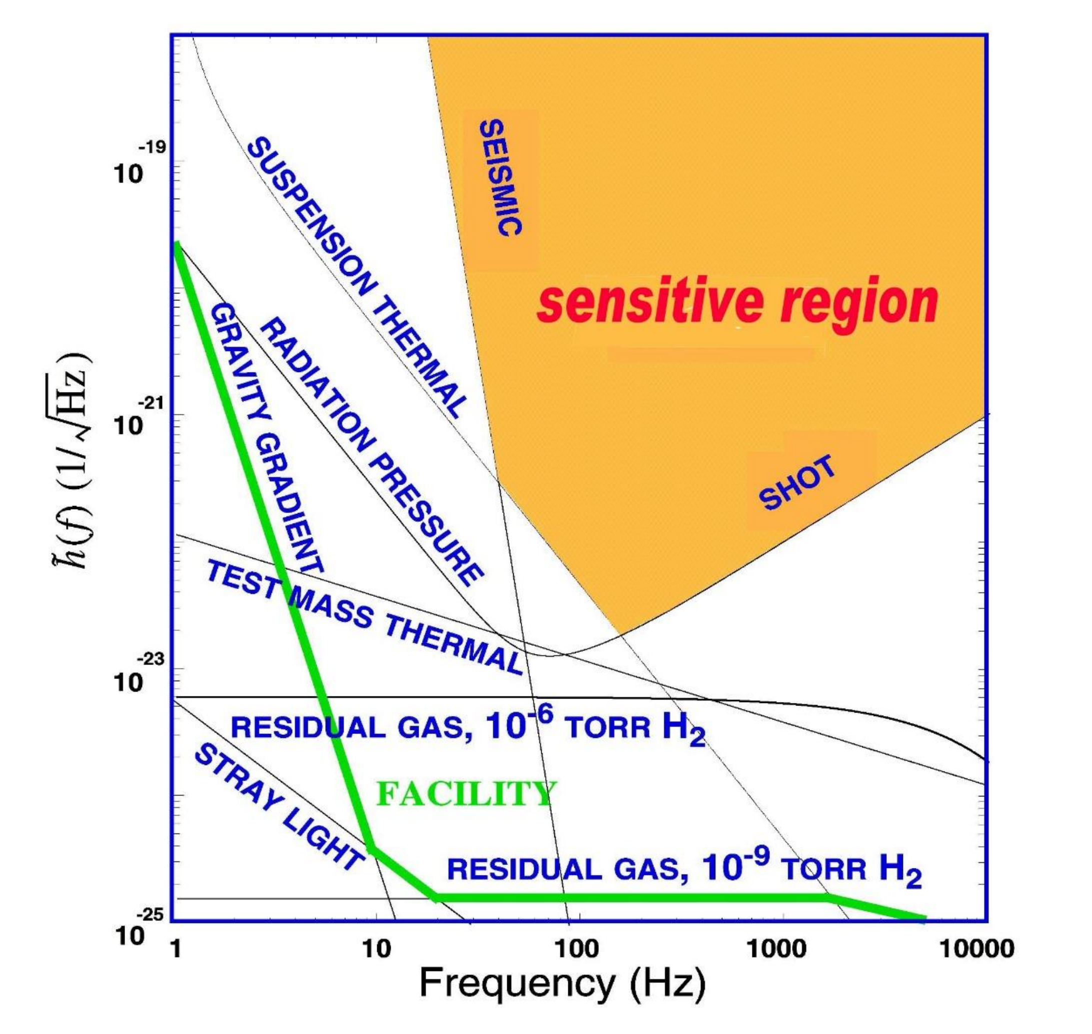
Power & signal recycling:
Enlarge optcial power with x5000
Isolation & extraction of GW signal

Input & output cleaning:
Cleaning of laser beams
Removal of stray light

Every Component = subproject:
10s to 100s of components
Years of development/optimization

Limitations on the measurement

- Seismic noise & vibration limit at low frequencies
- Atomic vibrations (Thermal Noise) inside components limit at mid frequencies
- Quantum nature of light (Shot Noise) limits at high frequencies
- Myriad details of the lasers, electronics, etc., can make problems above these levels



Multimessenger Astronomy

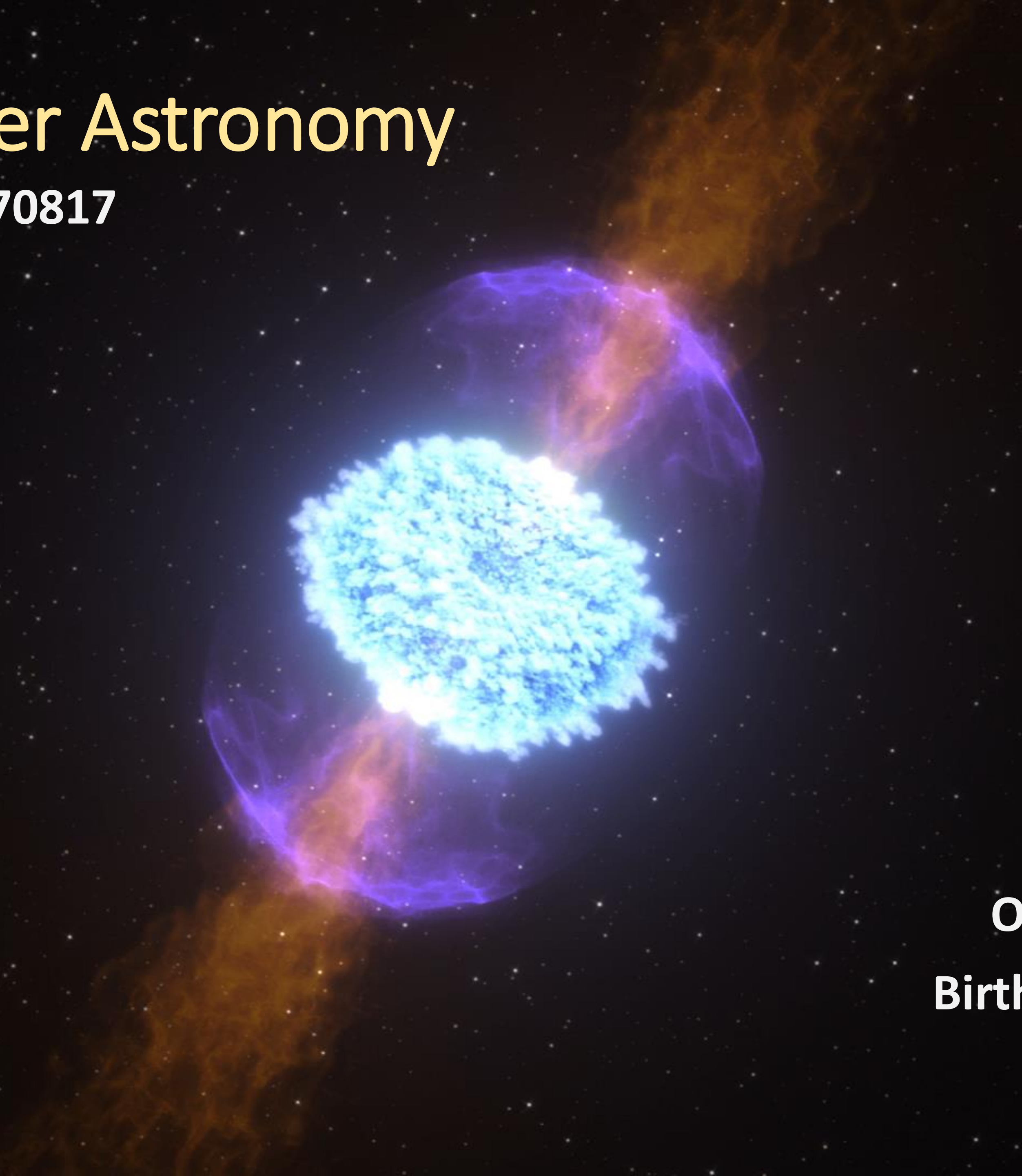
August 17, 2017: GW170817

Two Neutron Stars

Combined 2,8 $M_\odot$

LIGO + Virgo

70 observatoria



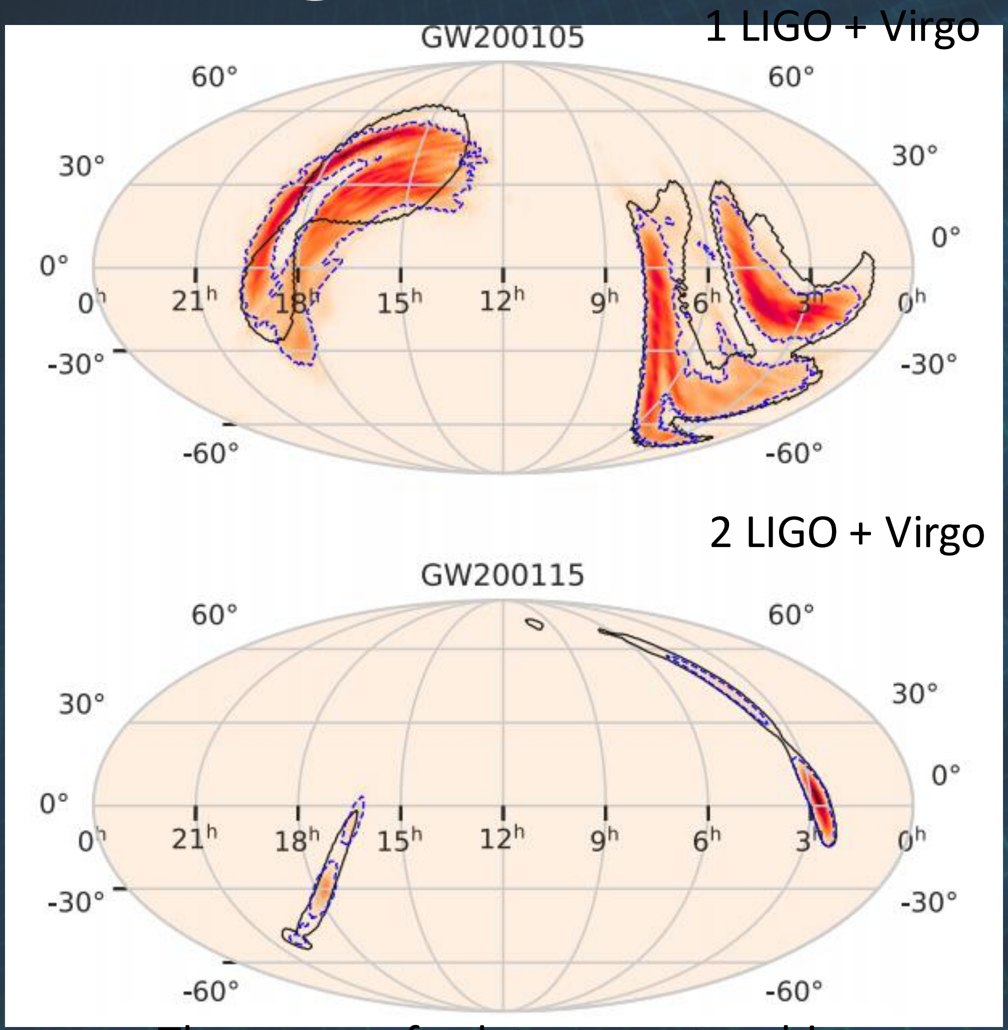
Observation: supernova

Birth of Gold and Platinum

(10 x earth mass)

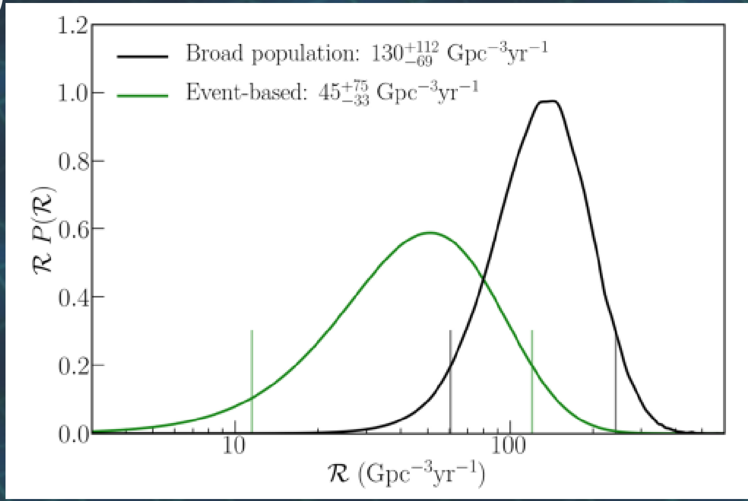
Black Hole – Neutron star mergers

- Discovered in Jan 2020 by resp. 2 and 3 interferometers (1 LIGO + Virgo and 2 LIGO + Virgo)
- Precise sky localisation for the 3 detector network!
- Several formation channels possible (isolated, young star cluster, active galactic nuclei, …)
- Component masses are in agreement with mass distributions for NS and BH respectively (no mass gap!)
- No evidence found for measurable tides or tidal disruption of the NS: Important for exotic nuclear theory
- No significant effective spin found (formation mechanism)



The power of a detector network!

Inferred merger rate



GW190521: A Binary Black Hole Merger with a Total Mass of 150 M⊙

First observation of an Intermediate Mass Black Hole (IMBH)

Proof of successive mergers of stellar mass black holes!

Black holes show precession: -> Random encounter

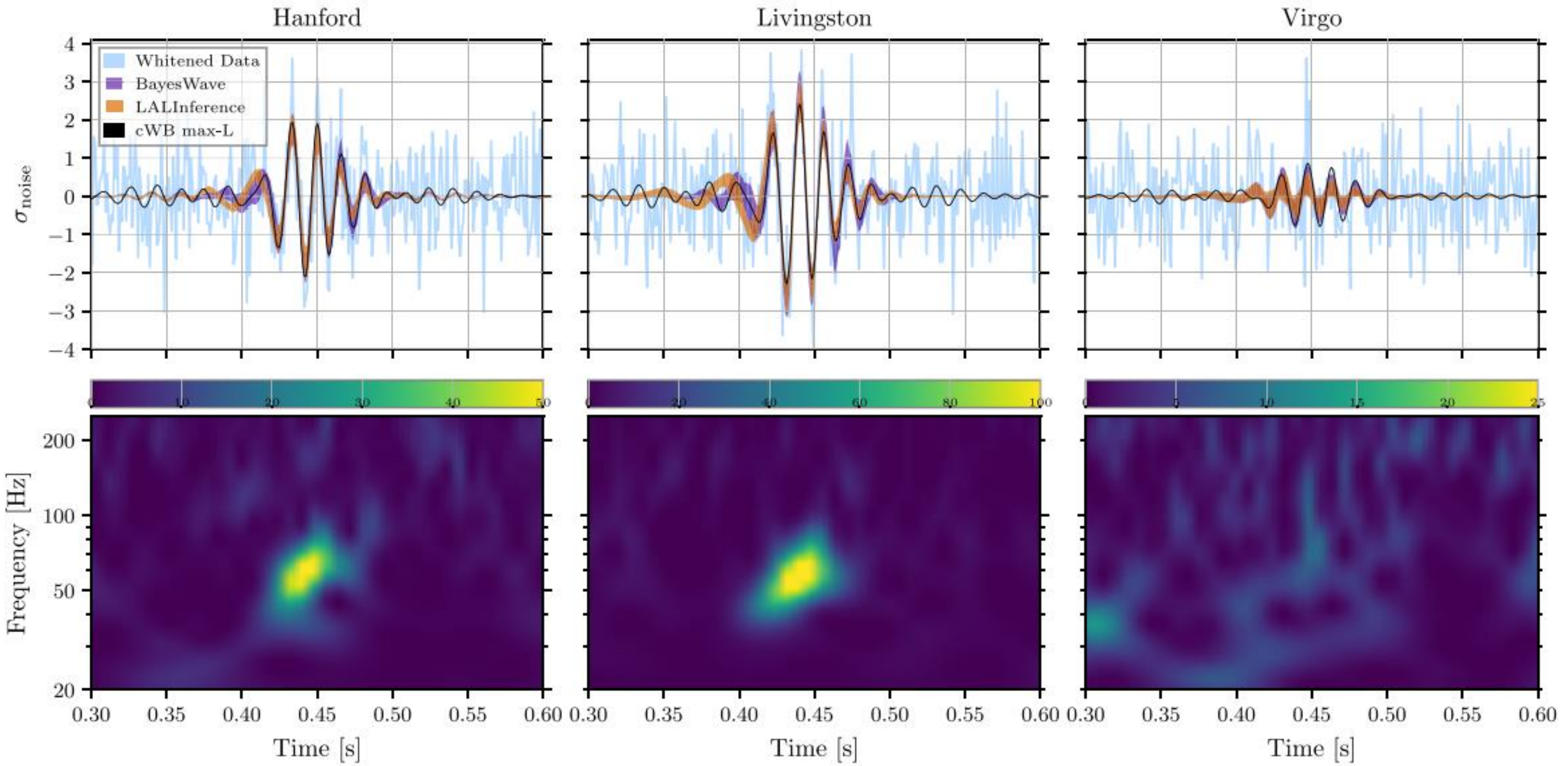
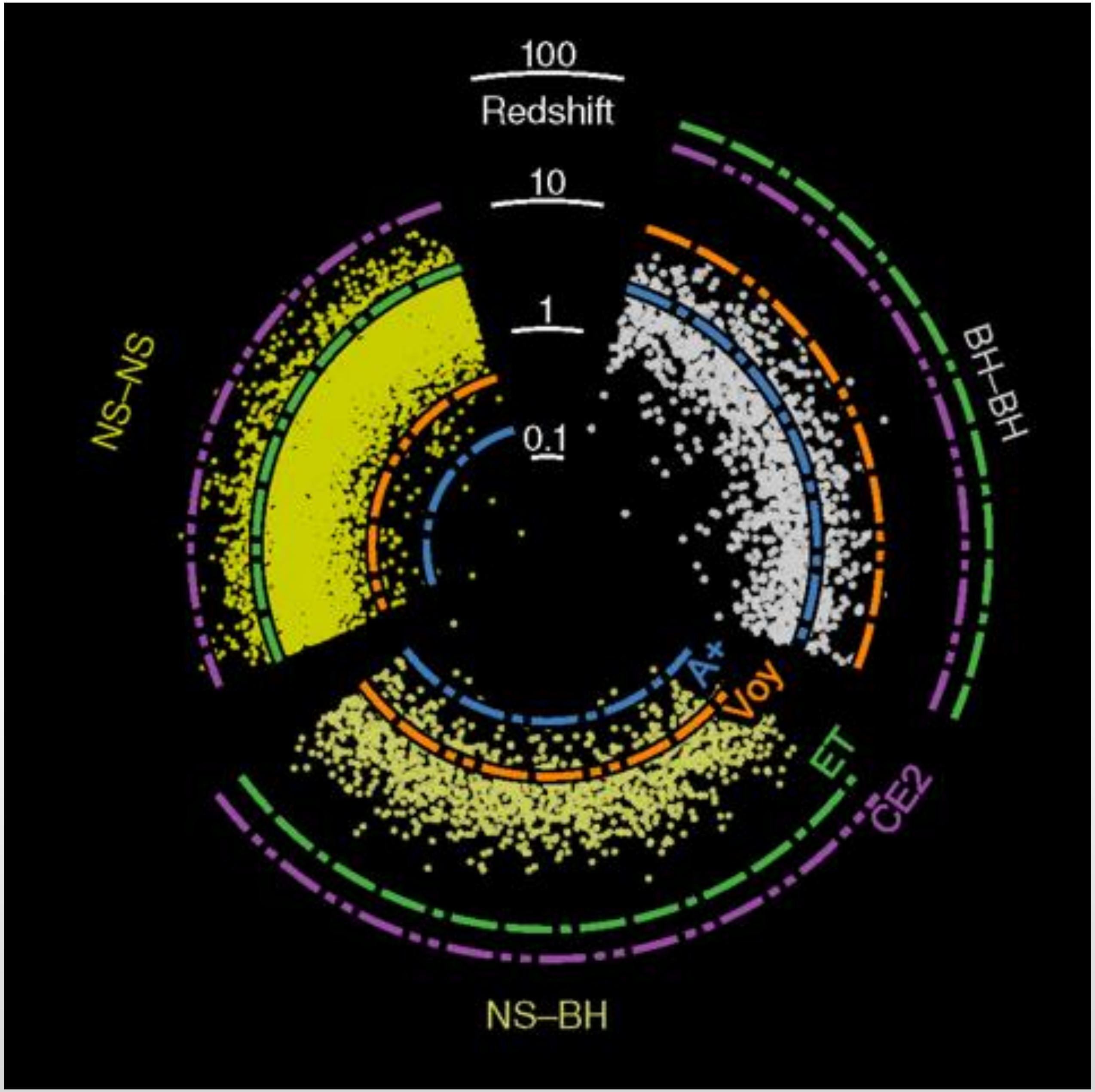


TABLE I. Parameters of GW190521 according to the NRSur7dq4 waveform model. We quote median values with 90% credible intervals that include statistical errors.

Parameter	
Primary mass	$85^{+21}_{-14}\ M_\odot$
Secondary mass	$66^{+17}_{-18}\ M_\odot$
Primary spin magnitude	$0.69^{+0.27}_{-0.62}$
Secondary spin magnitude	$0.73^{+0.24}_{-0.64}$
Total mass	$150^{+29}_{-17}\ M_\odot$
Mass ratio ($m_2/m_1 \leq 1$)	$0.79^{+0.19}_{-0.29}$
Effective inspiral spin parameter (χ_{eff})	$0.08^{+0.27}_{-0.36}$
Effective precession spin parameter (χ_{p})	$0.68^{+0.25}_{-0.37}$
Luminosity Distance	$5.3^{+2.4}_{-2.6}$ Gpc
Redshift	$0.82^{+0.28}_{-0.34}$
Final mass	$142^{+28}_{-16}\ M_\odot$
Final spin	$0.72^{+0.09}_{-0.12}$
$P\ (m_1 < 65\ M_\odot)$	0.32%
$\log_{10}$ Bayes factor for orbital precession	$1.06^{+0.06}_{-0.06}$
$\log_{10}$ Bayes factor for nonzero spins	$0.92^{+0.06}_{-0.06}$
$\log_{10}$ Bayes factor for higher harmonics	$-0.38^{+0.06}_{-0.06}$

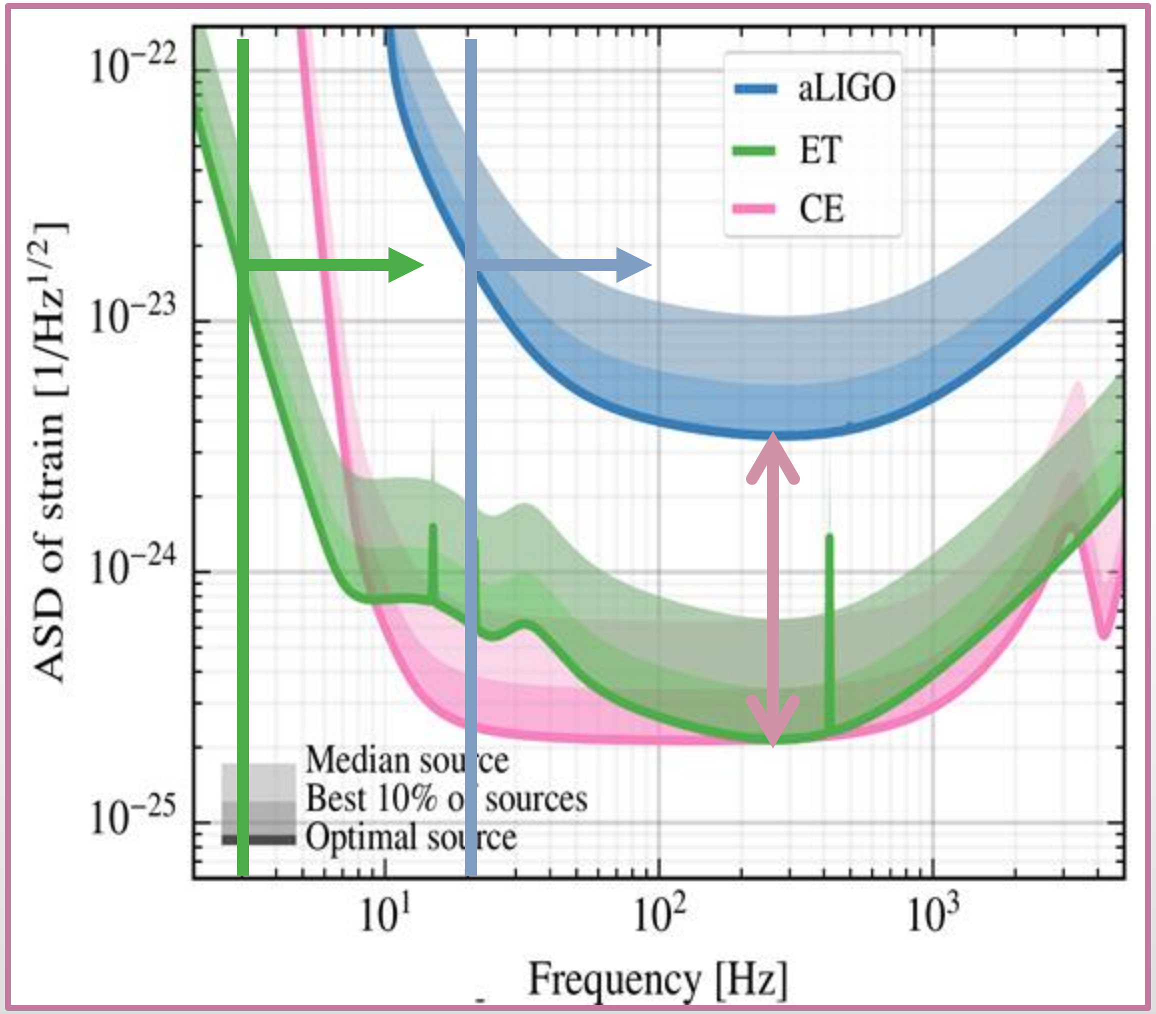


Physics potential of 3G detectors

Einstein Telescope (EU) & Cosmic Explorer (USA):

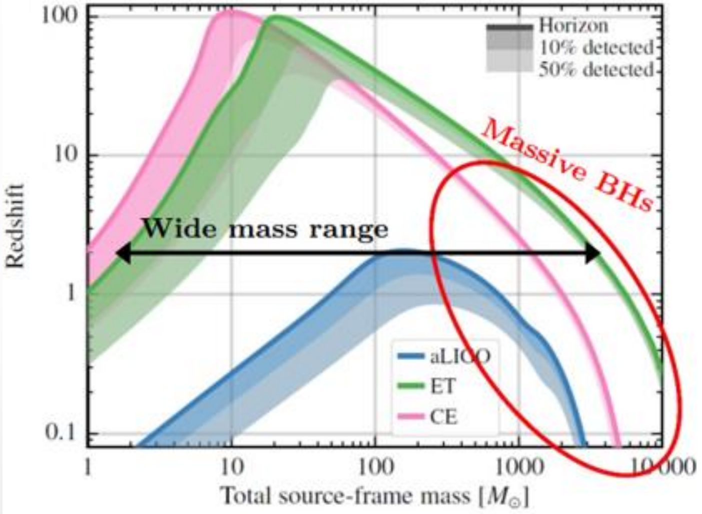
- **Probe entire populations of binary mergers**
- **Observations increase by factor 10.000:**
  $10^5 - 10^6$ BBH mergers /year
- **Access to wider mass range: $M_\odot$ to 100's $M_\odot$**
- **Observe mergers for longer times**
- **Look back into the dark ages**
- **Probe new objects: supernova's, pulsars, magnetars …**
- **Precision tests of GR**
- **Dark matter and dark energy**
- **Early universe cosmology**

2nd gen vs 3rd gen GW interferometers:



Credits: GWIC 3G Committee, the GWIC 3G Science Case Team, and the International 3G Science Team Consortium, "3G Science Book," 2020

- 2[nd] Generation (aLIGO, AdV, KAGRA) sensitive down to 20 Hz
- 3[rd] Generation (ET, CE) will be 10x more sensitive in the bucket
- ET will extend sensitivity down to 2Hz, allowing
  - Detection of more massive binary black holes



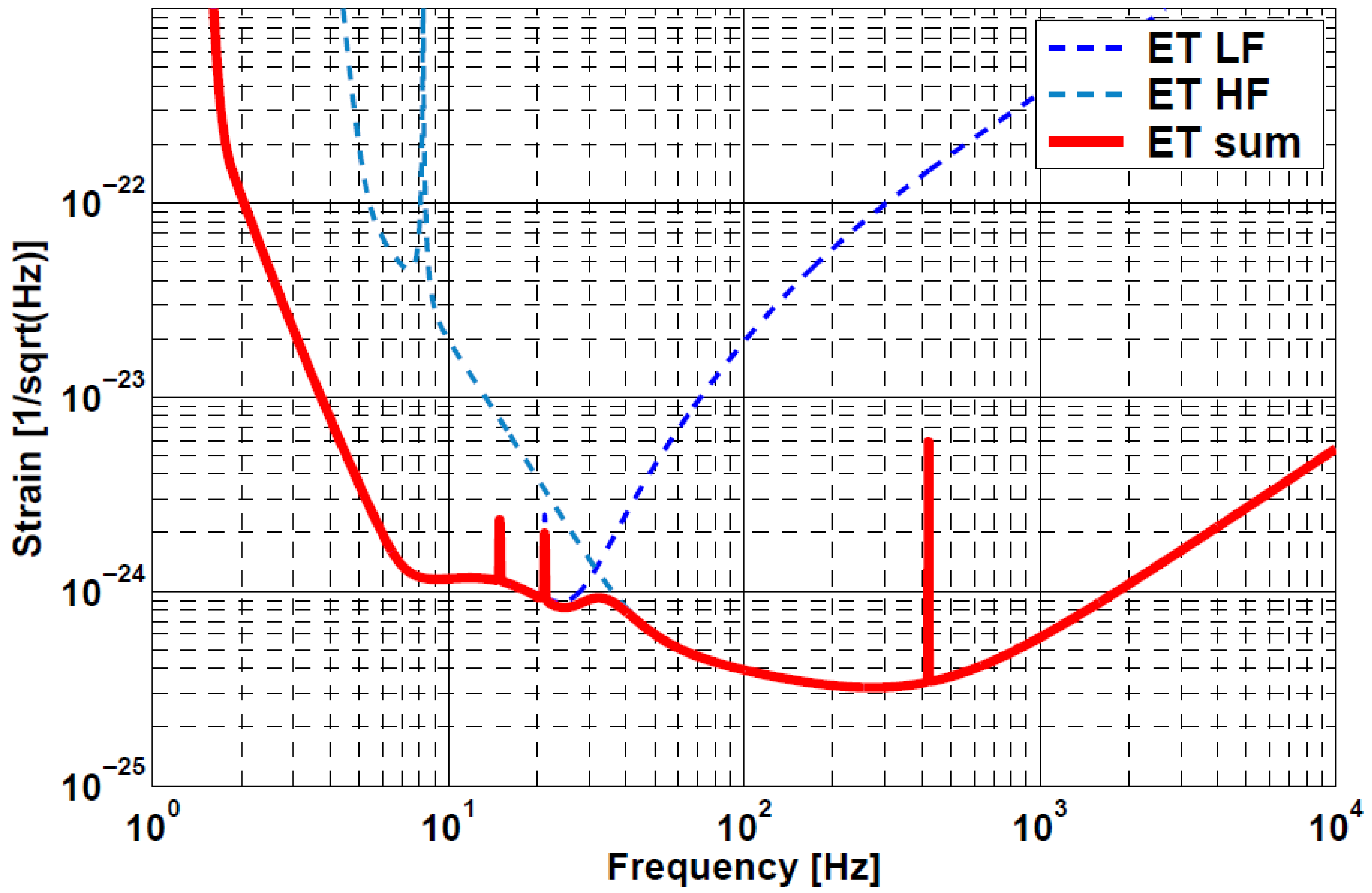
  - Extending the detection time prior to merger from <1sec to 30 minutes!

Source: M. Branchesi *et al* JCAP07(2023)068

Full (HFLF cryo) sensitivity detectors

Configuration	$\Delta\Omega_{90\%}$ [deg^2]	All orientation BNSs 30 min	All orientation BNSs 10 min	All orientation BNSs 1 min	BNSs with $\Theta_v < 15°$ 30 min	BNSs with $\Theta_v < 15°$ 10 min	BNSs with $\Theta_v < 15°$ 1 min
Δ10km	10	0	1	5	0	0	0
	100	10	39	113	2	8	20
	1000	85	293	819	10	34	132
	All detected	905	4343	23597	81	393	2312

It's all about controlling the noise:



Dominant instrument noise at low f

Suspension & coating thermal

$$h_{th}(f) \propto \frac{1}{L}\sqrt{\frac{T}{Qmf^5}}$$

Quantum radiation pressure

$$h_{rp}(f) = \frac{1}{mf^2L}\sqrt{\frac{\hbar P}{2\pi^3 c\lambda_{laser}}}$$

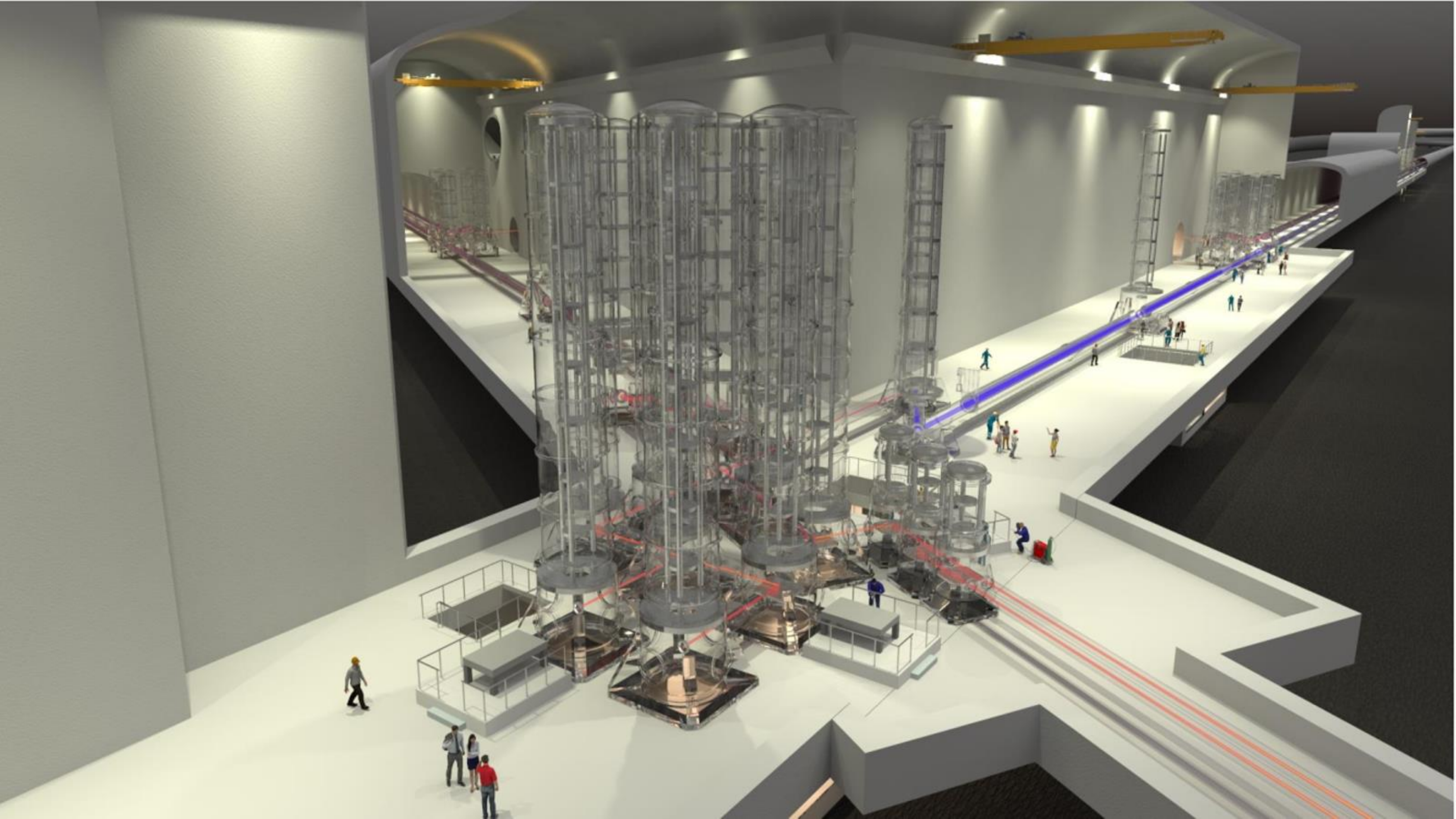
Dominant instrument noise at high f

Quantum shot noise

$$h_{sn}(f) = \frac{1}{L}\sqrt{\frac{\hbar c\lambda_{laser}}{2\pi P}}$$

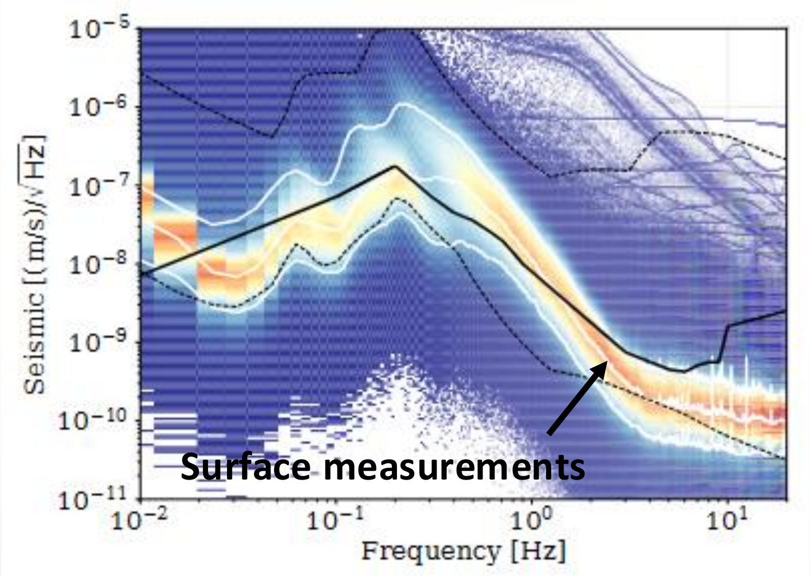
Decouple low f and high f in 2 instruments

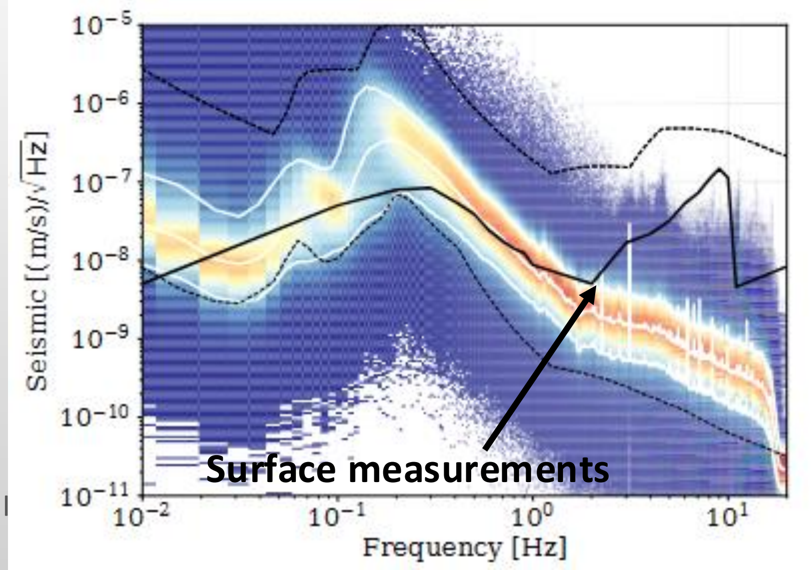
Source: [ET design report update 2020]



Surface vs underground:

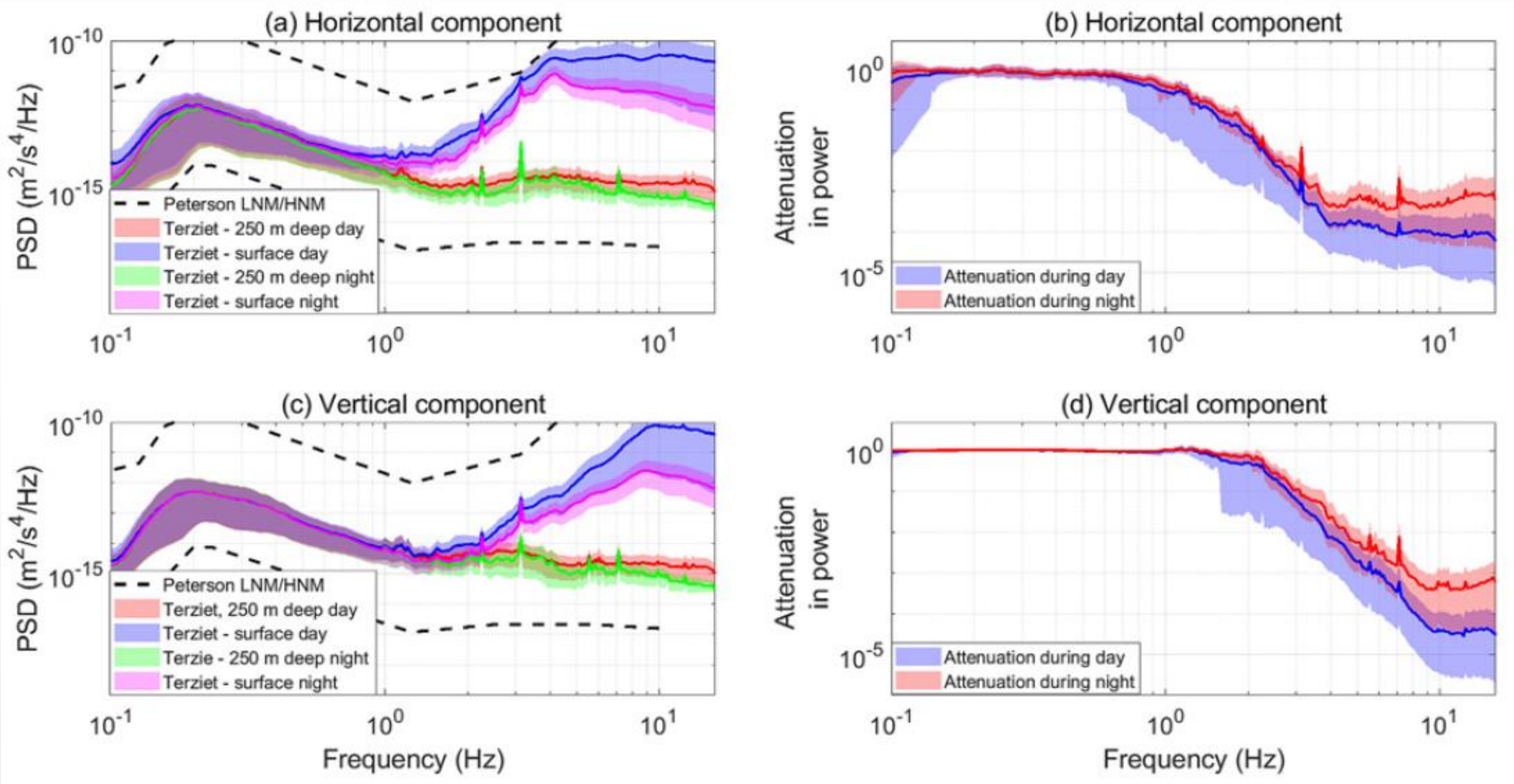
Seismic velocity spectra measured at
- Top: Sos-Enattos (Sardinia) P2 borehole at 264m depth
- Bottom: Terziet (NL) borehole at 250 m depth



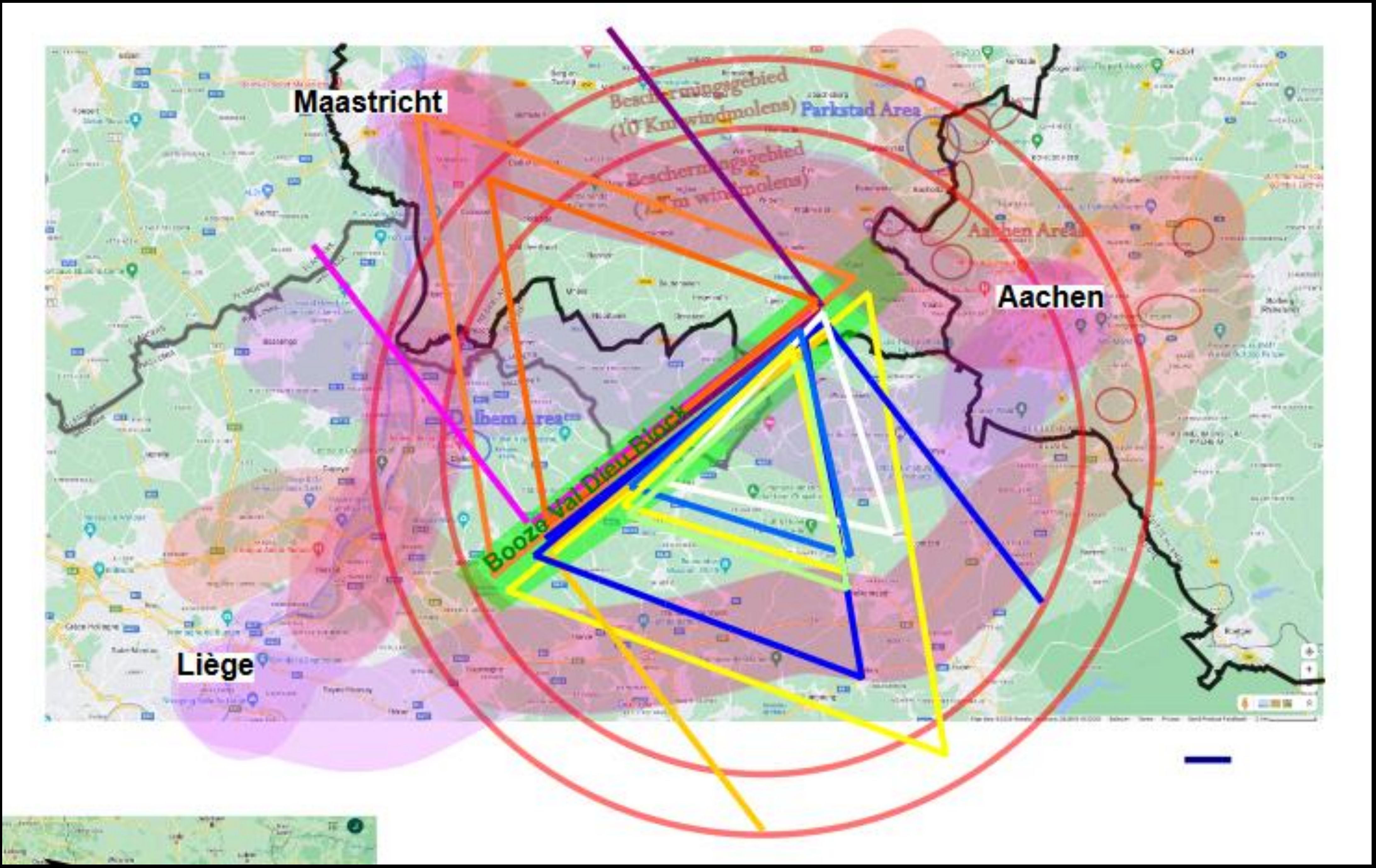


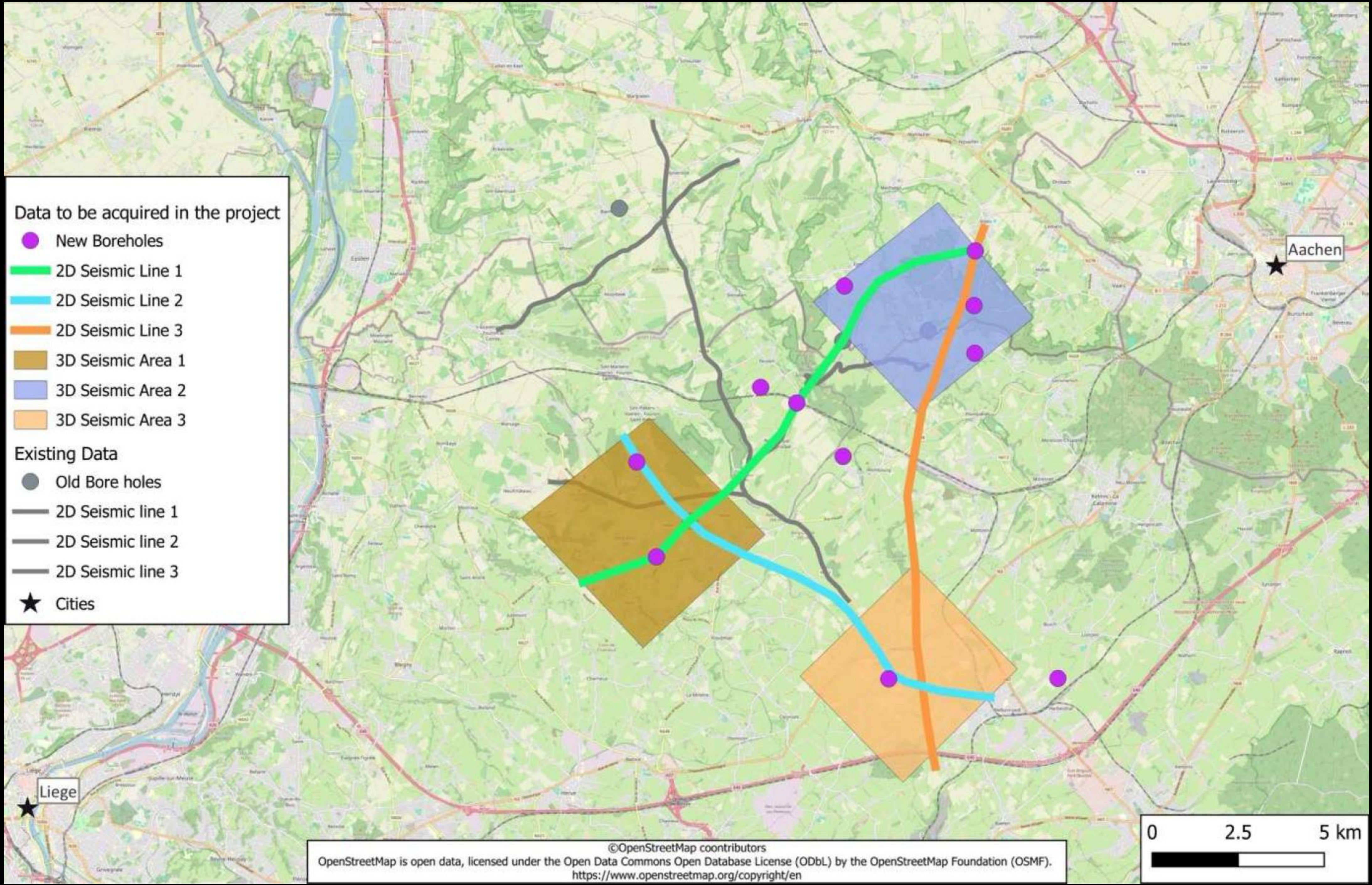
Power Spectral Density at Terziet Borehole:
- Day night difference at the surface indicates anthropomorphic component
- Power density can be suppressed by 4 orders of magnitude

Source: S. Koley *et al* 2022 *Class. Quantum Grav.* **39** 025008



From: Conceptual design and noise budget of Einstein Telescope (paper in preparation)


Maastricht
Parkstad Area
Aachen Area
Aachen
Dalhem Area
Booze Val Dieu Block
Liège


Data to be acquired in the project
New Boreholes
2D Seismic Line 1
2D Seismic Line 2
2D Seismic Line 3
3D Seismic Area 1
3D Seismic Area 2
3D Seismic Area 3
Existing Data
Old Bore holes
2D Seismic line 1
2D Seismic line 2
2D Seismic line 3
Cities
Aachen
Liege
0
2.5
5 km
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ETB06a
ETB06a
266
ETB06a
267.90
268
268.00
266.30
267.00

~60m depth: Mollusks from Namurian age 300Myr ago

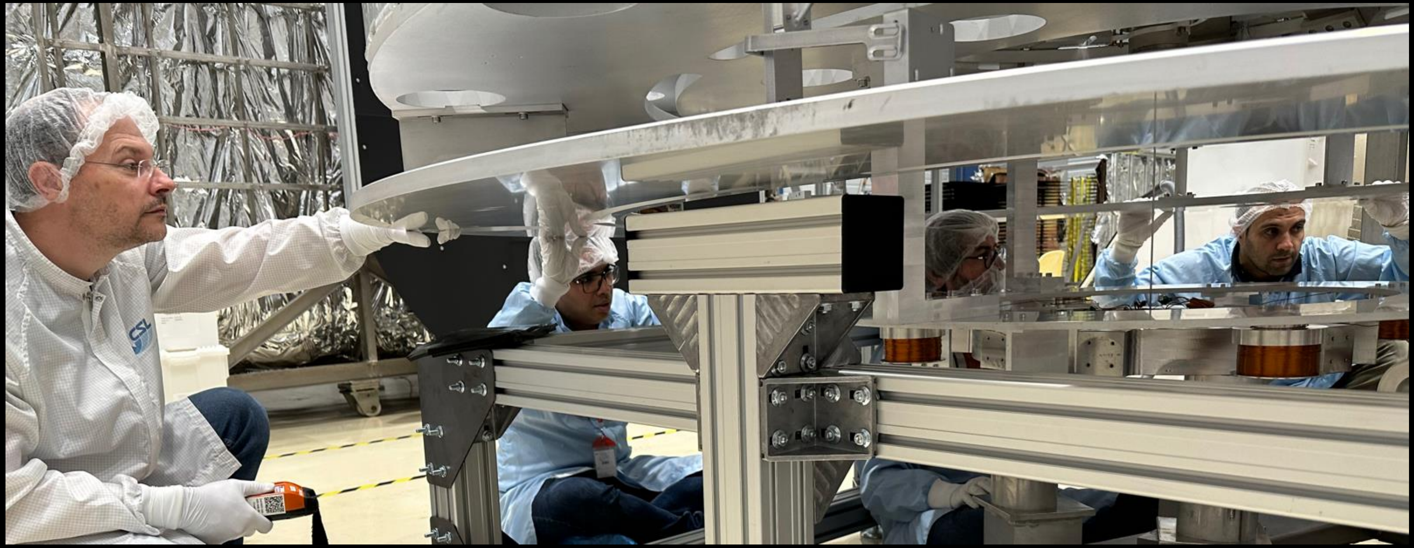
~220m depth: Corals from Carbonia era 335Myr ago

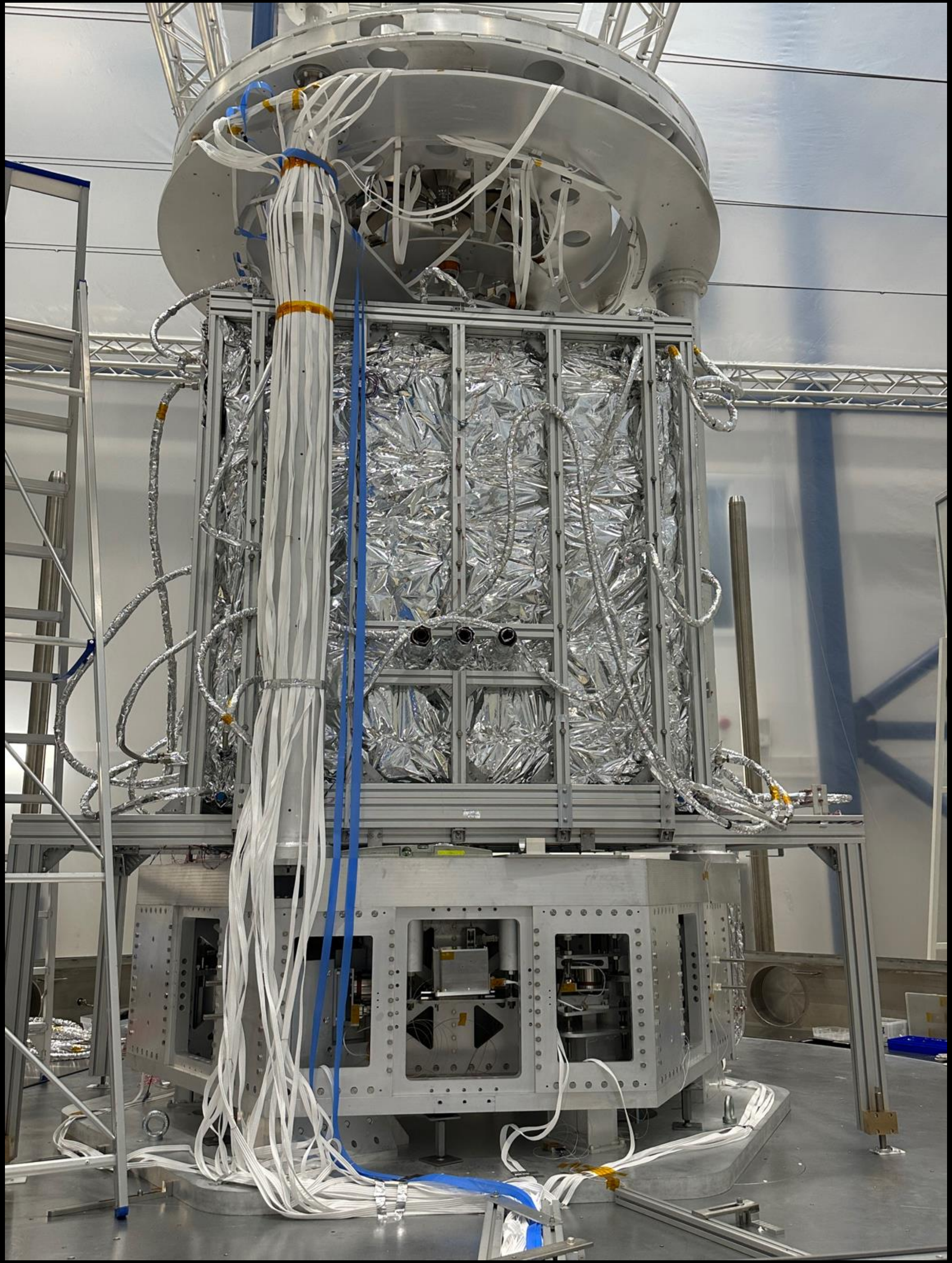
Plaats	Gemeente	Locatie	Periode
Hombourg (WA)	Plombières	Bounder	4 maart-11 april
Sint-Pieters-Voeren (VL)	Voeren	Brabant/Rullen	27 maart-30 mei
Teuven (VL)	Voeren	Kloosterhofstraat	24 mei-4 juli
Gemmenich (WA)	Plombières	Rue de Terstraeten	9 april-7 juni
Obsinnich (VL)	Voeren	Obsinnich nabij spoor	5 juni-19 juli
Aubel (zuid) (WA)	Aubel	Rte de Val Dieu / Bushaye	18 mei-4 juli
Henri-Chapelle (WA)	Welkenraedt	Rue de Verviers	30 mei-3 aug.
Epen (NL)	Gulpen-Wittem	Terrein schutterij	17 juli-31 aug.
Dal van Vijlen (NL)	Vaals	Groeneweg	17 mei-20 aug.
Herbesthal (WA)	Lontzen	Limburgstraat (terrein NMBS)	10 juni-8 aug.
Vijlenerbos (NL)	Vaals	Parkeerplaats	eind aug. / begin sept.
Sint-Pieters-Voeren (VL) (naboring)	Voeren	Brabant	datum staat nog niet vast

WA = Wallonië / VL=Vlaanderen / NL=Nederlands-Limburg


ALTMANN - 2 x 2 to

CRISTAL: Final installation at CSL





$$-\frac12\partial_\nu g^a_\mu\partial_\nu g^a_\mu - g_s f^{abc}\partial_\mu g^a_\nu g^b_\mu g^c_\nu - \frac14 g_s^2 f^{abc}f^{ade}g^b_\mu g^c_\nu g^d_\mu g^e_\nu +$$
$$\frac12 i g_s^2(\bar q^\sigma_i\gamma^\mu q^\sigma_j)g^a_\mu + \bar G^a\partial^2 G^a + g_s f^{abc}\partial_\mu\bar G^a G^b g^c_\mu - \partial_\nu W^+_\mu\partial_\nu W^-_\mu -$$
$$M^2W^+_\mu W^-_\mu - \frac12\partial_\nu Z^0_\mu\partial_\nu Z^0_\mu - \frac{1}{2c_w^2}M^2 Z^0_\mu Z^0_\mu - \frac12\partial_\mu A_\nu\partial_\mu A_\nu - \frac12\partial_\mu H\partial_\mu H -$$
$$\frac12 m_h^2 H^2 - \partial_\mu\phi^+\partial_\mu\phi^- - M^2\phi^+\phi^- - \frac12\partial_\mu\phi^0\partial_\mu\phi^0 - \frac{1}{2c_w^2}M\phi^0\phi^0 - \beta_h[\frac{2M^2}{g^2} +$$
$$\frac{2M}{g}H + \frac12(H^2+\phi^0\phi^0+2\phi^+\phi^-)] + \frac{2M^4}{g^2}\alpha_h - igc_w[\partial_\nu Z^0_\mu(W^+_\mu W^-_\nu -$$
$$W^+_\nu W^-_\mu) - Z^0_\nu(W^+_\mu\partial_\nu W^-_\mu - W^-_\mu\partial_\nu W^+_\mu) + Z^0_\mu(W^+_\nu\partial_\nu W^-_\mu -$$
$$W^-_\nu\partial_\nu W^+_\mu)] - igs_w[\partial_\nu A_\mu(W^+_\mu W^-_\nu - W^+_\nu W^-_\mu) - A_\nu(W^+_\mu\partial_\nu W^-_\mu -$$
$$W^-_\mu\partial_\nu W^+_\mu) + A_\mu(W^+_\nu\partial_\nu W^-_\mu - W^-_\nu\partial_\nu W^+_\mu)] - \frac12 g^2 W^+_\mu W^-_\mu W^+_\nu W^-_\nu +$$
$$\frac12 g^2 W^+_\mu W^-_\nu W^+_\mu W^-_\nu + g^2c_w^2(Z^0_\mu W^+_\mu Z^0_\nu W^-_\nu - Z^0_\mu Z^0_\mu W^+_\nu W^-_\nu) +$$
$$g^2s_w^2(A_\mu W^+_\mu A_\nu W^-_\nu - A_\mu A_\mu W^+_\nu W^-_\nu) + g^2 s_w c_w[A_\mu Z^0_\nu(W^+_\mu W^-_\nu -$$
$$W^+_\nu W^-_\mu) - 2A_\mu Z^0_\mu W^+_\nu W^-_\nu] - g\alpha[H^3 + H\phi^0\phi^0 + 2H\phi^+\phi^-] -$$
$$\frac18 g^2\alpha_h[H^4+(\phi^0)^4+4(\phi^+\phi^-)^2+4(\phi^0)^2\phi^+\phi^-+4H^2\phi^+\phi^-+2(\phi^0)^2H^2] -$$
$$gMW^+_\mu W^-_\mu H - \frac12 g\frac{M}{c_w^2}Z^0_\mu Z^0_\mu H - \frac12 ig[W^+_\mu(\phi^0\partial_\mu\phi^- - \phi^-\partial_\mu\phi^0) -$$
$$W^-_\mu(\phi^0\partial_\mu\phi^+ - \phi^+\partial_\mu\phi^0)] + \frac12 g[W^+_\mu(H\partial_\mu\phi^- - \phi^-\partial_\mu H) - W^-_\mu(H\partial_\mu\phi^+ -$$
$$\phi^+\partial_\mu H)] + \frac12 g\frac{1}{c_w}(Z^0_\mu(H\partial_\mu\phi^0 - \phi^0\partial_\mu H) - ig\frac{s_w^2}{c_w}MZ^0_\mu(W^+_\mu\phi^- - W^-_\mu\phi^+) +$$
$$igs_wMA_\mu(W^+_\mu\phi^- - W^-_\mu\phi^+) - ig\frac{1-2c_w^2}{2c_w}Z^0_\mu(\phi^+\partial_\mu\phi^- - \phi^-\partial_\mu\phi^+) +$$
$$igs_wA_\mu(\phi^+\partial_\mu\phi^- - \phi^-\partial_\mu\phi^+) - \frac14 g^2 W^+_\mu W^-_\mu[H^2+(\phi^0)^2+2\phi^+\phi^-] -$$
$$\frac14 g^2\frac{1}{c_w^2}Z^0_\mu Z^0_\mu[H^2+(\phi^0)^2+2(2s_w^2-1)^2\phi^+\phi^-] - \frac12 g^2\frac{s_w^2}{c_w}Z^0_\mu\phi^0(W^+_\mu\phi^- +$$
$$W^-_\mu\phi^+) - \frac12 ig^2\frac{s_w^2}{c_w}Z^0_\mu H(W^+_\mu\phi^- - W^-_\mu\phi^+) + \frac12 g^2 s_w A_\mu\phi^0(W^+_\mu\phi^- +$$
$$W^-_\mu\phi^+) + \frac12 ig^2 s_w A_\mu H(W^+_\mu\phi^- - W^-_\mu\phi^+) - g^2\frac{s_w}{c_w}(2c_w^2-1)Z^0_\mu A_\mu\phi^+\phi^- -$$
$$g^1 s_w^2 A_\mu A_\mu\phi^+\phi^- - \bar e^\lambda(\gamma\partial + m_e^\lambda)e^\lambda - \bar\nu^\lambda\gamma\partial\nu^\lambda - \bar u^\lambda_j(\gamma\partial + m_u^\lambda)u^\lambda_j -$$
$$\bar d^\lambda_j(\gamma\partial + m_d^\lambda)d^\lambda_j + igs_wA_\mu[-(\bar e^\lambda\gamma^\mu e^\lambda) + \frac23(\bar u^\lambda_j\gamma^\mu u^\lambda_j) - \frac13(\bar d^\lambda_j\gamma^\mu d^\lambda_j)] +$$
$$\frac{ig}{4c_w}Z^0_\mu[(\bar\nu^\lambda\gamma^\mu(1+\gamma^5)\nu^\lambda) + (\bar e^\lambda\gamma^\mu(4s_w^2-1-\gamma^5)e^\lambda) + (\bar u^\lambda_j\gamma^\mu(\frac43 s_w^2 -$$
$$1-\gamma^5)u^\lambda_j) + (\bar d^\lambda_j\gamma^\mu(1-\frac83 s_w^2-\gamma^5)d^\lambda_j)] + \frac{ig}{2\sqrt2}W^+_\mu[(\bar\nu^\lambda\gamma^\mu(1+\gamma^5)e^\lambda) +$$
$$(\bar u^\lambda_j\gamma^\mu(1+\gamma^5)C_{\lambda\kappa}d^\kappa_j)] + \frac{ig}{2\sqrt2}W^-_\mu[(\bar e^\lambda\gamma^\mu(1+\gamma^5)\nu^\lambda) + (\bar d^\kappa_j C^\dagger_{\lambda\kappa}\gamma^\mu(1+$$
$$\gamma^5)u^\lambda_j)] + \frac{ig}{2\sqrt2}\frac{m_e^\lambda}{M}[-\phi^+(\bar\nu^\lambda(1-\gamma^5)e^\lambda) + \phi^-(\bar e^\lambda(1+\gamma^5)\nu^\lambda)] -$$
$$\frac{g}{2}\frac{m_e^\lambda}{M}[H(\bar e^\lambda e^\lambda) + i\phi^0(\bar e^\lambda\gamma^5 e^\lambda)] + \frac{ig}{2M\sqrt2}\phi^+[-m_d^\kappa(\bar u^\lambda_j C_{\lambda\kappa}(1-\gamma^5)d^\kappa_j) +$$
$$m_u^\lambda(\bar u^\lambda_j C_{\lambda\kappa}(1+\gamma^5)d^\kappa_j] + \frac{ig}{2M\sqrt2}\phi^-[m_d^\lambda(\bar d^\lambda_j C^\dagger_{\lambda\kappa}(1+\gamma^5)u^\kappa_j) - m_u^\kappa(\bar d^\lambda_j C^\dagger_{\lambda\kappa}(1-$$
$$\gamma^5)u^\kappa_j] - \frac g2\frac{m_u^\lambda}{M}H(\bar u^\lambda_j u^\lambda_j) - \frac g2\frac{m_d^\lambda}{M}H(\bar d^\lambda_j d^\lambda_j) + \frac{ig}{2}\frac{m_u^\lambda}{M}\phi^0(\bar u^\lambda_j\gamma^5 u^\lambda_j) -$$
$$\frac{ig}{2}\frac{m_d^\lambda}{M}\phi^0(\bar d^\lambda_j\gamma^5 d^\lambda_j) + \bar X^+(\partial^2 - M^2)X^+ + \bar X^-(\partial^2-M^2)X^- + \bar X^0(\partial^2 -$$
$$\frac{M^2}{c_w^2})X^0 + \bar Y\partial^2 Y + igc_wW^+_\mu(\partial_\mu\bar X^0 X^- - \partial_\mu\bar X^+ X^0) + igs_wW^+_\mu(\partial_\mu\bar Y X^- -$$
$$\partial_\mu\bar X^+ Y) + igc_wW^-_\mu(\partial_\mu\bar X^- X^0 - \partial_\mu\bar X^0 X^+) + igs_wW^-_\mu(\partial_\mu\bar X^- Y -$$
$$\partial_\mu\bar Y X^+) + igc_wZ^0_\mu(\partial_\mu\bar X^+ X^+ - \partial_\mu\bar X^- X^-) + igs_wA_\mu(\partial_\mu\bar X^+ X^+ -$$


ANGELVM GALLIE CVSTODEM CHRISTVS PATRIE FATA DOCET
18 17 16 15 14 13 12 11 10


Gustave Eiffel: Observatoire de Nice Côte D'Azur; 1880's