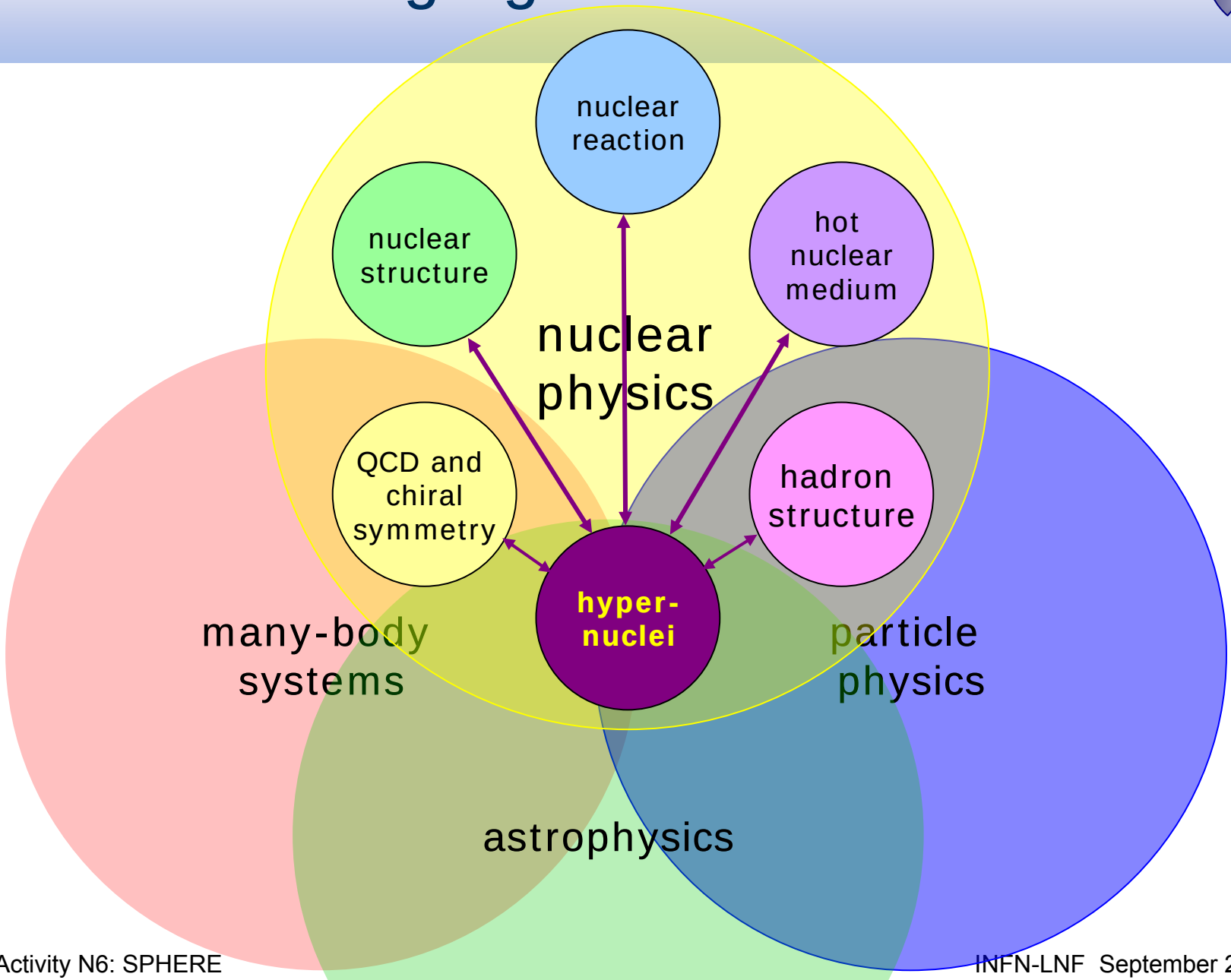
Proposal for a Network Activity N6

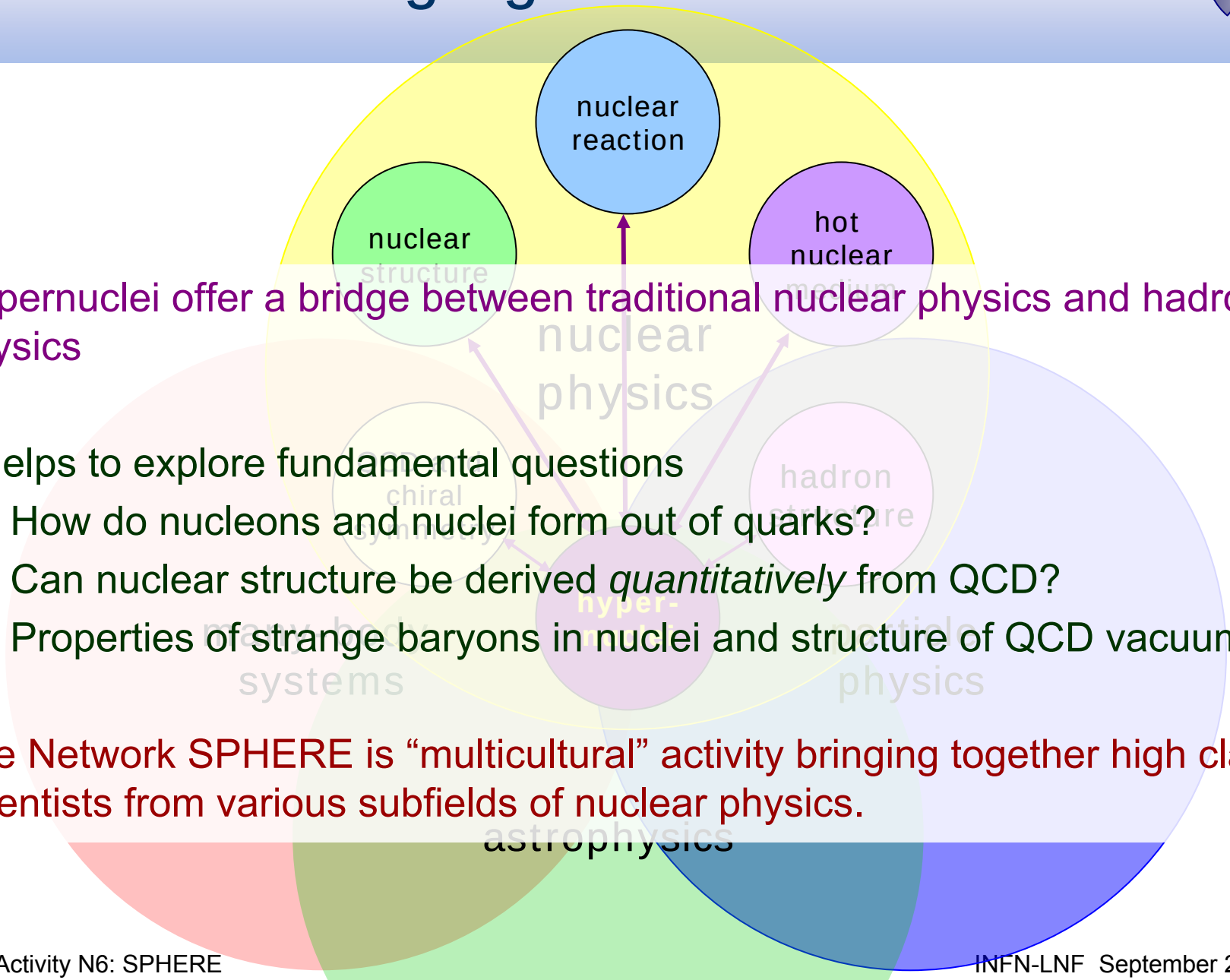
- Hypernuclei
  - Physics objectives
  - Future in Europe
- SPHERE
  - Participants
  - Tasks
  - Deliverables
  - Finances

Strange
Particles in
Hadronic
Environment
Research in
Europe

Nature of emerging structures



Nature of emerging structures

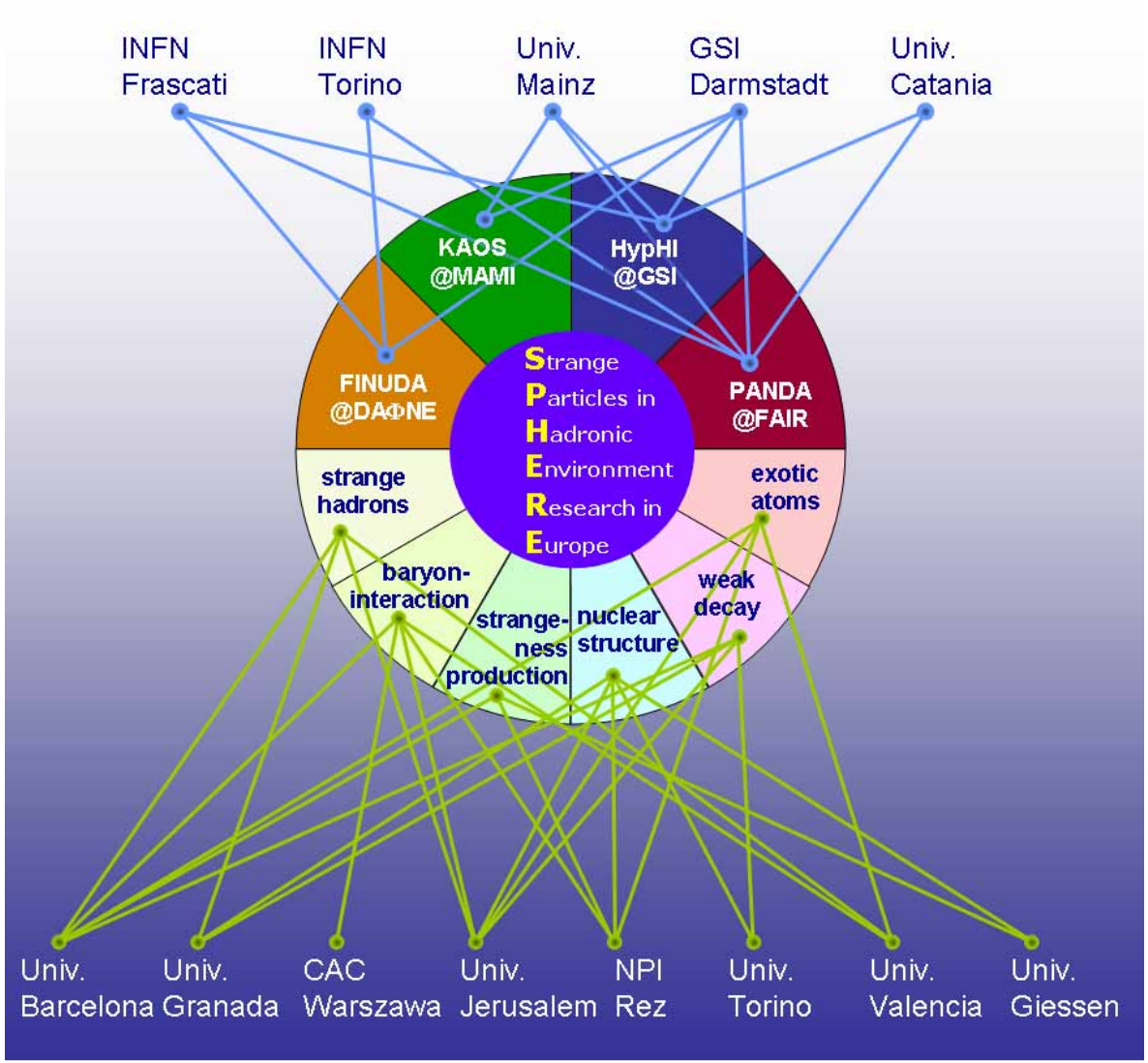


- Hypernuclei offer a bridge between traditional nuclear physics and hadron physics
- It helps to explore fundamental questions
  - How do nucleons and nuclei form out of quarks?
  - Can nuclear structure be derived *quantitatively* from QCD?
  - Properties of strange baryons in nuclei and structure of QCD vacuum?
- The Network SPHERE is “multicultural” activity bringing together high class scientists from various subfields of nuclear physics.

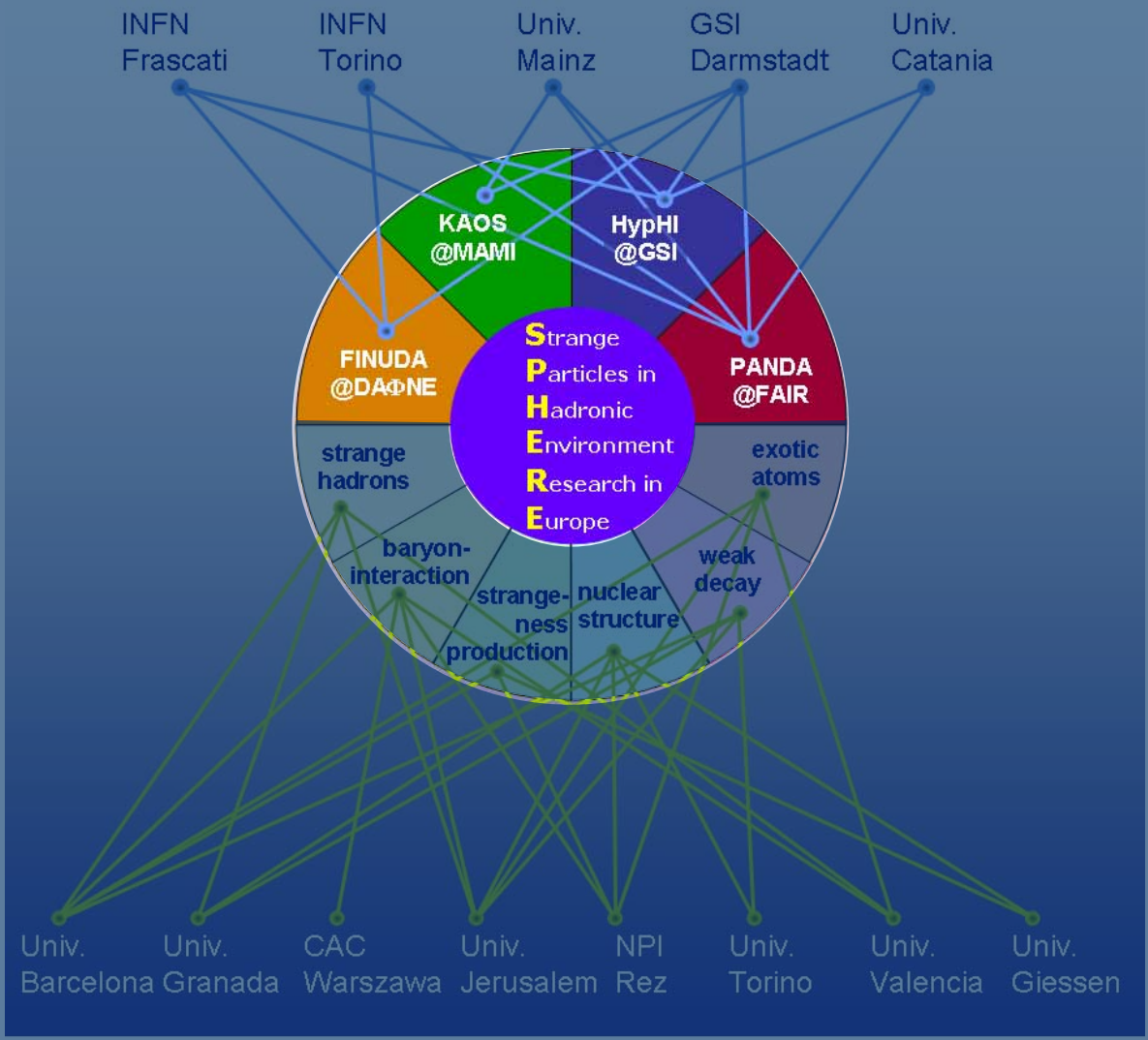
Physics of Hypernuclei

- the (low energy) Y-N interactions
  - the role played by quark degrees of freedom, flavour symmetry and chiral models in nuclear and hypernuclear phenomena
  - the nuclear structure, e.g. the origin of the spin-orbit interaction
  - relevance for stellar systems
- weak decays
  - baryon-baryon weak interactions
  - asymmetries of w.d. and the role of two-meson/σ exchange and direct quark mechanisms
  - role of FSI and nuclear structure
- $\Lambda\Lambda$-hypernuclei
  - Y-Y interaction
  - $\Lambda\Lambda$K vertex
- nuclear medium properties of hyperons (Λ, Σ, Ξ)

Common interest within SPHERE



Backbone of SPHERE



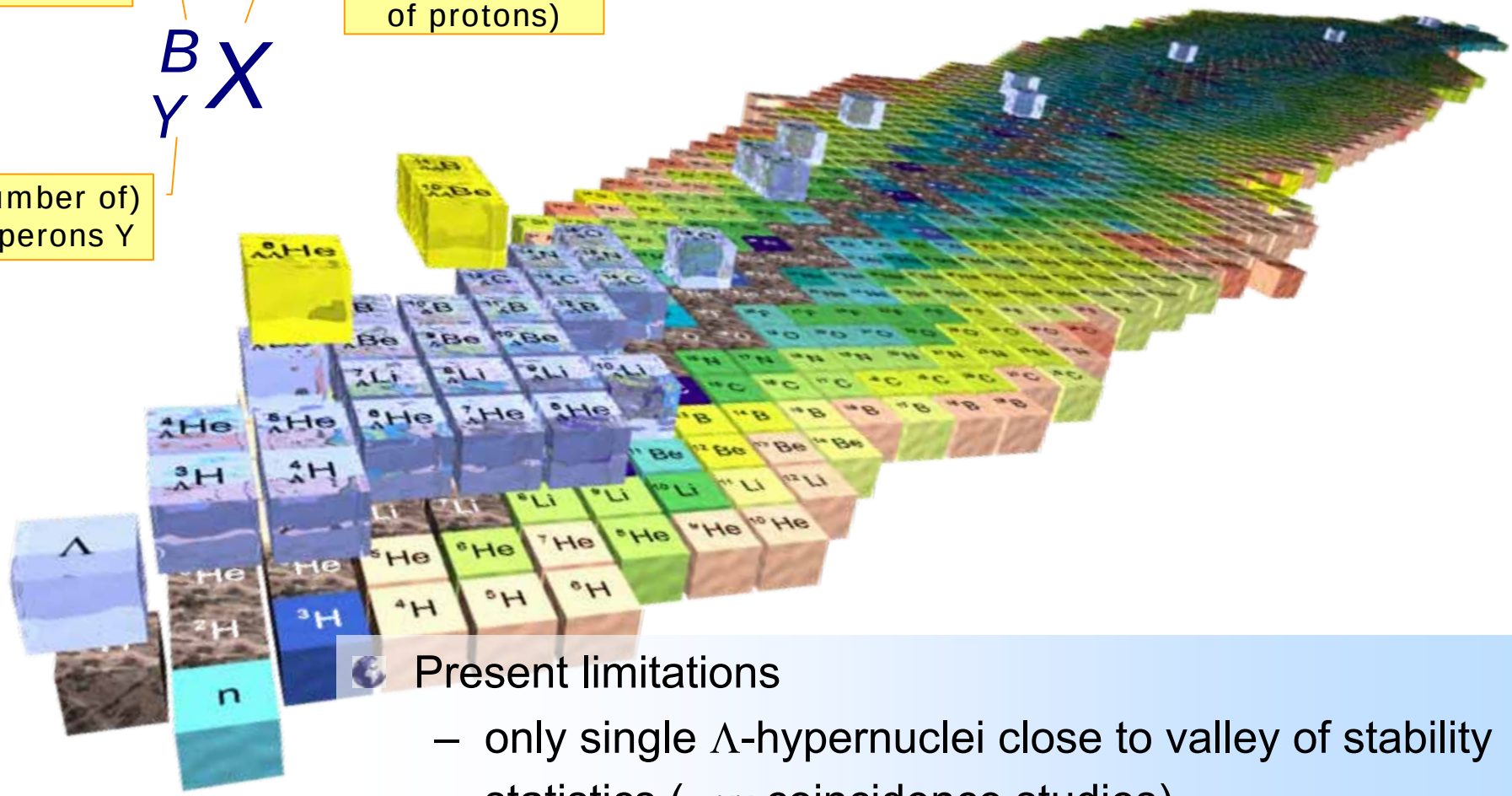
Hypernuclei – Present Situation

number of baryons N+Z+Y

element = total charge (not number of protons)

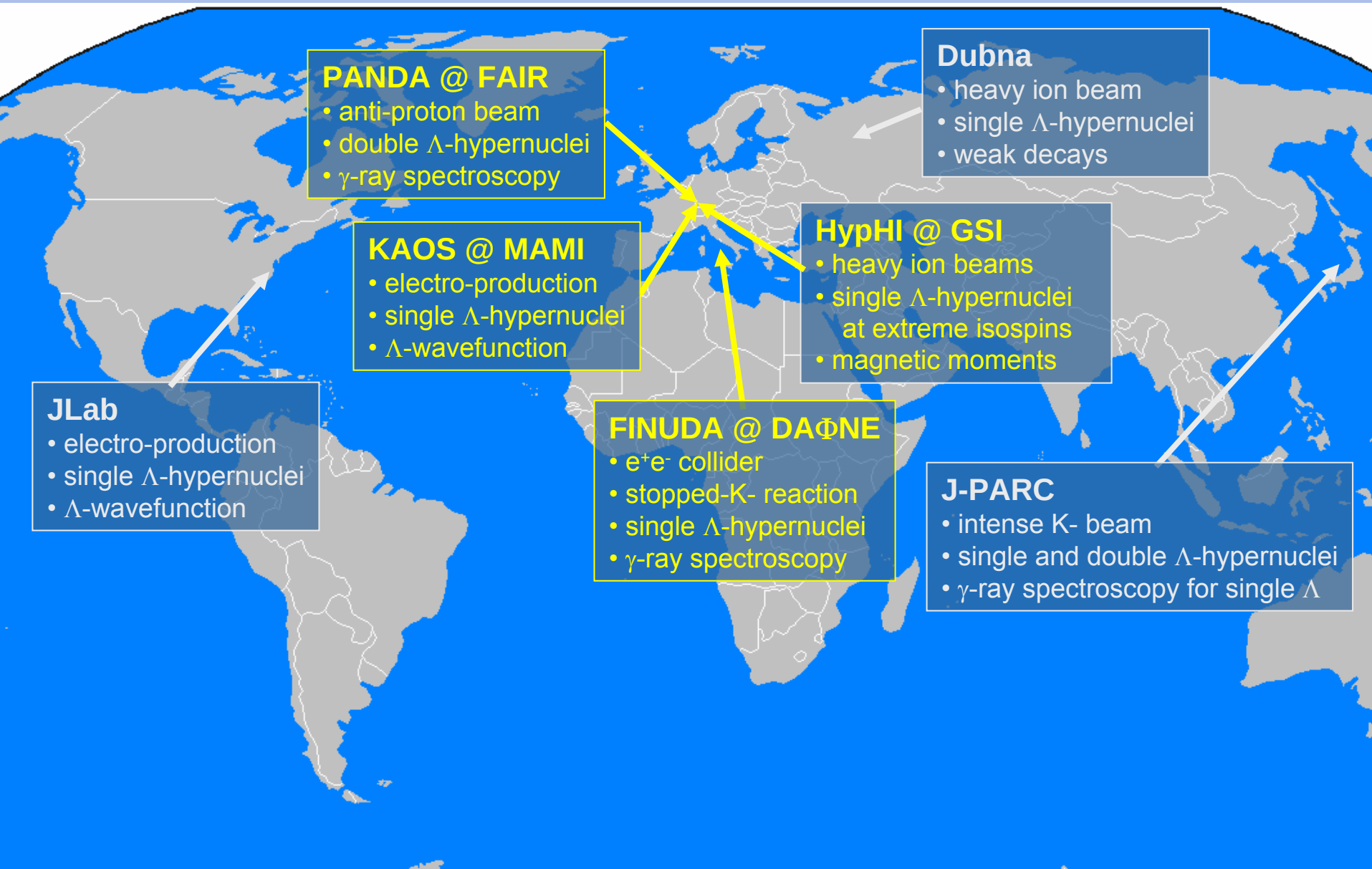
$${}^{B}_{Y}X$$

(number of) hyperons Y



- Present limitations
  - only single Λ-hypernuclei close to valley of stability
  - statistics (→γγ coincidence studies)
  - only very few ΛΛ-hypernuclei *events*

International Hypernuclear Network



International Hypernuclear Network

PANDA @ FAIR
- anti-proton beam
- clei

MI
- tion
- nuclei
- n

Dubna
- heavy ion beam
- single Λ-hypernuclei
- weak decays

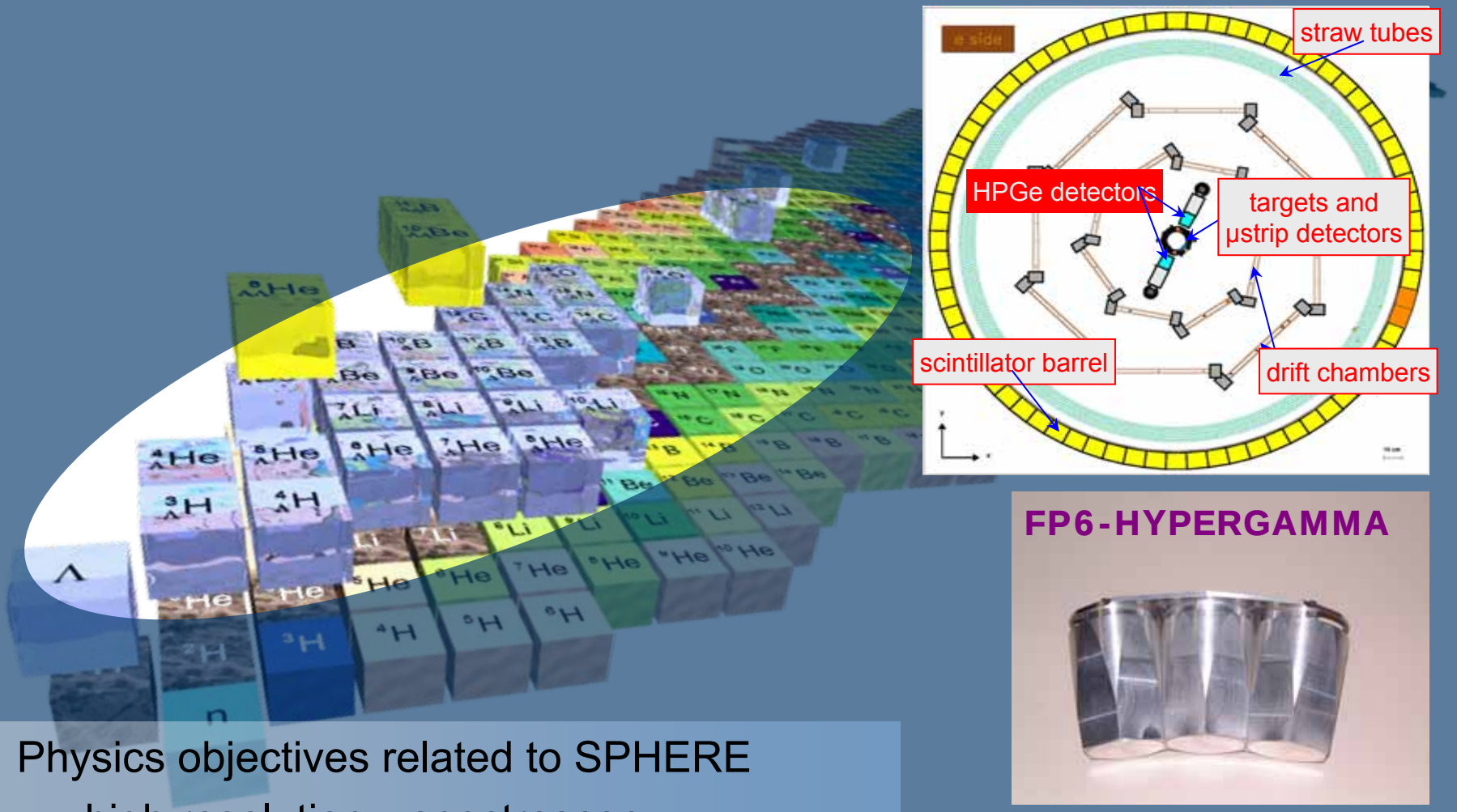
HypHI @ GSI
- heavy ion beams
- single Λ-hypernuclei at extreme isospins
- magnetic moments

FINUDA @ DAΦNE
- e^+e^- collider
- stopped-K- reaction
- single Λ-hypernuclei
- γ-ray spectroscopy

J-PARC
- intense K^- beam
- single and double Λ-hypernuclei
- γ-ray spectroscopy for single Λ

It is presently *THE* hypernuclear factory in Europe

FINUDA @ DAΦNE

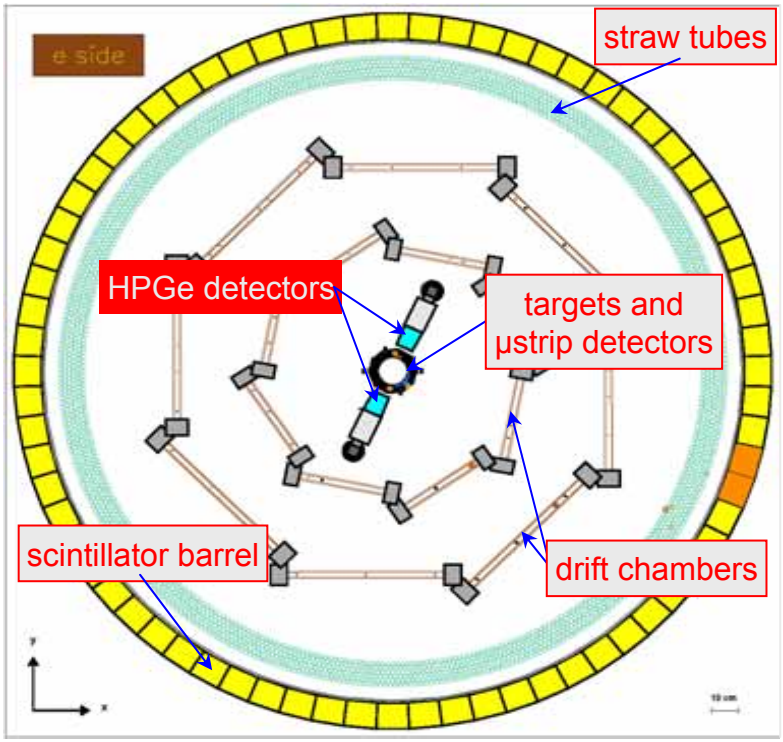


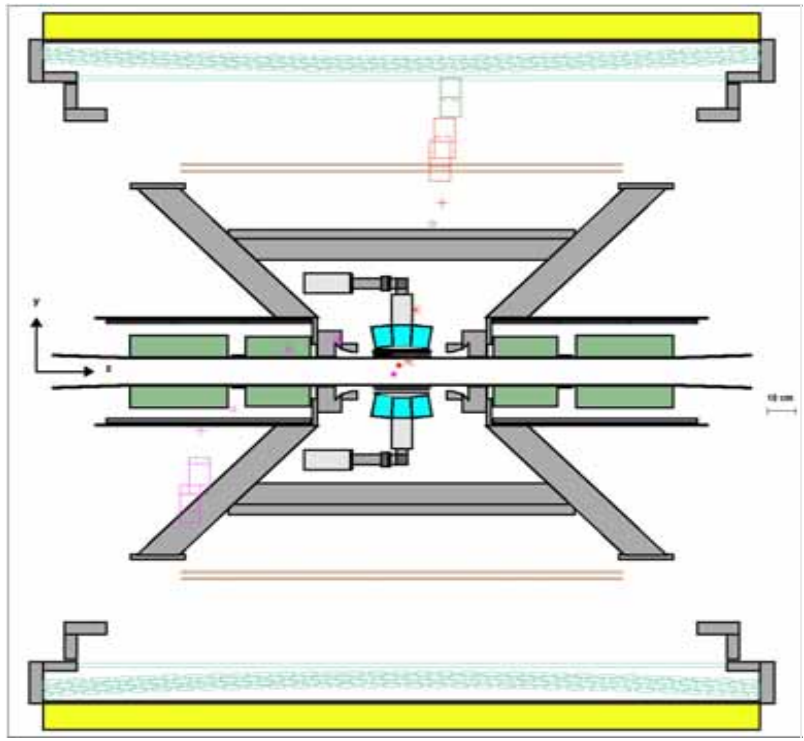
FP6-HYPERGAMMA

- Physics objectives related to SPHERE
  - high resolution γ-spectroscopy
  - high statistics weak decay

FINUDA @ DAΦNE

- Timeline
  - 2007: Letter of Intent
  - 2008: completion of FINUDA physics program
  - 2009: FINUDA upgrade; pilot run at DAΦNE (500 pb^{-1})
  - 201X: ???





International Hypernuclear Network

PANDA @ FAIR
- anti-proton beam
- double Λ-hypernuclei
- γ-ray spectroscopy

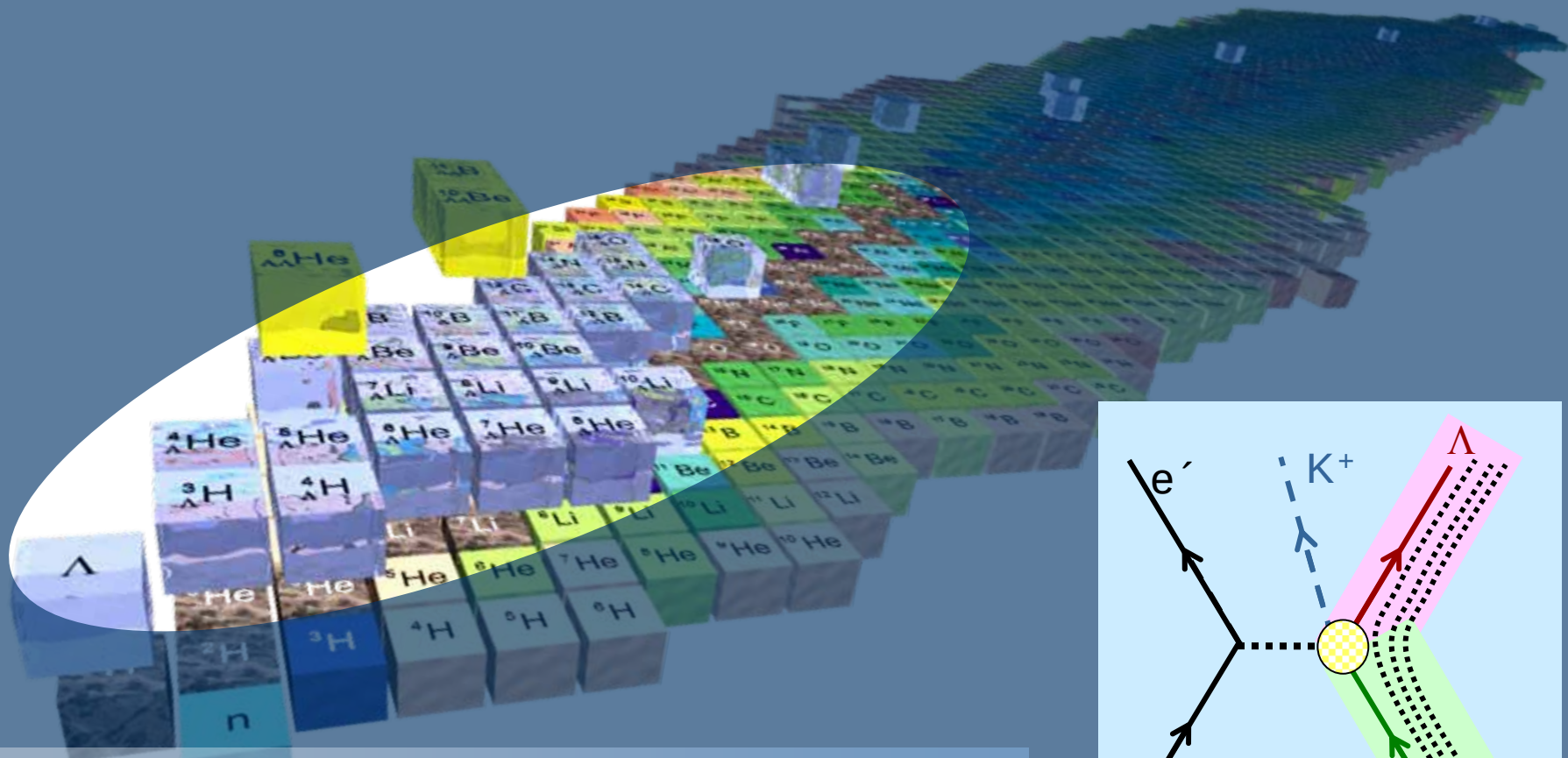
Dubna
- heavy ion beam
- single Λ-hypernuclei

KAOS @ MAMI
- electro-production
- single Λ-hypernuclei
- Λ-wavefunction

JLab
- electro-production
- single Λ-hypernuclei
- Λ-wavefunction

FINUDA
- e^+e^- colli
- stopped-
- single Λ-
- γ-ray spe

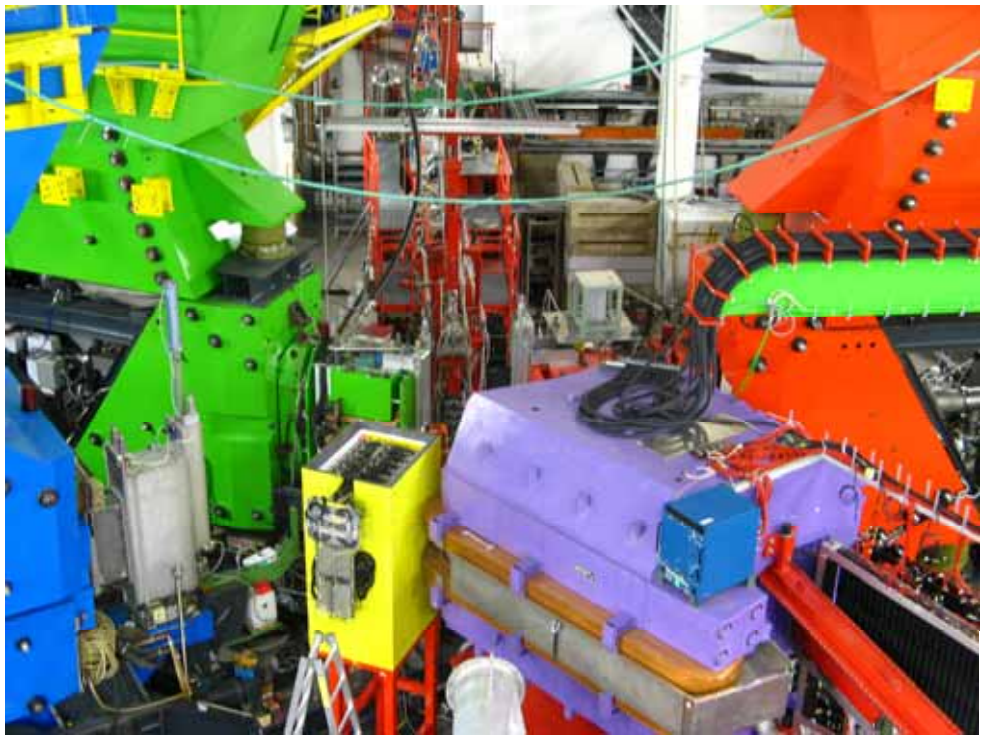
KAOS @ MAMI



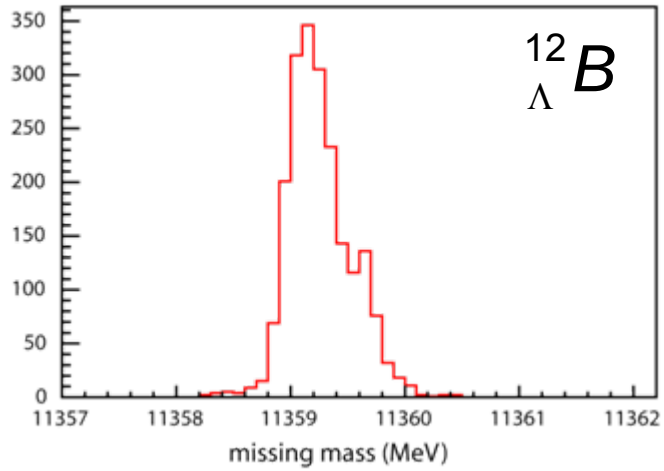
- Physics objectives related to SPHERE
  - wave function of Λ
  - large momentum transfer components

KAOS @ MAMI

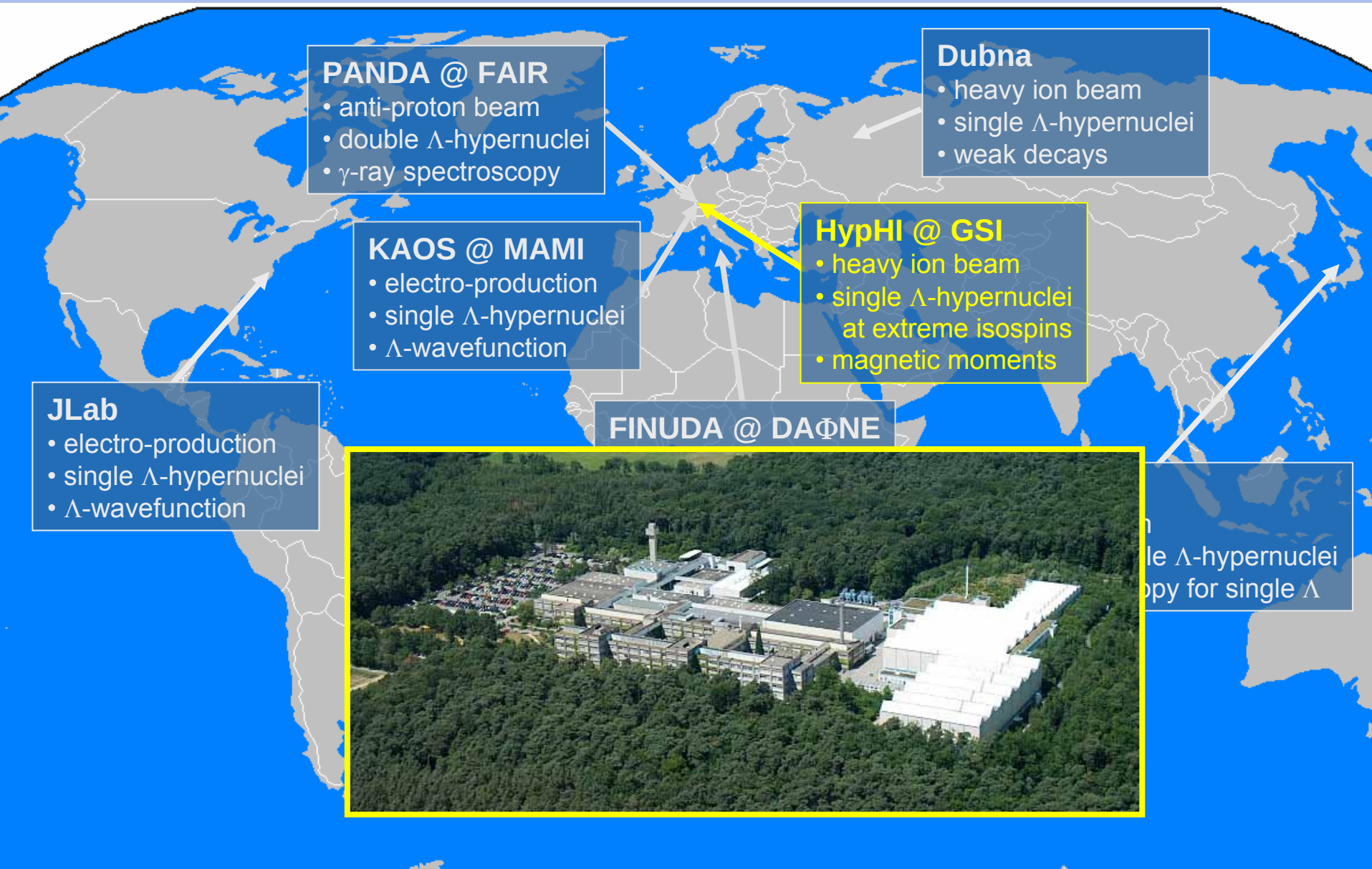
- Timeline
  - 2008: first proposal, pilot run
  - 2008/09: completion of KAOS double spectrometer for high intensity runs at 0°
  - 2009/10: data taking for hypernuclei production



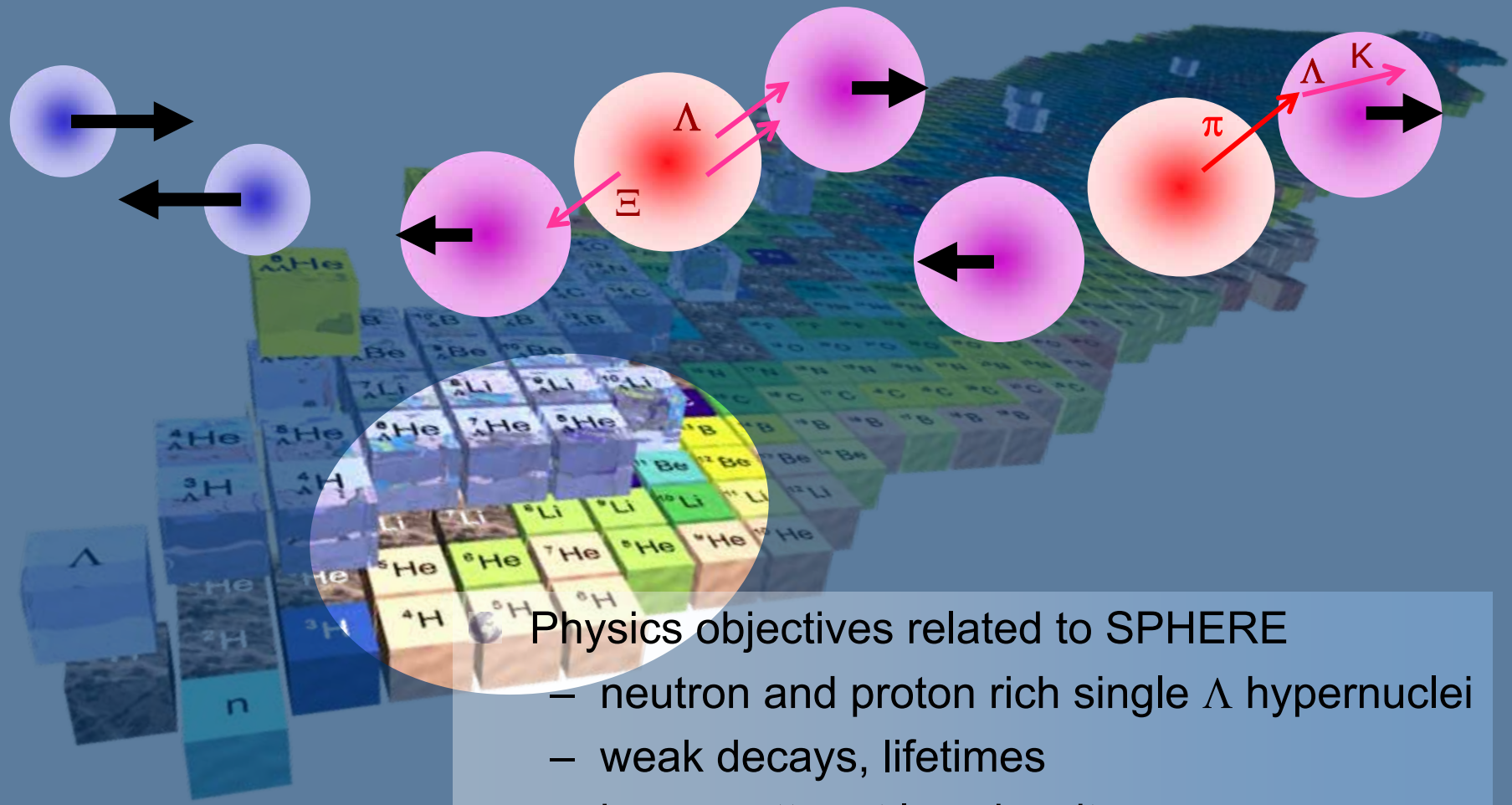
Expected mass resolution
$\sigma_m = 275keV$



International Hypernuclear Network



HYPHI @ GSI/FAIR



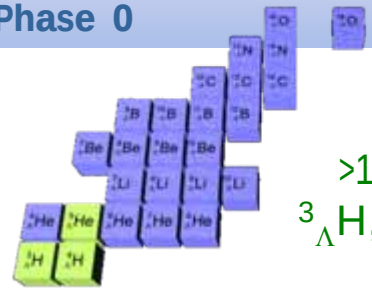
Physics objectives related to SPHERE

- neutron and proton rich single Λ hypernuclei
- weak decays, lifetimes
- hypermatter at low density
- magnetic moment of Λ inside nucleus

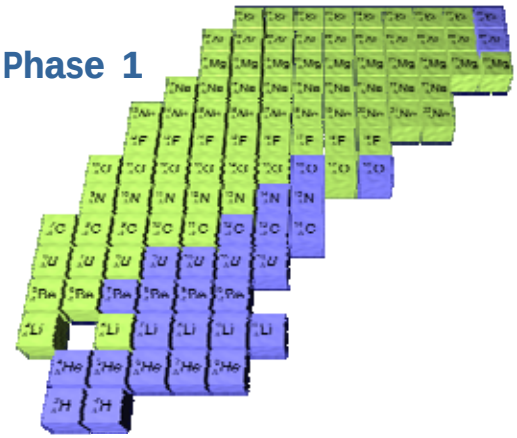
HYPHI @ GSI/FAIR

- Design study, preparation for the phase 0 experiment
- Phase 0: experiment with $^{3}_{\Lambda}$H, $^{4}_{\Lambda}$H and $^{5}_{\Lambda}$He
- Design study for the setup for hypernuclear non-mesonic weak decay measurements
- Phase 1: Experiments for proton rich hypernuclei
- Phase2: Experiment for neutron rich hypernuclei at NuSTAR/FAIR
- Phase 3: Hypernuclear separator
  - Hypernuclear magnetic moments
  - Hypernuclear driplines

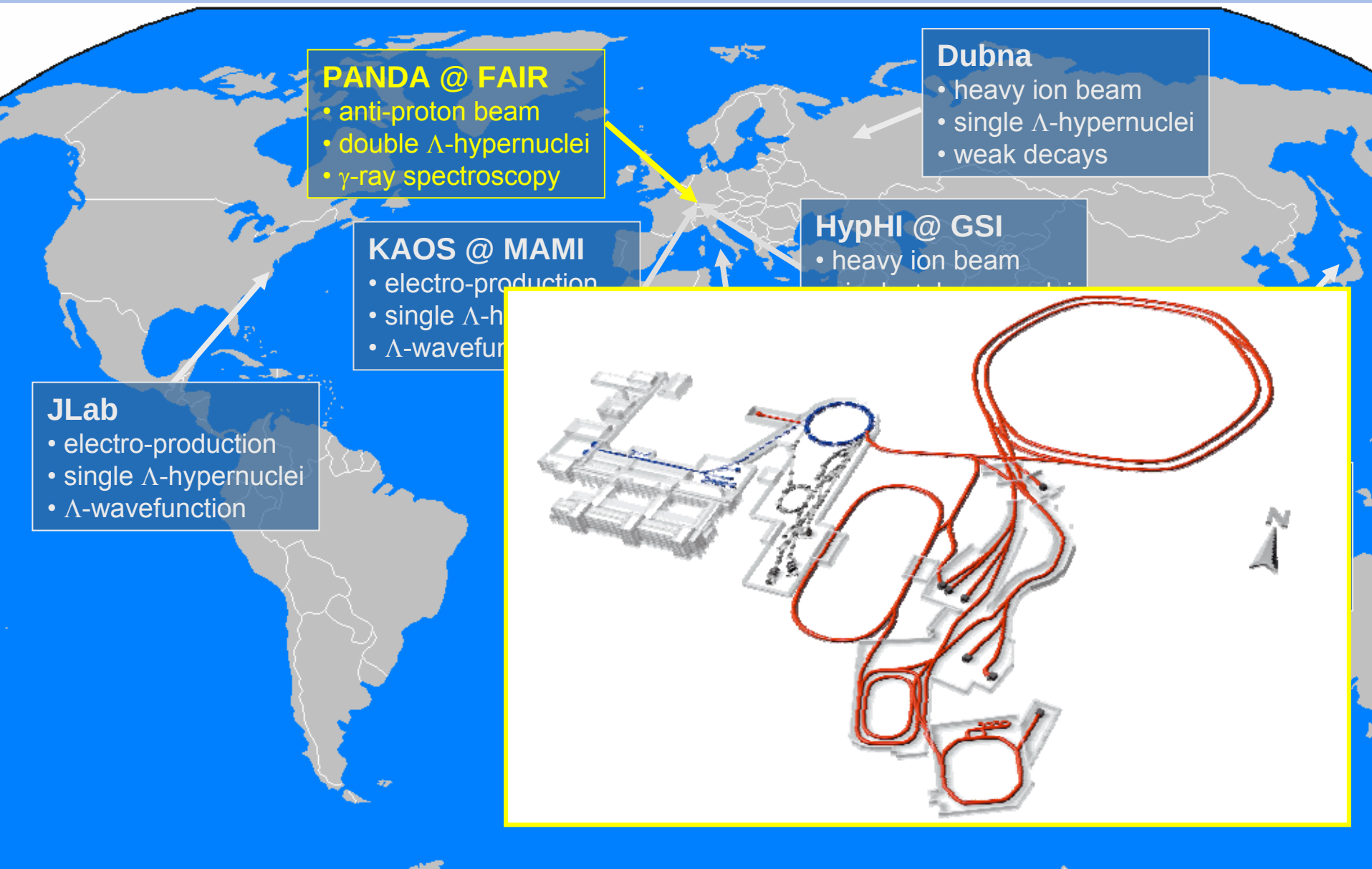
2008
2009
2010
2011
2012
2013



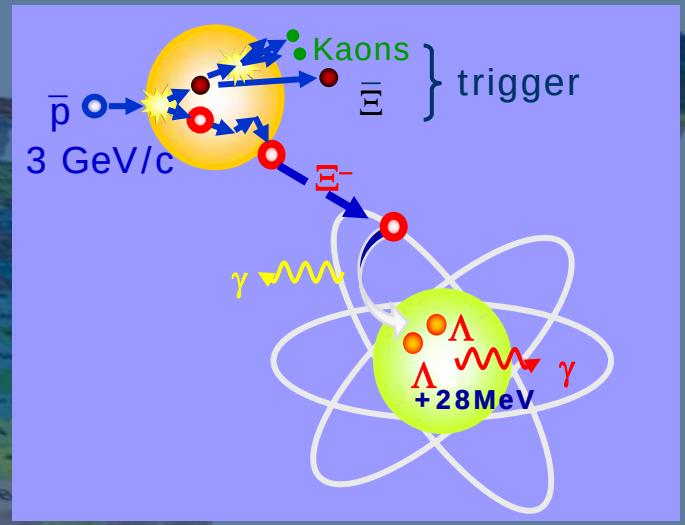
>10^4/week
$^{3}_{\Lambda}$H, $^{4}_{\Lambda}$H, $^{5}_{\Lambda}$He



International Hypernuclear Network



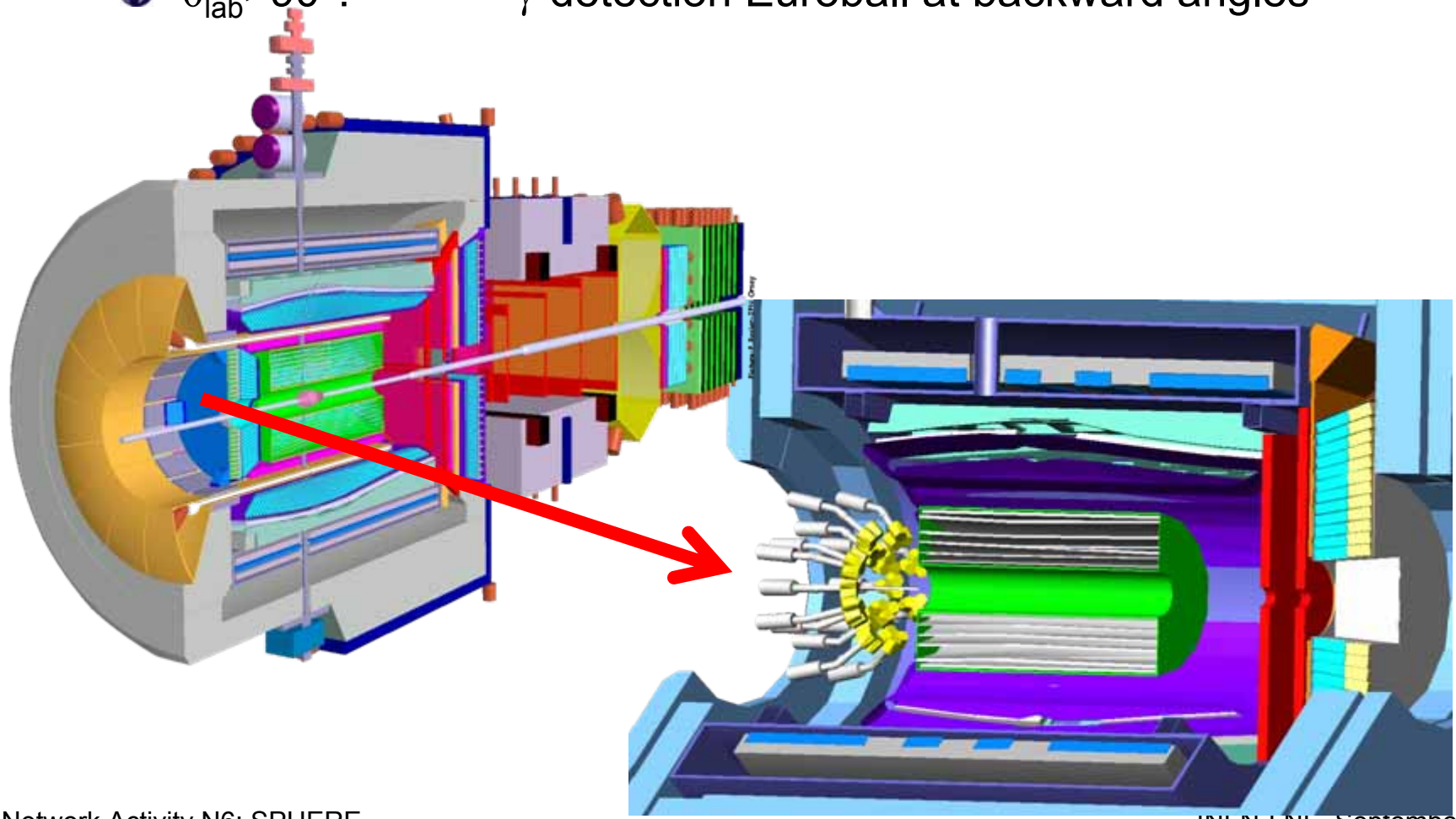
PANDA @ FAIR



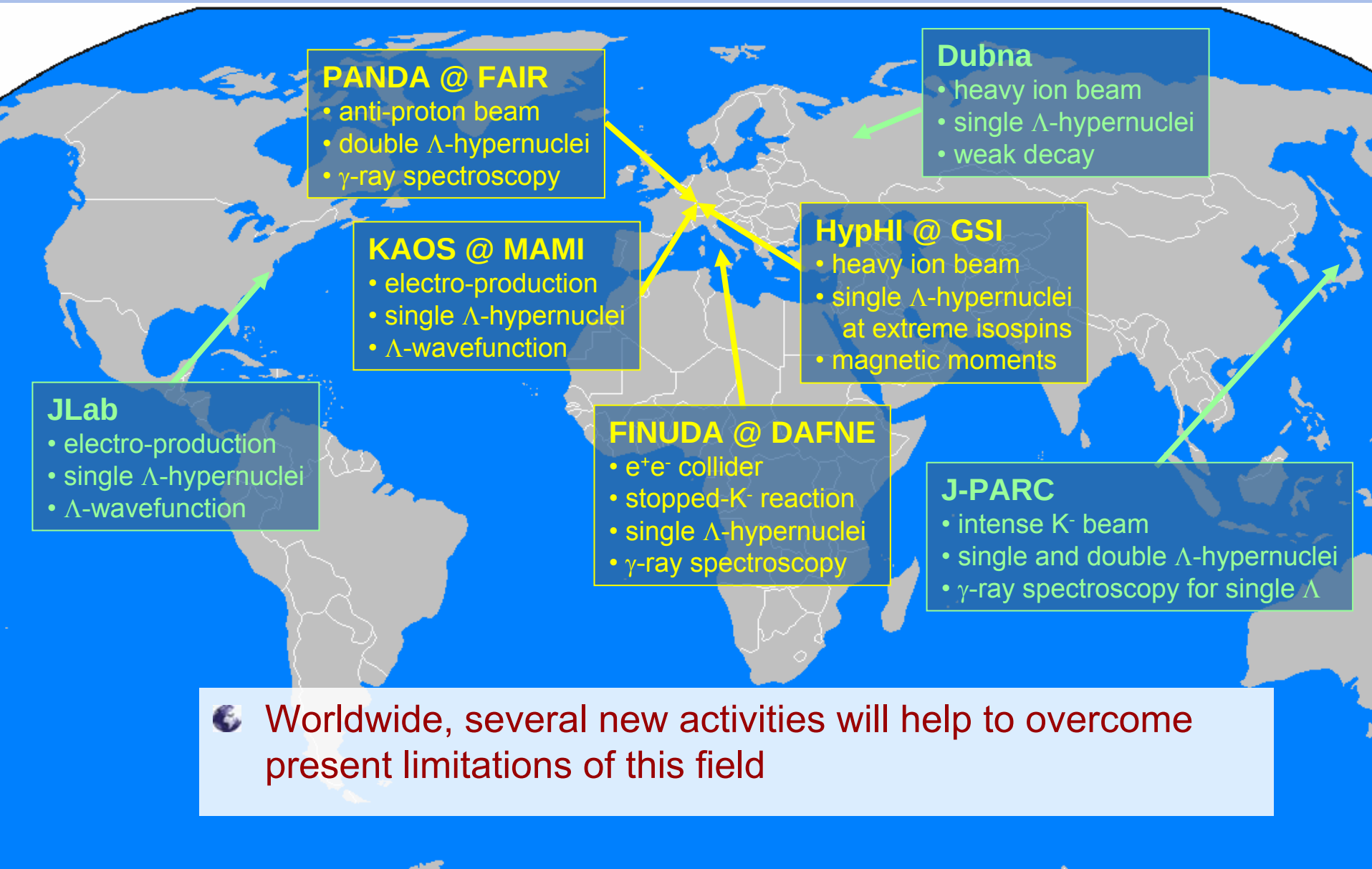
- Physics objectives related to SPHERE
  - High resolution γ-spectroscopy of double $\Lambda\Lambda$ hypernuclei
  - weak decays

PANDA Setup

- θ_{lab}< 45°: Ξ-bar, K trigger (PANDA)
- θ_{lab}= 45°-90°: Ξ-capture, hypernucleus formation
- θ_{lab}>90°: γ-detection Euroball at backward angles



International Hypernuclear Network



- Worldwide, several new activities will help to overcome present limitations of this field

Members of SPHERE

- Barcelona
- Catania
- Darmstadt
- Frascati
- Giessen
- Granada
- Jerusalem
- Mainz
- Rez/Prague
- Torino/Theo
- INFN Torino
- Valencia
- Warsaw

- Czech Republic
- Germany
- Israel
- Italy
- Poland
- Spain

- 80 Physicists senior scientists : postdoc : students = 1 : 1 : 2

Expertise of Participants

Barcelona	A. Ramos
Catania	G. Raciti
Darmstadt	T. Saito
Frascati	V. Lucherini
Giessen	H. Lenske
Granada	J. Nieves
Jerusalem	A. Gal
Mainz	J. Pochodzalla
Rez/Prague	J. Mares
Torino/Theo	G. Garbarino
INFN Torino	T. Bressani
Valencia	E. Oset
Warsaw	P. Haensel

- More than 250 published scientific articles in last 3 years
- Renowned world experts on e.g. the theory hypernuclei, weak decays, neutron stars
- Leading roles in ongoing or planned experimental hypernuclear activities at FINUDA, MAMI, GSI and FAIR

Work Packages

- DET^{ector}:
  - Exchange of knowledge to develop, built, integrate and operate new experimental equipment and analysis tools
  - Sharing of complex experimental devices to open new experimental possibilities
- EXP^{eriment}:
  - coordinate planning, analysis and the interpretation of hypernuclear experiments
- PHY^{sics}:
  - guide and define the goals of future experiments
  - develop coordinated research programs
- THE^{ory}:
  - develop theoretical methods appropriate for the analysis of hypernuclear production and structure data, including large-scale numerical simulations.
  - derive elementary baryon observables from the hypernuclear data and investigate their relation and application to fields outside SPHERE

Tasks (1)

Institute *Activity*	Tasks
Barcelona *PHY, THE*	Influence of strong $\Lambda N \rightarrow \Sigma N$ transitions in the weak decay of hypernuclei Weak decay of neutron-rich hypernuclei. *(HYPHI)* Hyperon-nucleon scattering length from lattice QCD. Determination of the Λ-dripline in multistrange systems. *(HYPHI)* Properties of strange and charm mesons in a nuclear environment. *(KAOS,FINUDA,PANDA)*
Catania *PHY, EXP, DET*	Feasibility study for a secondary SiC strips target wafer for tracking in Hypernuclei production experiments. *(PANDA)* Properties of SiPMT in high-rate experiments. (*PANDA,HYPHI)*
Darmstadt *PHY, EXP, DET*	Setting up the HypHI experiment at GSI. Developments of SciFi detectors, TOF walls, diamond detectors and trigger electronics. Data and physics analysis of the HypHI experiments. *(HYPH)* Optimization of the Ge detectors for the γ-ray spectroscopy with FINUDA. *(FINUDA,PANDA)* Development of the electronics modules for the tracking trigger. *(KAOS)*

Tasks (2)

Institute *Activity*	Tasks
INFN Frascati *PHY, EXP, DET*	Λ-Hypernuclei production and decay. Low momentum interactions of charged kaons on nuclei. *(FINUDA)* Development of straw tube detectors for the tracking of charged particles. *(PANDA)*
Gießen *PHY, EXP, THE*	Theory of electropoduction of hypernuclei by direct and resonance scenarios, assessment of the role of the nucleon and hyperon in-medium self-energies. *(KAOS)* Transport theory for the production of hypernuclei in heavy ion collisions. *(HYPHI)* NY and YY in-medium interaction by Dirac-Brueckner theory. *(PANDA)* Density functional theory for nuclei, hypernuclei, and neutron stars *(ALL)*
Granada *PHY, EXP*, THE	Λ–Λ and Λ-^{4}He systems- Solution of the Schrödinger Equation (SE) with the χPT. Two Pion Exchange potential. Renormalization of the SE using the method of boundary conditions. Study of the pionic decay of the $^4He_\Lambda$ hypernucleus. *(HYPHI,PANDA)* $^4He_{\Lambda\Lambda}$ hypernucleus: Variational approach to solve the three body (Λ-Λ-^{4}He) problem with the TPE potentials studied above. Study of its pionic decay. *(HYPHI,PANDA)*

Tasks (3)

Institute *Activity*	Tasks
Jerusalem *PHY, THE*	*Few-body Kbar cluster calculations. (KAOS)* *Exploratory study of stable S=-3 systems, such as $\Lambda\Lambda\Xi$-^{4}He. (HYPHI, PANDA)*
Mainz *PHY, EXP, DET*	Setting up and operation of KAOS spectrometer; preparation of proposals for electroproduction experiments of f mesons in nuclei. *(KAOS)* Preparation of technical design report; Monte Carlo calculations to optimize setup; implementation of Ge-detectors. *(PANDA)* Development of a scintillating fiber START detectors with SiPMT readout. *(PANDA, HYPHI)*
Rez/Prague *PHY, THE*	Reaction mechanisms of photo- and electroproduction of strange particles in the framework of the effective Lagrangian and the Regge model. *(KAOS)* Photo- and electropoduction of hypernuclei; shell-model analysis. *(KAOS)* Production and structure of neutron rich hypernuclei. *(HYPHI)* Antikaon – nucleus and antiproton-nucleus interactions; K- atoms, K- -nuclei. *(KAOS)* Multi-channel Faddeev calculations of few-body systems with strangeness *(ALL)*

Tasks (4)

Institute *Activity*	Tasks
Torino-Th *PHY, THE*	Investigation of the effects of novel contributions in the weak transition potential on hypernuclear decay rates and asymmetries. In particular, application to neutron- and proton-rich hypernuclei. *(HYPHY)* Development of alternative models for simulating the nucleon final state interactions in non-mesonic decays. Study of the $\Delta I=1/2$ isospin rule in the non-mesonic weak decay and, in general, in four-baryon strangeness changing processes. *(ALL)*
Torino INFN *PHY, EXP, DET*	Preparation of a new run on the precise measurement of non Mesonic weak decays and Gamma g-spectroscopy with Ge- detectors. *(FINUDA)* Simulations for the experiment on Double Hypernuclei production. Implementation on vertex detectors. *(PANDA)*
Valencia *PHY, THE*	Λ-N and $\Lambda-\Lambda$ interaction using chiral dynamics, and their medium modification. Weak decay of new hypernuclei. *(HYPHI,PANDA)* Chiral unitary theory of meson nucleus interaction including charmed mesons. Exploring the possibility to form charmed hypernuclei. *(PANDA)*
Warsawa *PHY, THE*	Explore relation between the properties of neutron stars and hyper on-baryon interactions. *(ALL)*

Deliverables

- Annual progress reports (delivered after annual Workshop)
- Technical reports
- Proposals based on the SPHERE activity
- Publications in scientific journals (continuously)

Physics driven Activity $\Rightarrow$ exact time difficult to predict

Quality assessment

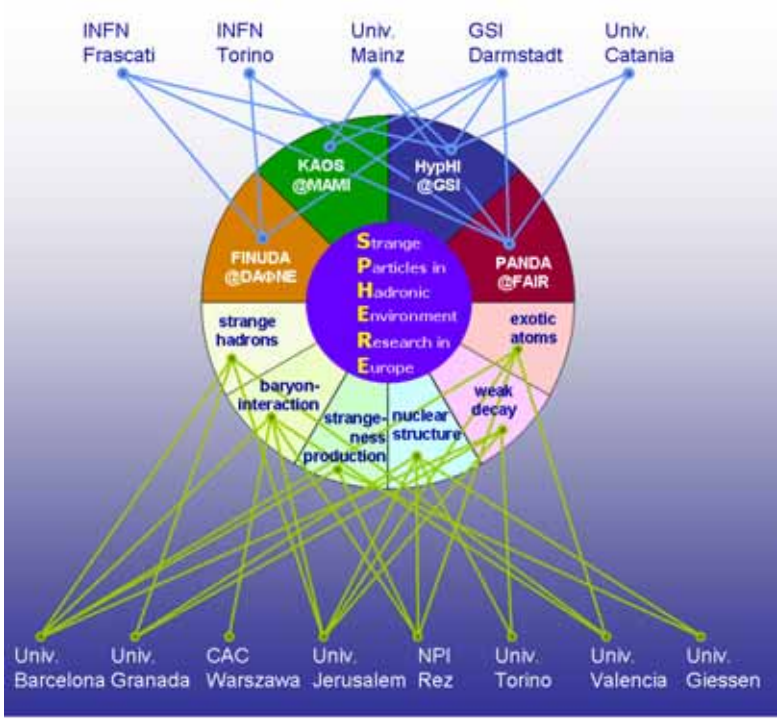
- internal meetings
- elected steering board
- quality and number of scientific publications
- invitation to international conferences
- outside attendance at the annual open SPHERE workshops
- new collaborative experimental efforts

Finances

- Duration: 4 years
- Requested EC contribution
  - Personnel (23 PhD years) 696k€
  - Travels 238k€
  - Workshops (4) 40k€
  - Overhead (~20%) 190k€
  - Total 1164k€
- Non EC contribution
  - Personnel 4359k€
  - Durables 453k€
  - Consumables 326k€
  - Travels 341k€
  - Workshops 30k€
  - Overhead 318k€
  - Total 5827k€

Summary

- SPHERE is a well *focused* activity
- It comprises both experimentalists and theoreticians
- It is embedded in the European research infrastructure




Sixth Framework Programme
Bundesministerium
für Bildung
und Forschung
Thank you!