JINR Long-term Strategy in Particle Physics and AstroPhysics

Dmitry V.Naumov

Feb.04 2020
PAC-52 for PP

Preface

- 2024-2030 = Mid-term (MT)
- 2031-2037 = Long-term (LT)

} Terminology used

- Particle Physics (PP) in my talk= PP-NICA {Covered by B. Sharkov}

- The reported Strategy
  - corresponds to two chapters (six and seven) in the entire JINR draft.
  - Is a consolidated effort of DLNP and VBLHEP researchers.
  - Yet, it is not equivalent to MT and LT peer-reviewed seven-years plans.
  - Funds requested may change

Why any further development of PP?

- The Standard Model (SM) is firmly established both theoretically and experimentally with 55 Nobel Prizes (NP) for it so far.
- All PP is in exceptionally good or in very good agreement with predictions of the SM.
- «There is nothing new to be discovered in physics now. All that remains is more and more precise measurement» Attributed to Lord Kelvin (around 1900).

He never said anything like that

- a paraphrase of Albert A.Machelson, who in 1894 stated: «... it seems probable that most of the grand underlying principles have been firmly established ... the future truths of physical science are to be looked for in the sixth place of decimals.»

Why any further development of PP?

Shortages of the SM

- Baryon asymmetry of the Universe
- Lack of dark matter particle candidate
- Cannot incorporate GR or account for accelerated expansion of the Universe (hypothetic dark energy)

All issues driven by Cosmology

- SM cannot explain mass hierarchy of quarks and leptons and their weak mixing

Beyond SM (BSM) is wanted

Three main directions to search for BSM

- Identify phenomena diverging from the SM expectations at high energies.
- Look for specific predictions of new models.
- Increase the measurement precision to test further the SM predictions.

{ Understanding of the Universe evolution could give a deeper insight into PP }

Understanding of the Universe evolution

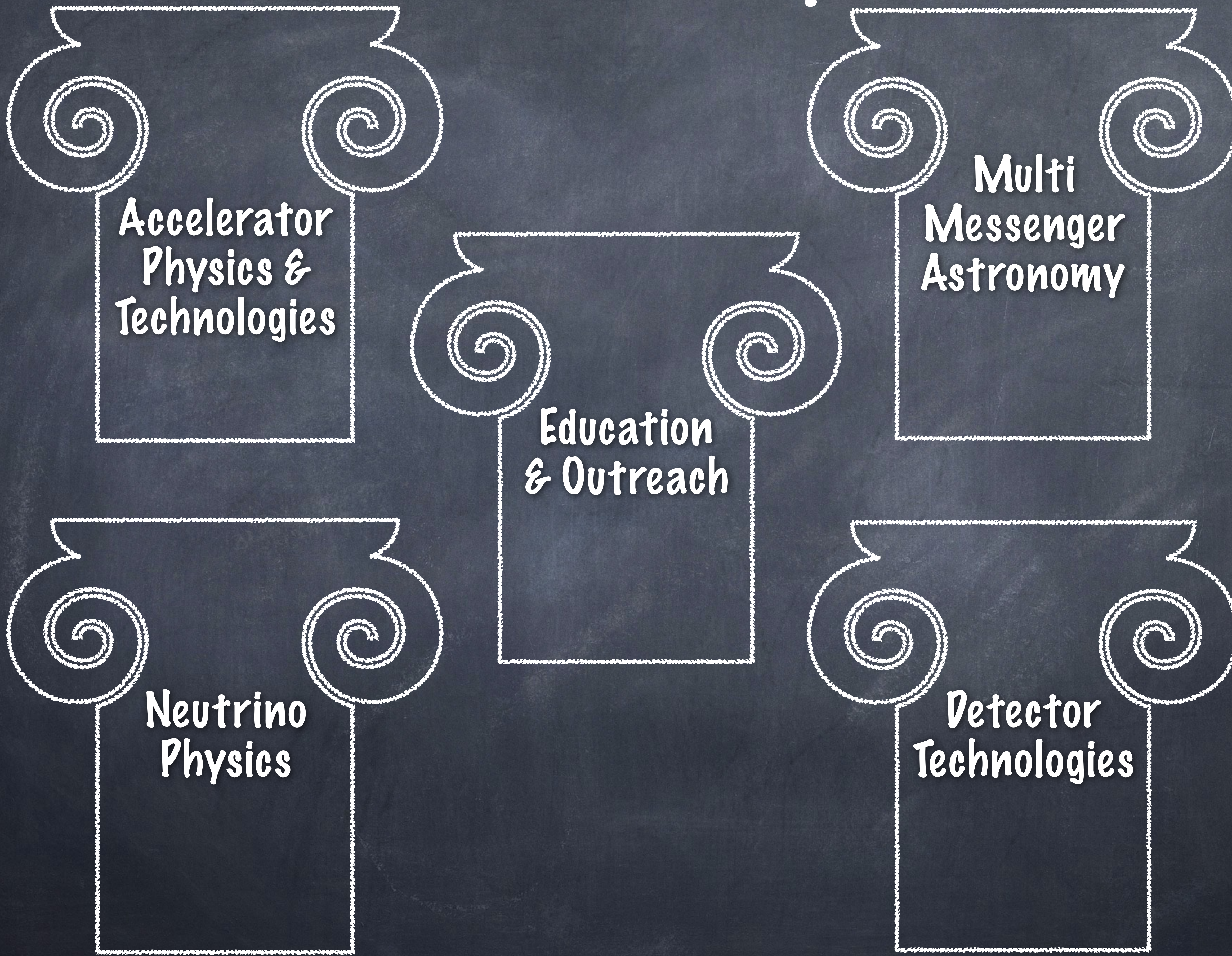
- Search for sources of ultra-high energy photons and neutrinos in the cosmic radiation.
- Multi-Messenger Astronomy.
- Relic neutrino observation.
- Diffuse neutrino observation.
- Gravitational waves observation.

The MT & LT Strategy should be an appropriate balance between these directions based on sensible selection principles

Selection Principles

- The projects should have great discovery potential
- International context: The program should be attractive to the worldwide community and to the JINR Member States.
- Growing expertise at JINR: maintain and develop critical expertise and guarantee an unceasing stream of scientific results.
- Budget: fit into a realistic budget of the JINR
- JINR's role: JINR's leadership is required.

JINR PP & AP five pillars



Accelerator Physics & Technologies

- ATLAS
- CMS
- ALICE
- Future Colliders
- NICA

Proposed Research

- Studies of the proton structure, hadronization, QCD coupling and of hadron's spectra.
- Tests of the Standard Model at the LHC energies.
- Searches for Supersymmetry.
- Searches for new heavy particles and new interactions.
- Precision measurements of the properties of elementary particles and heavy baryons.
- Searches for signals predicted by scenarios of low-energy multidimensional gravity, extended gauge models, models with dark matter candidates, and scenarios with fermion flavor violation.

ATLAS

- Phase I **0.1 MCHF**
  - 32 quadruplets for New Small Wheel
  - LAr CMOS electronics, tests
  - Tile calorimeter: commissioning, tests
- Phase II **3.6 MCHF**
  - TDAQ
  - LAr: Preamp-Shaper, Optical Link, FEB2, Front-end Power Distribution System, LAr signal Processor
  - Tile calorimeter: LV services
  - MUON: RPC chambers, FE electronics, Gas System, Power System
  - HGTD

CMS

- Upgrade in the framework of the CMS Upgrade Project during the long technical stop LS3 (2024-2026).
- R&D for the upgrade of the CMS detector system planned for the LS4 (2030) and the LS5 (2034).
- Maintenance of the CMS detector system within the JINR responsibilities (endcap muon and hadron calorimetry systems).
- Upgrade of the First Forward muon station (ME1/1) and other ME2,3,4/1 muon stations.
- Participation in the construction of new High Granularity Hadron Calorimeters (HGCAL).
- Procurement of various components of the HGCAL, etc.

Future Colliders

- Accelerator technology R&D based on precision laser inclinometer developed in JINR.

- Development (and later implementation) of the experimental program of the future colliders in the following fields: precision measurement of the Higgs boso properties; observation of the triple-Higgs vertex; top quark physics; physics of two-photon collisions; direct searches for the new phenomena at high energies.

- Participation in the GRID computing infrastructure for t decentralized data processing.

- Development of novel particle detectors, in particular compact forward calorimeter developed in the FCAL collaboration, pixel detectors based on GaAs sensors and MPGD detectors (Micromegas, RPC, etc) which are currently developed in JINR.

- Creation of the theoretical program for complete one-loo calculations of the electron-positron annihilation into different final states including the polarization effects.

Neutrino Physics & AstroPhysics

- Baikal-GVD
- TAIGA
- Gravitational Wave Detector

} MM Astronomy

- JUNO
- NOvA
- DUNE, HK

} MH, CP

- Dark-Side-20k
- ARGO
- Edelweiss

} Dark Matter

- DANSS
- NuGEN, RICOCHET
- GEMMA-III

} Mag. Moment, Coherent, Sterile

- GERDA
- SuperNEMO
- LEGEND-1000

} $0\nu\beta\beta$

- KATRIN Mass Meas.

Accelerator Physics & Technologies. MT

	24	25	26	27	28	29	30	Main physics goal Budget, USD
ATLAS & CMS	LS3 upgrade			RUN4			LS4	Beyond the SM, precision EW and QCD 3.4M & 2.8M
				LS4, LS5 R&D				
Future Colliders								Beyond the SM, precision EW and QCD 3.4M & 2.8M
NICA-SPD								TMD PDF, 21M

R&D	Construction& Commissioning	Data taking	STOP	Decision Point

Accelerator Physics & Technologies. LT

	31	32	33	34	35	36	37	Main physics goal Budget, USD
ATLAS & CMS	RUN5				LS5	RUN6		Beyond the SM, precision EW and QCD 3.4M & 2.8M
	LS5 R&D							
Future Colliders								Beyond the SM, precision EW and QCD 3.4M & 2.8M
NICA-SPD								TMD PDF, 21M

R&D	Construction& Commissioning	Data taking	STOP	Decision Point

Neutrino Physics & AstroPhysics. MT

	24	25	26	27	28	29	30	Main physics goal Budget, USD
Baikal-GVD	Phase II up to 1.2 km3				Phase III			UHE Neutrino sources, 45M
	R&D for Phase III							
JUNO								Neutrino mass ordering, precision lepton mixing, SN, proton decay 7.5M
NOvA			STOP data taking. Analyses continue					Neutrino mass ordering, CP-violation in the lepton sector 10M
DUNE								
HK								

R&D	Construction& Commissioning	Data taking	STOP	Decision Point

	24	25	26	27	28	29	30	Main physics goal Budget, USD
DarkSide-20k	DarkSide-20k data taking							Dark Matter, 0.7M
ARGO								
TAIGA	TAIGA IACT+HiScore data taking One IACT gamma-telescope/year							High energy cosmic ray and gamma spectrum above 10^{15} eV 1.8M
Edelweiss	R&D for new detector and cryogenic system				Next phase of bolometric search in LSM			Dark Matter,
GERDA	R&D Legend-1000		LEGEND-1000					$0\nu\beta\beta$
SuperNEMO								$0\nu\beta\beta$
VIRGO								GW, 1.4M

R&D	Construction&	Data taking	STOP	Decision Point

Neutrino Physics & AstroPhysics. LT

	31	32	33	34	35	36	37	Main physics goal Budget, USD
Baikal-GVD	Phase III up to 2.4 km3							UHE Neutrino sources, 45M
JUNO								Neutrino mass ordering, precision lepton mixing, SN, proton decay 6.4M
DUNE HK								Neutrino mass ordering, CP-violation in the lepton sector 1.5M

R&D	Construction& Commissioning	Data taking	STOP	Decision Point

	31	32	33	34	35	36	37	Main physics goal Budget, USD
ARGO								Dark Matter, 0.7M
TAIGA	TAIGA IACT+HiScore data taking							High energy cosmic ray and gamma spectrum above 10^{15} eV 1.8M
	One IACT gamma-telescope/year							
Edelweiss								Dark Matter,
LEGEND-1000								$0\nu\beta\beta$
SuperNEMO								
VIRGO								GW, 35M
EINSTEIN								

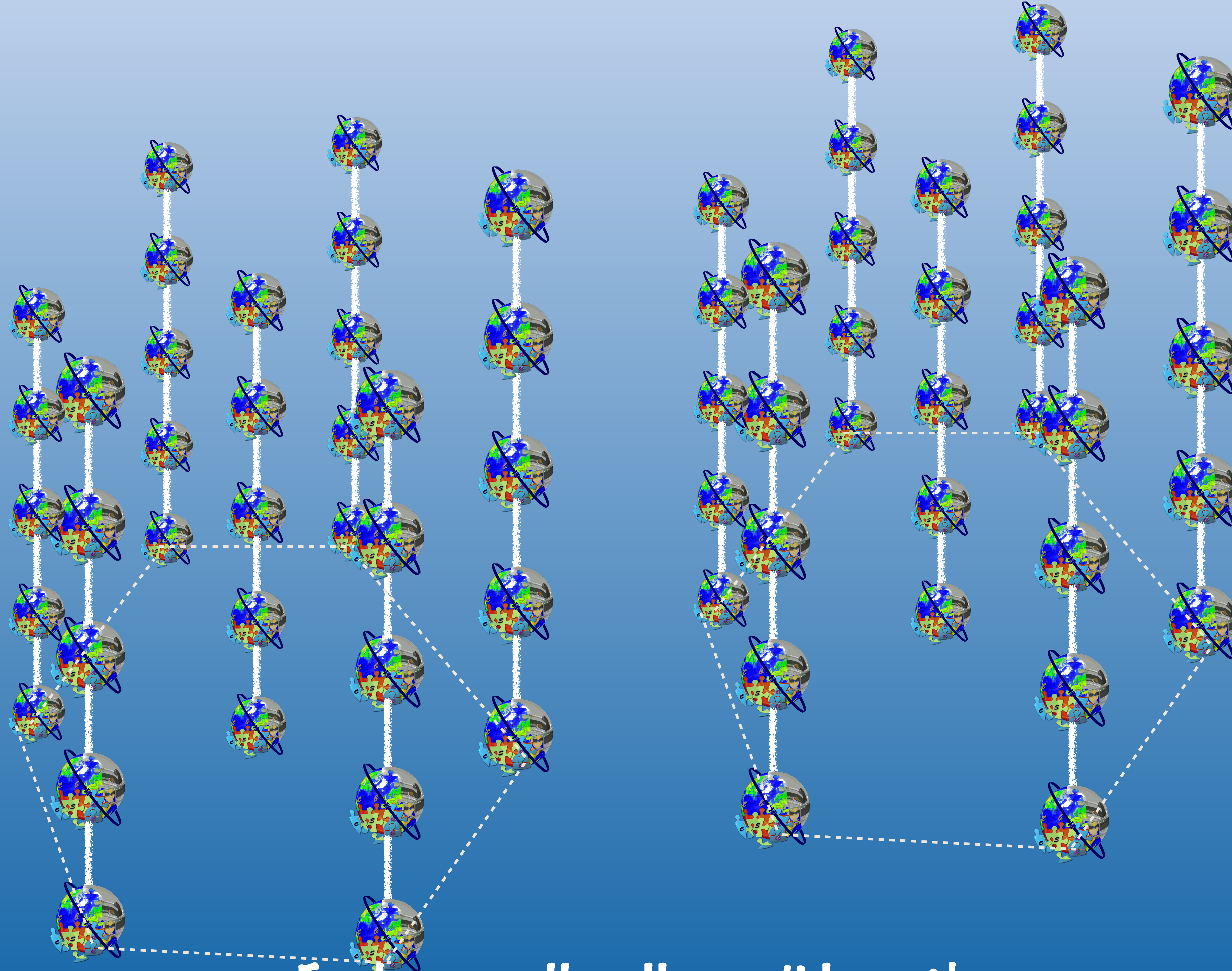
R&D	Construction&	Data taking	STOP	Decision Point

Dark energy, dark matter - what rules them? What binds them?

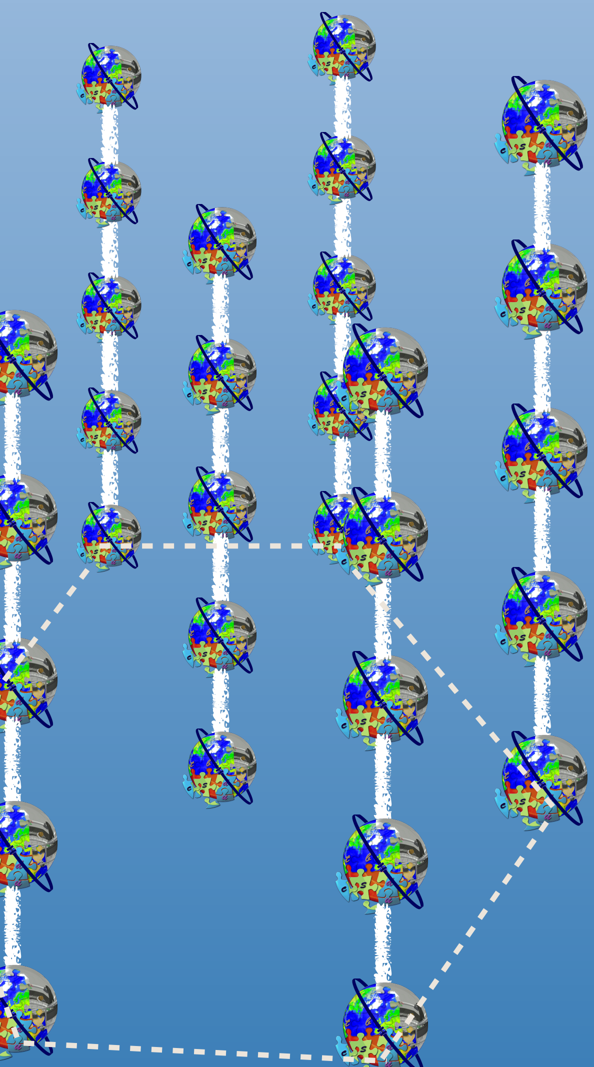
«One Ring to rule them all, One Ring to find them,
One Ring to bring them all and in the darkness bind them»

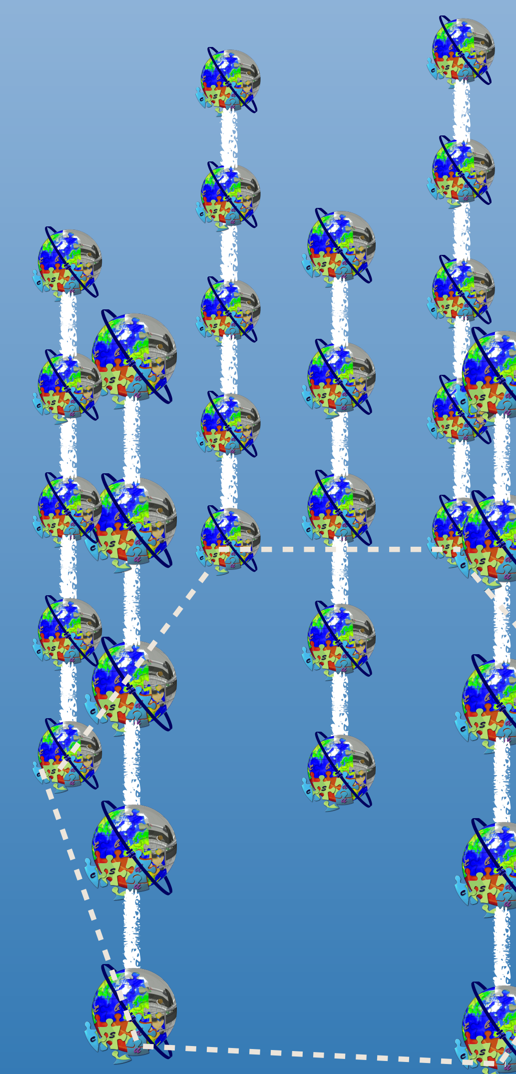
J.R.R. Tolkien

Our Strategy is to explore different paths to find the true root

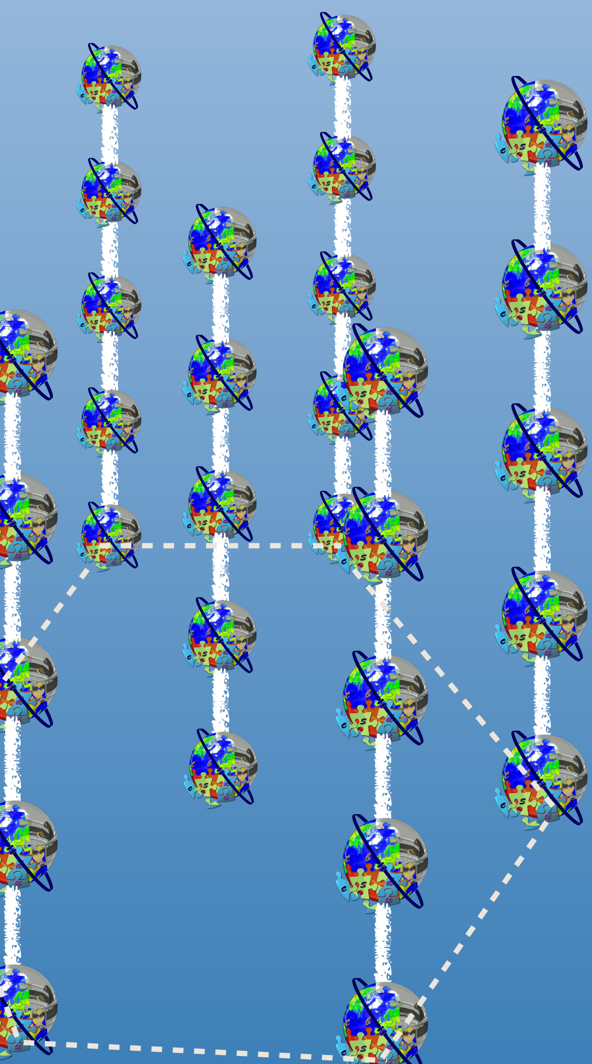


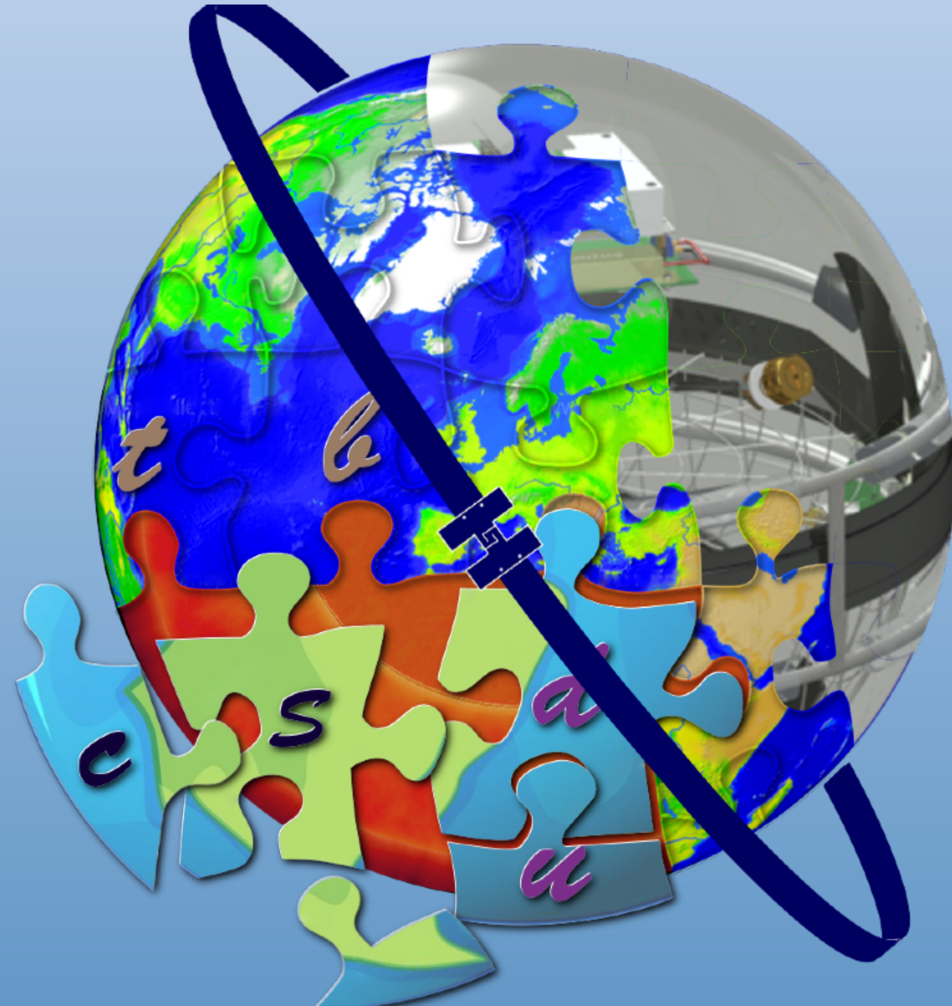
Explore really all possible paths



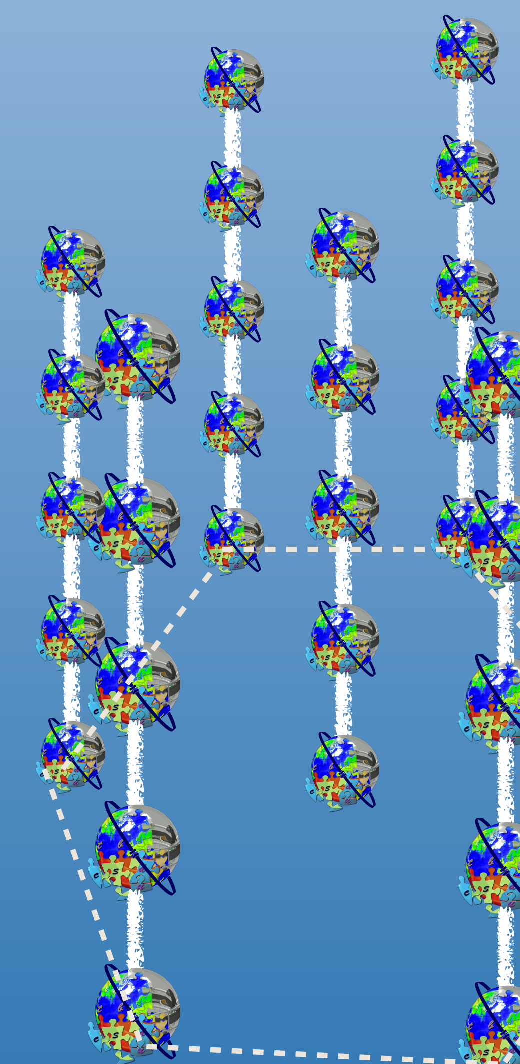


Explore really all possible paths





Colliders, Detectors,
Multi-Messengers...
Many paths to
The One Rina



Explore really all possible paths

Expertise to develop

- Application Specific Integrated Circuit (ASIC)
- FPGA Electronics
- Robotics
- Quantum computing
- General Relativity and gravitational interferometry
- Project management
- Follow modern technologies

Gravitational interferometer in Dubna

Additional Materials

Accelerator Physics and Technologies
ATLAS and CMS

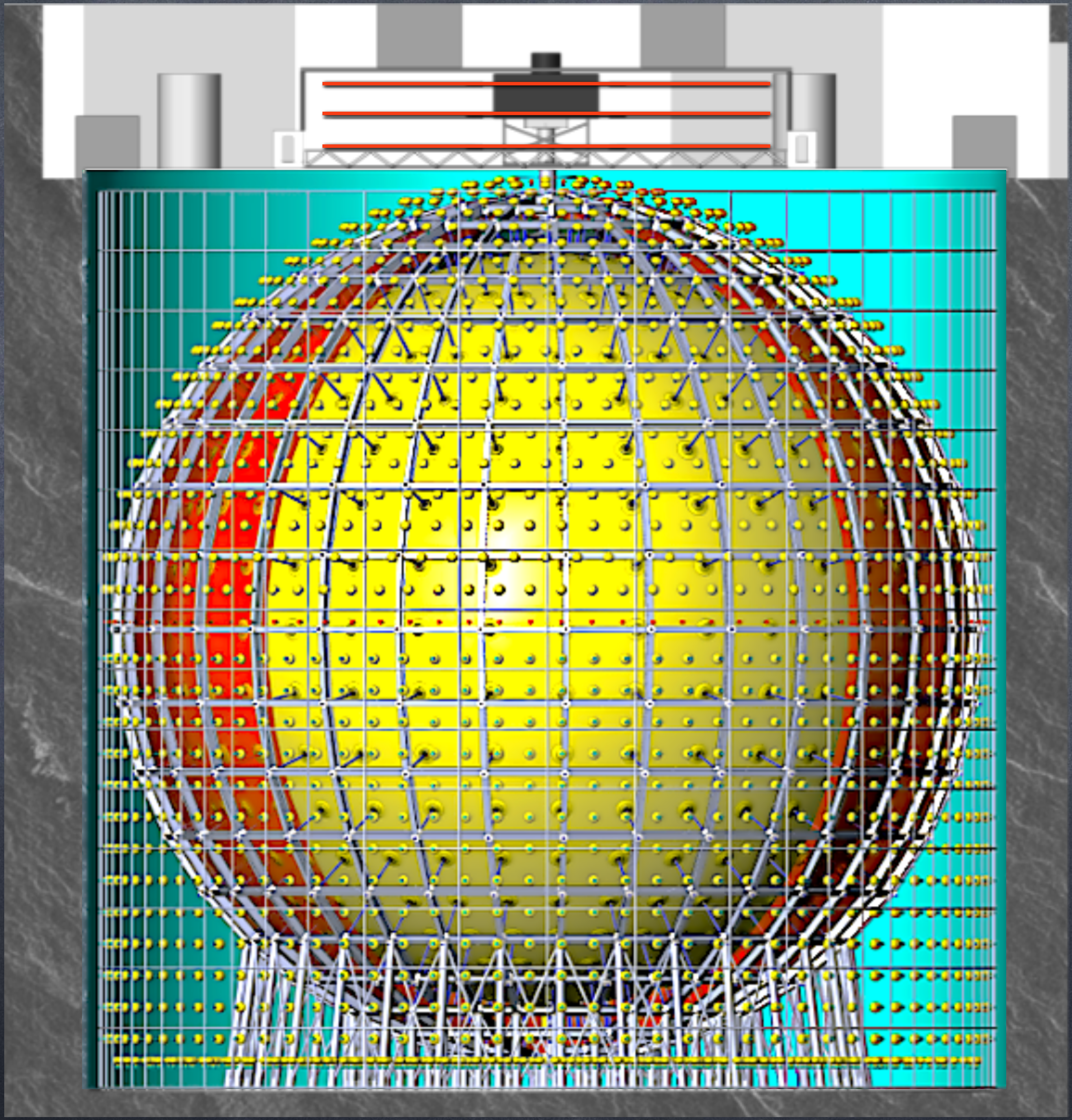
MT

- Studies of the proton structure, hadronization, QCD coupling and of hadron's spectra.
- Tests of the Standard Model at the LHC energies.
- Searches for Supersymmetry.
- Searches for new heavy particles and new interactions.
- Precision measurements of the properties of elementary particles and heavy baryons.
- Searches for signals predicted by scenarios of low-energy multidimensional gravity, extended gauge models, models with dark matter candidates, and scenarios with fermion flavor violation.

BAIKAL GVD

- 3D Array of photo-sensors
  - Now: 0.25 km3
  - Phase I: 0.4 km3 (by 2021)
  - Phase II: 1.2 km3 (by 2027)
  - Phase III: 2.3 km3 (by 2037)
- Flagship Experiment of JINR
  - Hardware
  - Software
  - Everything
- JINR & INR are leading institutes
- Aim to identify sources

JUNO



JINR is THE Major Collaborator in JUNO

- Powering JUNO. **2 M$**

High Voltage Units for
20k LPMTs and 18k sPMTs: design, production, tests, calib, installation

- Muon Veto. **1.25 M$**

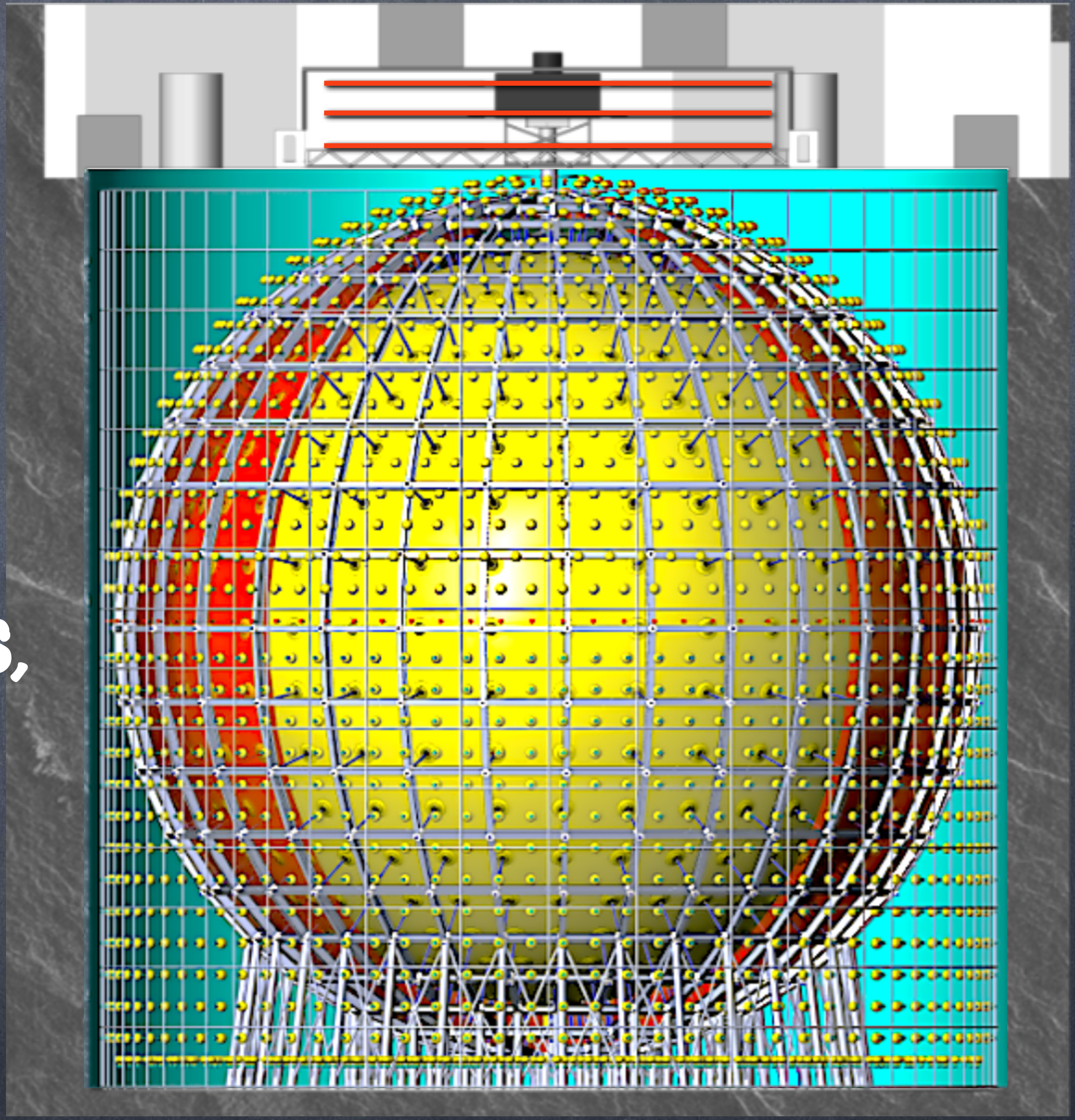
design, production, tests, calibrations, installation

- PMT tests. **0.1 M$**

design, production, tests, methods, calibrations, installation

- TAO (near det). **1 M$**

SiPM purchase, design, tests, methods, calibrations



Total: **4.35M$**

With JUNO before 2030

- Mass Ordering determination (3-4σ)
- Lepton mixing better than in the quark sector
- Largest dataset of geo-neutrinos
- Solar neutrino
- If lucky:
    - SuperNOVA with 10000 events
    - Proton decay
    - Diffused SN neutrino
    - And much more

- DarkSide
- Edelweiss

$\Bigg\}$ Dark matter

- NOvA: MO, CP-violation
- Kalinin PP: magnetic moment, coherent, sterile *
- TAIGA: 100 TeV gamma *
- GERDA, SuperNEMO: $0\nu\beta\beta$

*= home experiment

Long-term plan after 2030

Long-term plan after 2030

- NOvA → DUNE : Scintillation light RO in LAr TPC (now)
  Or
  → HyperK : Yet to be determined
- BAIKAL GVD
- JUNO
- ATLAS High Luminosity
- Gravitational waves interferometers: LIGO/VIRGO/Einstein or interferometer @DUBNA