

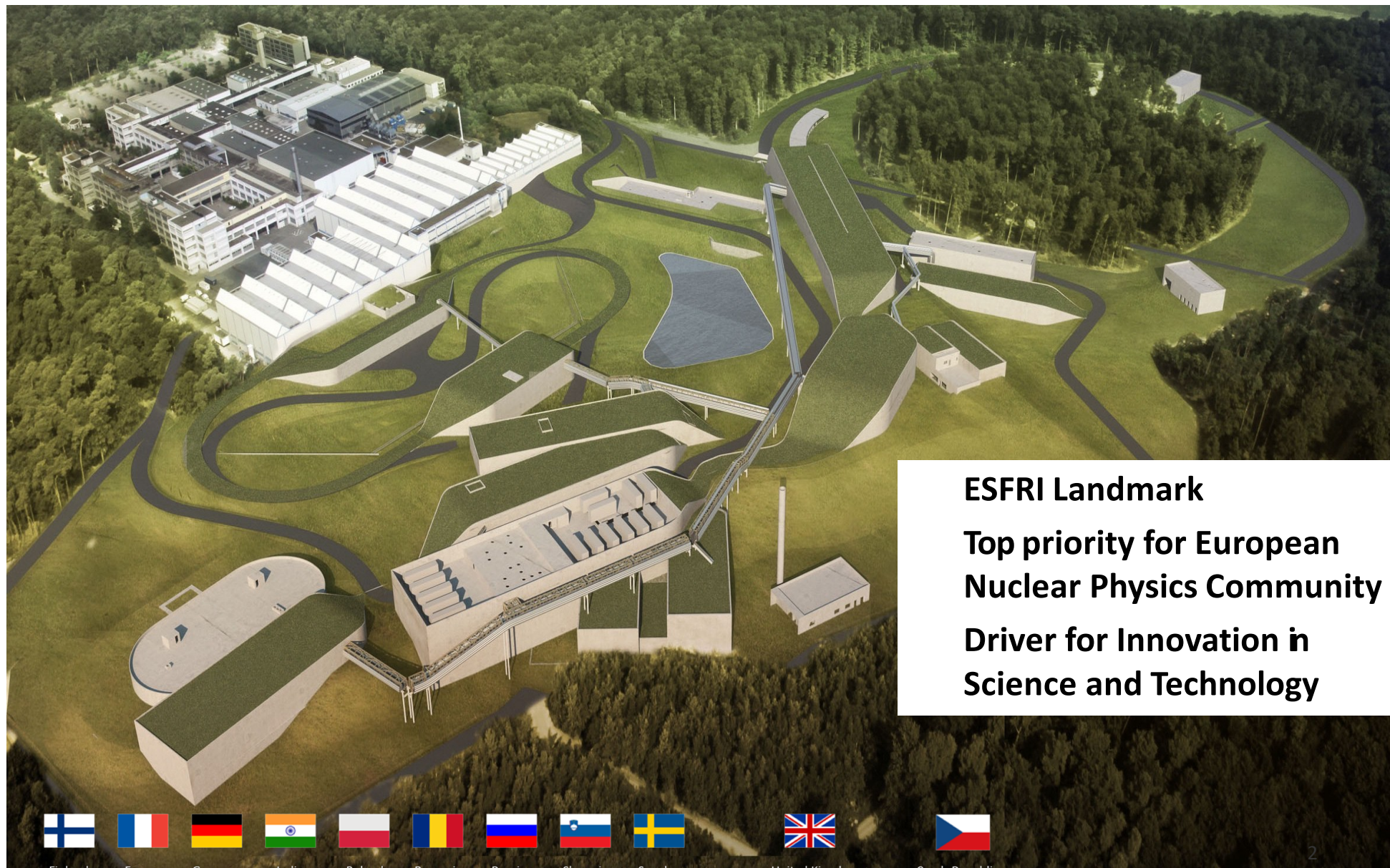
A detailed wireframe model of a particle accelerator complex, showing various circular and linear sections, likely representing the FAIR facility. The model is rendered in a light gray wireframe style, highlighting the intricate geometry of the accelerator's components.

# FAIR, Belle II, (Theorie)

Computingstrategie in der HL-LHC-Ära  
Thorsten Kollegger, Thomas Kuhr  
and input from many colleagues

May 6, 2020

# FAIR: Facility for Antiproton and Ion Research



**ESFRI Landmark**  
**Top priority for European**  
**Nuclear Physics Community**  
**Driver for Innovation in**  
**Science and Technology**



Finland

France

Germany

India

Poland

Romania

Russia

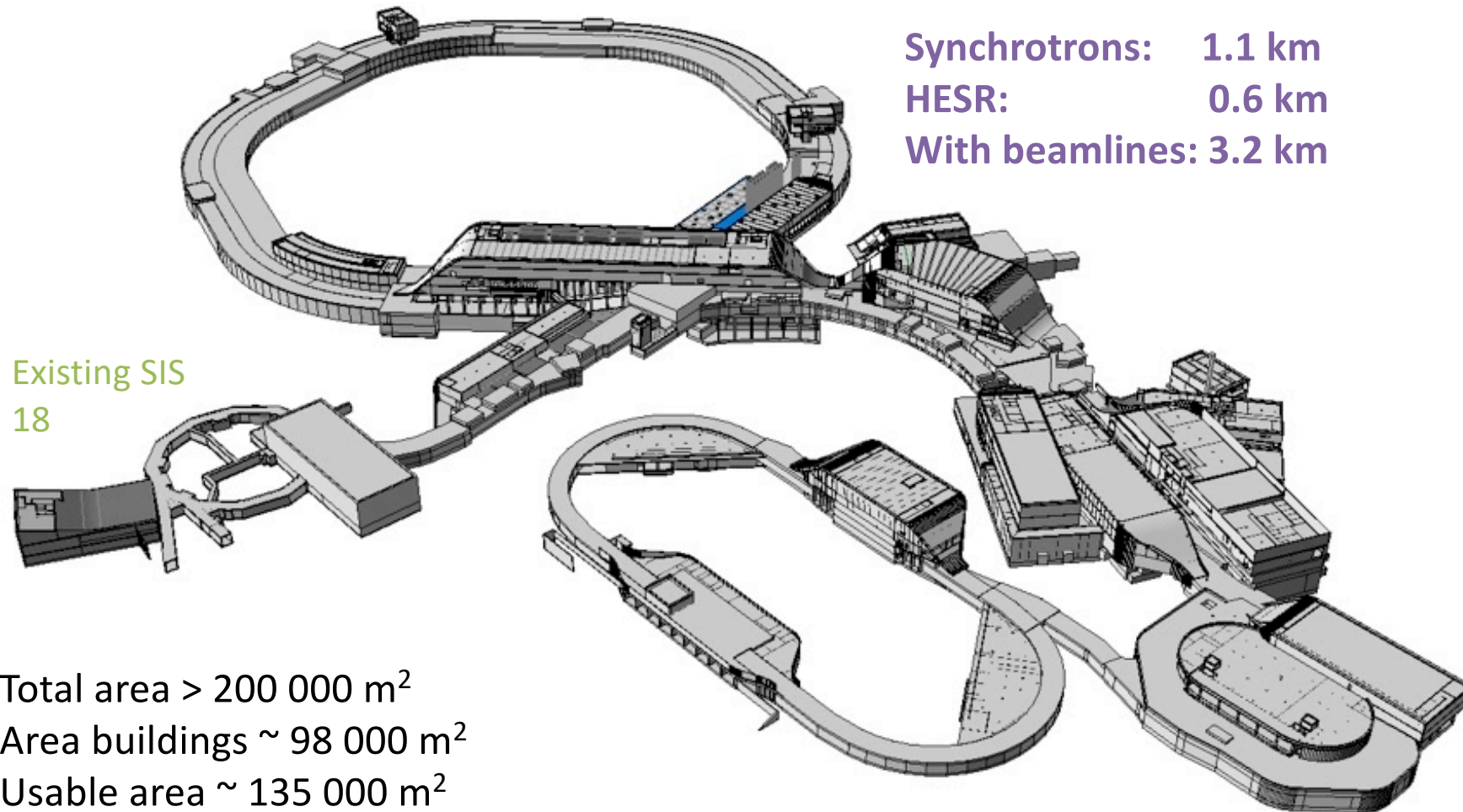
Slovenia

Sweden

United Kingdom

Czech Republic

# FAIR – Civil Construction



Synchrotrons: 1.1 km  
 HESR: 0.6 km  
 With beamlines: 3.2 km

Existing SIS  
 18

Total area > 200 000 m<sup>2</sup>  
 Area buildings ~ 98 000 m<sup>2</sup>  
 Usable area ~ 135 000 m<sup>2</sup>  
**Volume of buildings ~ 1 049 000 m<sup>3</sup>**  
 Substructure: ~ 1500 pillars, up to 65 m deep

# FAIR – Civil Construction

FAIR Construction Site: October 2019



GSI Green Cube  
Computing

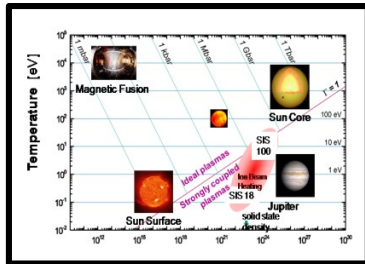
Contract for Area South  
Shell Construction awarded  
in April 2020

First tunnel segments  
constructed

Tunnel Excavation nearly  
completed

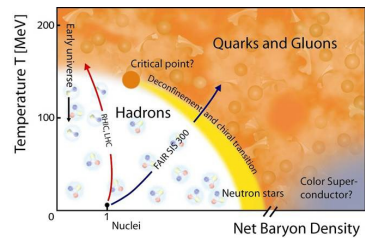
Video from March 2020: <https://youtu.be/U6WuXJ5lj6E>

# The FAIR science: four pillars



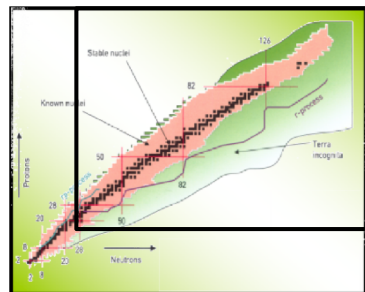
atomic physics, biophysics,  
plasma physics, material research,  
other applications

**APPA**



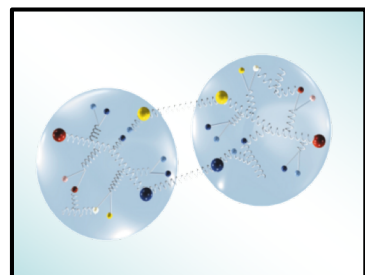
nuclear- and quark-matter

**CBM**



nuclear structure and  
nuclear astrophysics

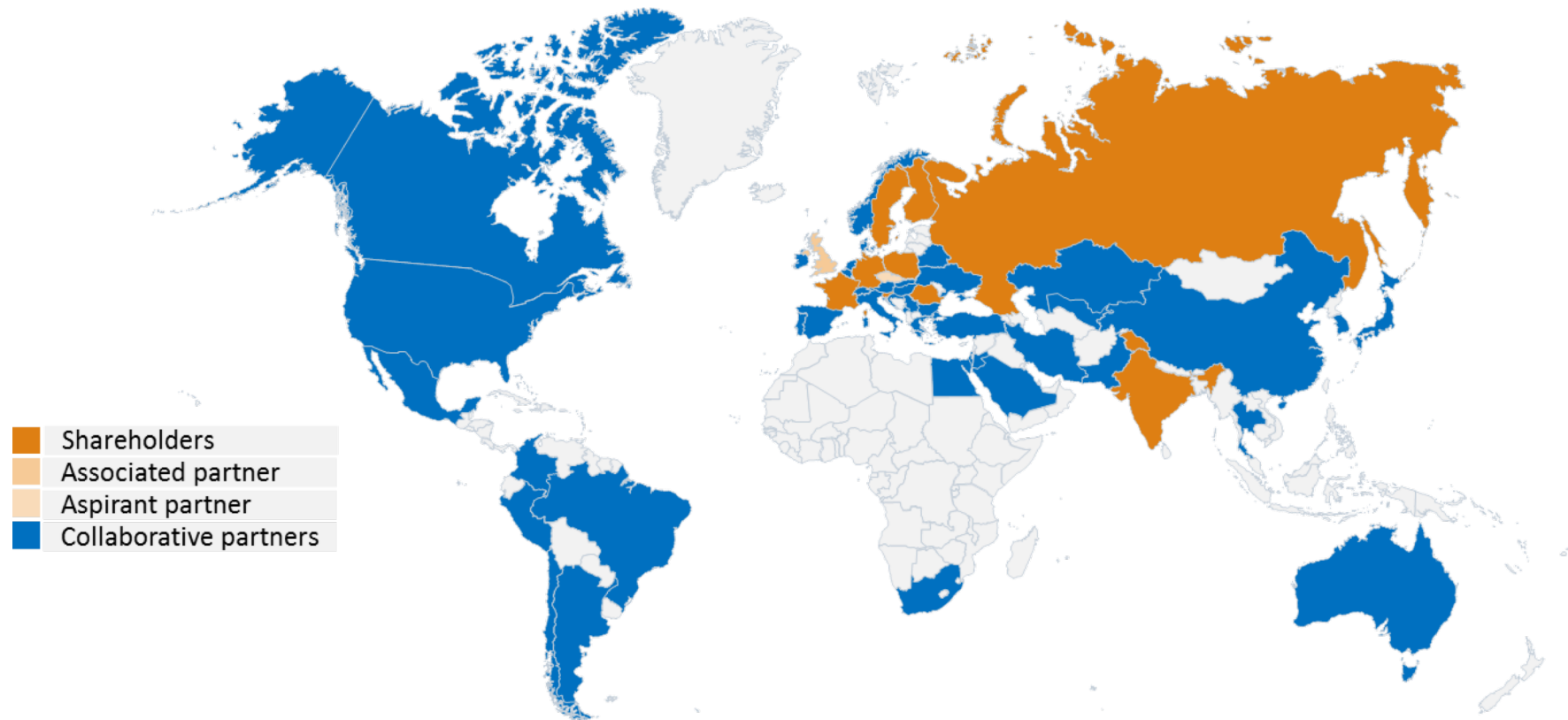
**NuSTAR**



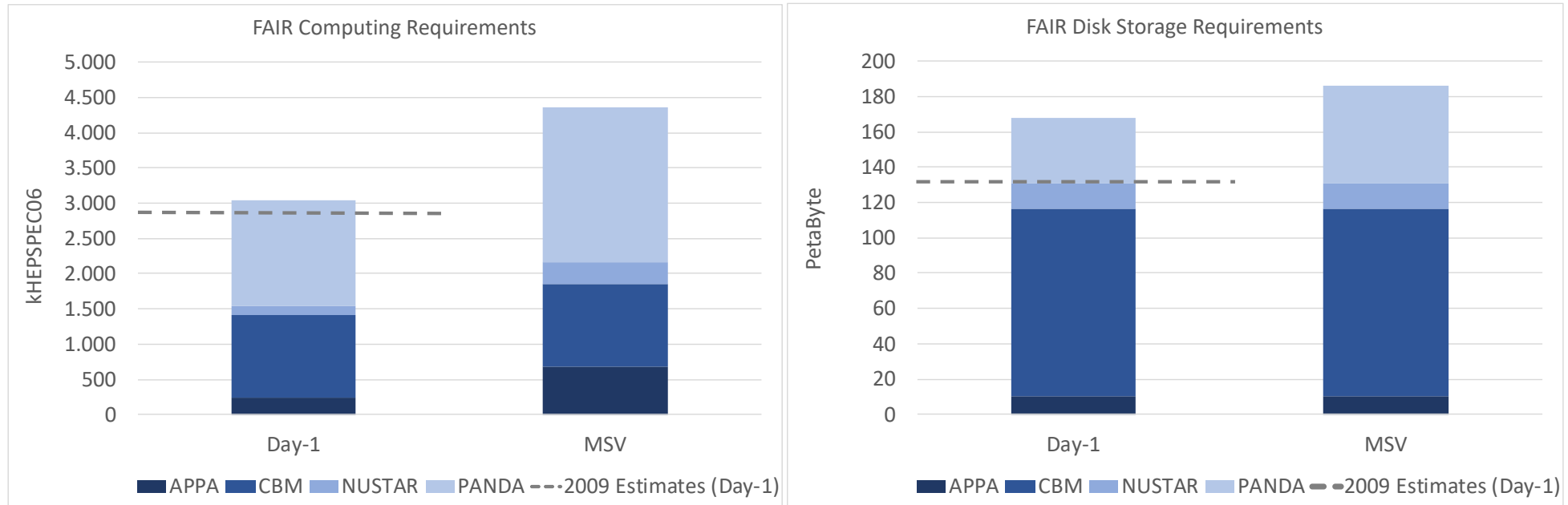
hadron structure and dynamics

**PANDA**

# FAIR: International Cooperation



- **9 international FAIR Shareholders**
- 1 Associated Partner (United Kingdom)
- 1 Aspirant Partner Czech Republic (Since 2018)
- Participation of **3.000 scientists from all continents**



Assumptions for resource requirements:  
Day-1 and MSV detector setups, nominal accelerator performance,  
multi-year integrated values (data lifetime)

# FAIR Computing Requirements



Day-1

Pillar	Experiment	Permanent Storage/year	Additional Disk Storage	Raw Data/year	Raw Data #years	Raw Data Total
APPA	Plasma	5	2	5	1	5
APPA	Atomic	2.000	0	2.000	2	4.000
APPA	BioMat	100	0	0	0	0
CBM	CBM	18.000	11.000	18.000	2	36.000
CBM	HADES	500	0	700	5	3.500
NUSTAR	NUSTAR	5.000	500	5.000	2	10.000
PANDA	PANDA	12.000	100	2.000	2	4.000
<b>Sum (TB)</b>		<b>37.605</b>	<b>11.602</b>	<b>27.705</b>		<b>57.505</b>

Pillar	Experiment	Simulation/year	Simulation #years	Simulation Total	Derived	#years	Derived Total	Disk Total
APPA	Plasma	2.000	1	2.000	1	1	1	2.008
APPA	Atomic			0	1.000	4	4.000	8.000
APPA	BioMat	0	0	0	100	2	200	200
CBM	CBM	9.000	4	36.000	4.000	5	20.000	103.000
CBM	HADES	0	0	0	0	0	0	3.500
NUSTAR	NUSTAR	500	2	1.000	1.250	2	2.500	14.000
PANDA	PANDA	3.500	2	7.000	6.500	4	26.000	37.100
<b>Sum (TB)</b>		<b>15.000</b>		<b>46.000</b>	<b>12.851</b>		<b>52.701</b>	<b>167.808</b>

~168 PB total disk required  
 ~38 PB on tape per year

Single replica

# FAIR Computing Requirements



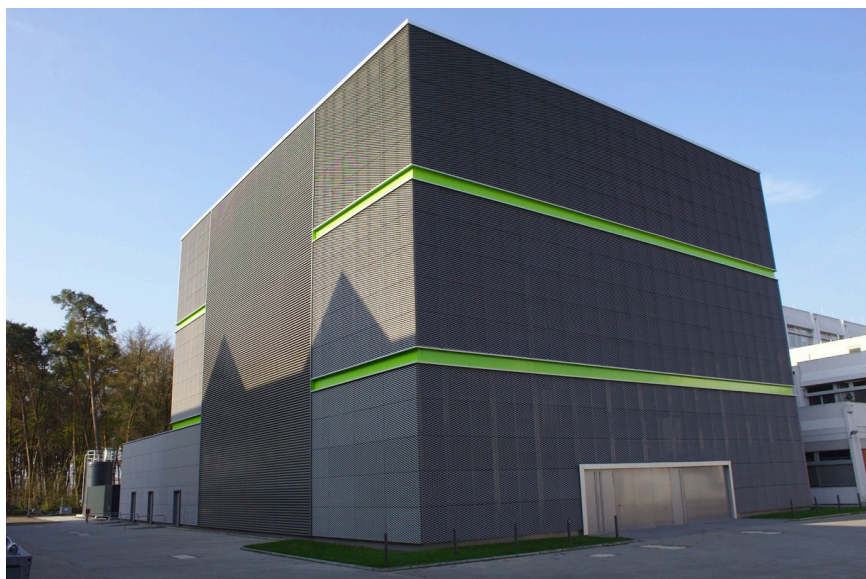
Day-1

		Planned Computing Resource Requirements (in HEPSPEC06)					
Compute Class		1.a	1.b	1.c	1.d	2.a	2.b
Pillar	Experiment						
APPA	Plasma	0	0	0	0	220.000	0
APPA	Atomic	0	0	0	0	22.000	0
APPA	BioMat	0	0	0	0	2.200	0
CBM	CBM	2.200	0	0	0	1.000.000	980.000
CBM	HADES	0	0	0	0	176.000	22.000
NUSTAR	NUSTAR	12.000	0	0	0	120.000	0
PANDA	PANDA	0	0	0	0	1.500.000	1.100.000
<b>Sum (HEPSPEC06)</b>		<b>14.200</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>3.040.200</b>	<b>2.102.000</b>

No significant installations at experiment locations foreseen

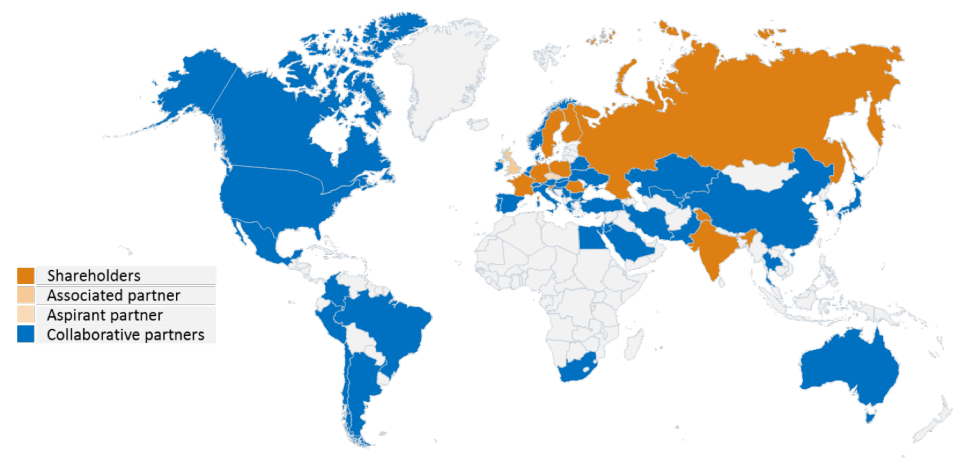
“Offline resources”  
Year-averaged resource request

“Online resources”  
Guaranteed resources during operation



## GSI/FAIR Green Cube Common data center for

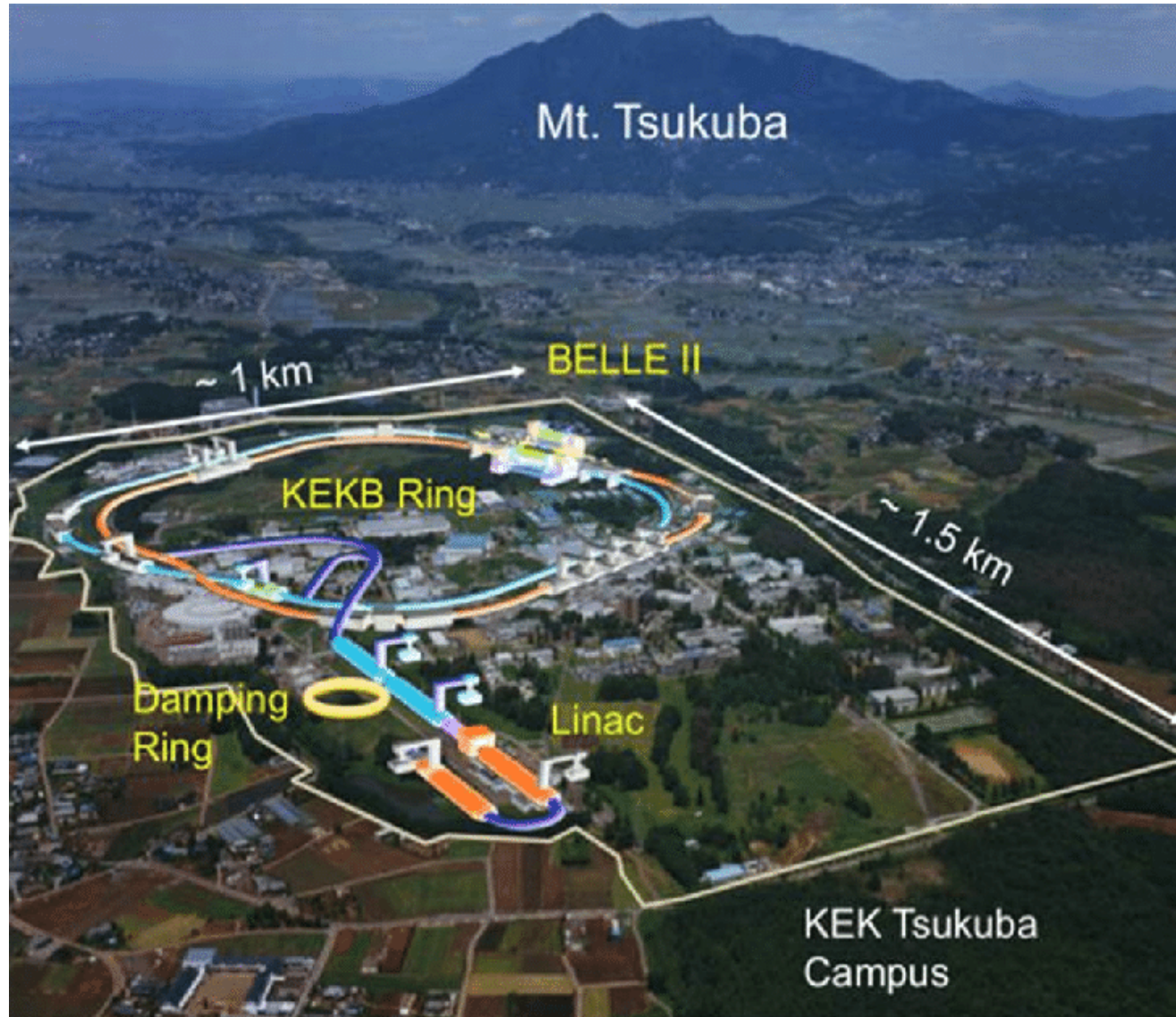
- FAIR Tier 0
- FAIR Experiment Online Clusters (HLT's)
- GSI Computing



## Significant resource contribution from partner countries

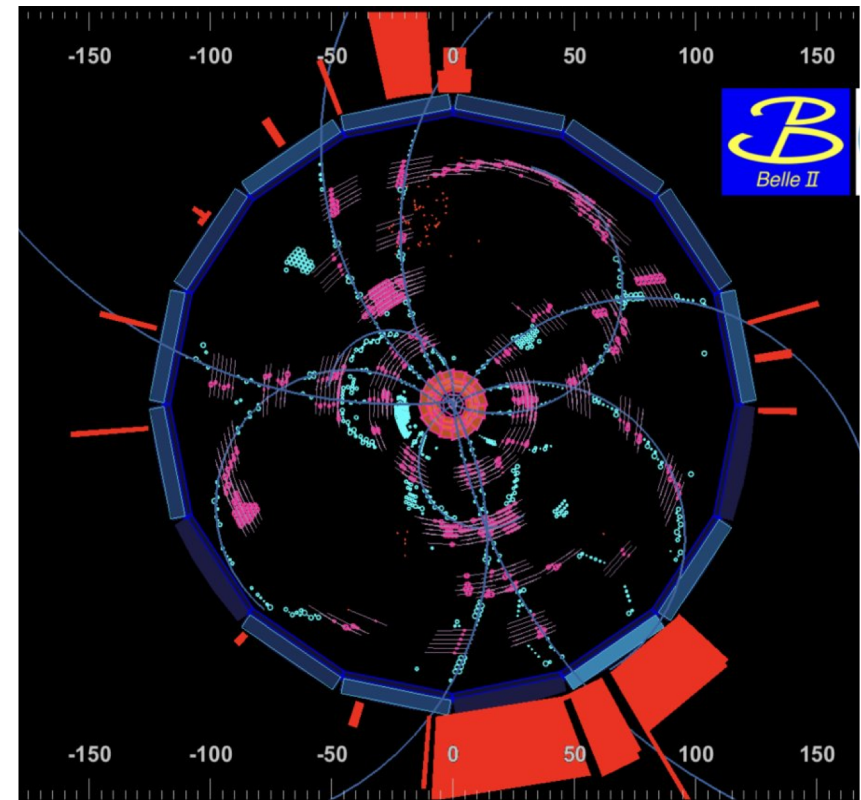
- Replica of (raw) data
- Compute resources and associated storage for efficient use

# Belle II



# Belle II Experiment

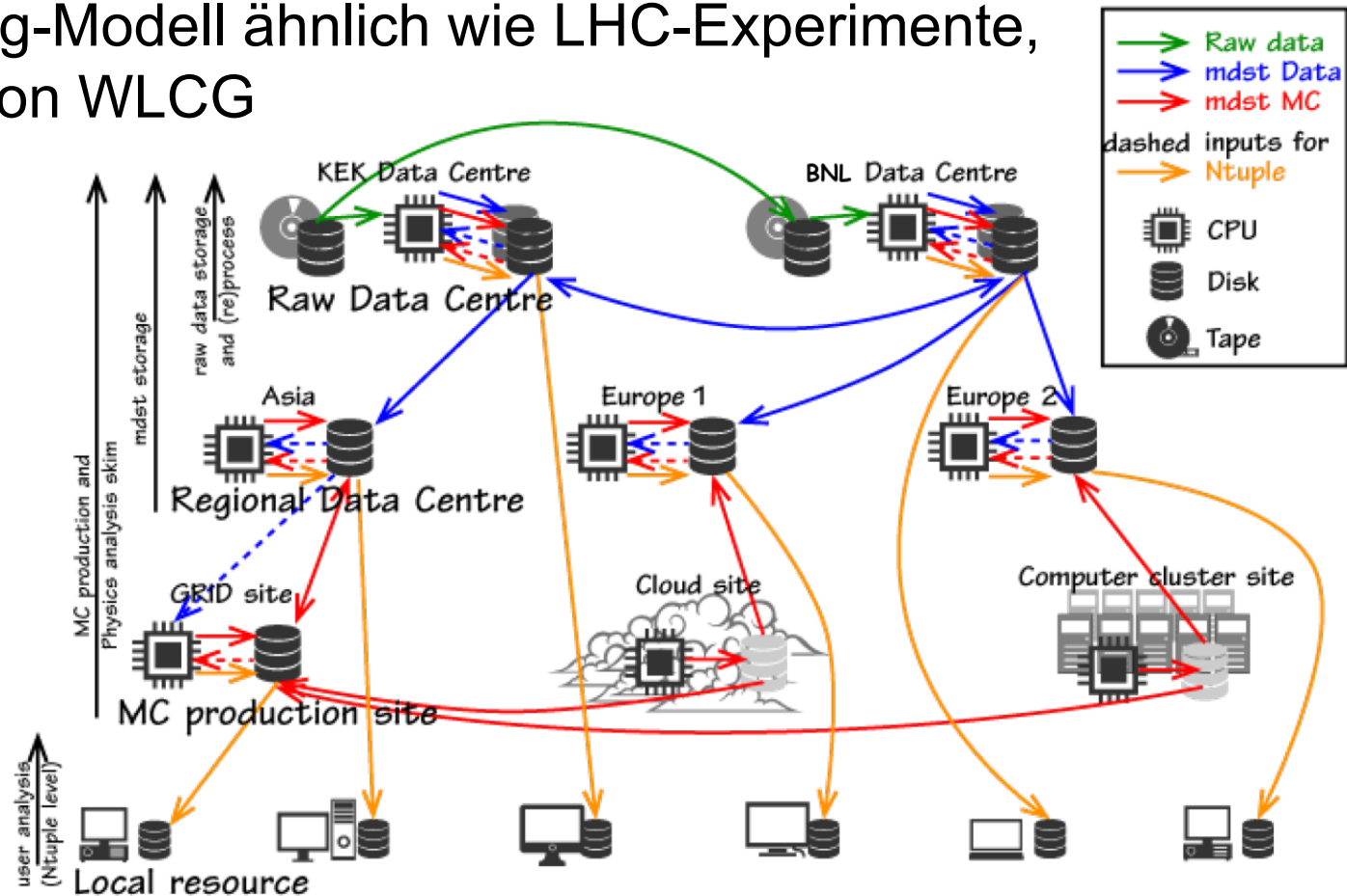
- Suche nach neuer Physik durch Präzisionsmessungen von Zerfällen von B-Mesonen, Charm-Hadronen, tau-Leptonen; Studium von (exotischen) hadronischen Zuständen; ...
- Ziel: 50 mal mehr Daten als Belle bis 2029
- $e^+e^-$  @  $\sqrt{s} \approx 10.6$  GeV
- ➔ Start des Physik-Runs 2019
- O(10) Spuren pro Event, Rohdaten; 100-200 kB pro Event, Analyse (mdst): ~10 kB pro Event
- HLT-Output-Rate bis ~10 kHz  
→ O(GB/s)



# Belle II Computing

- Computing-Modell ähnlich wie LHC-Experimente, Mitglied von WLCG

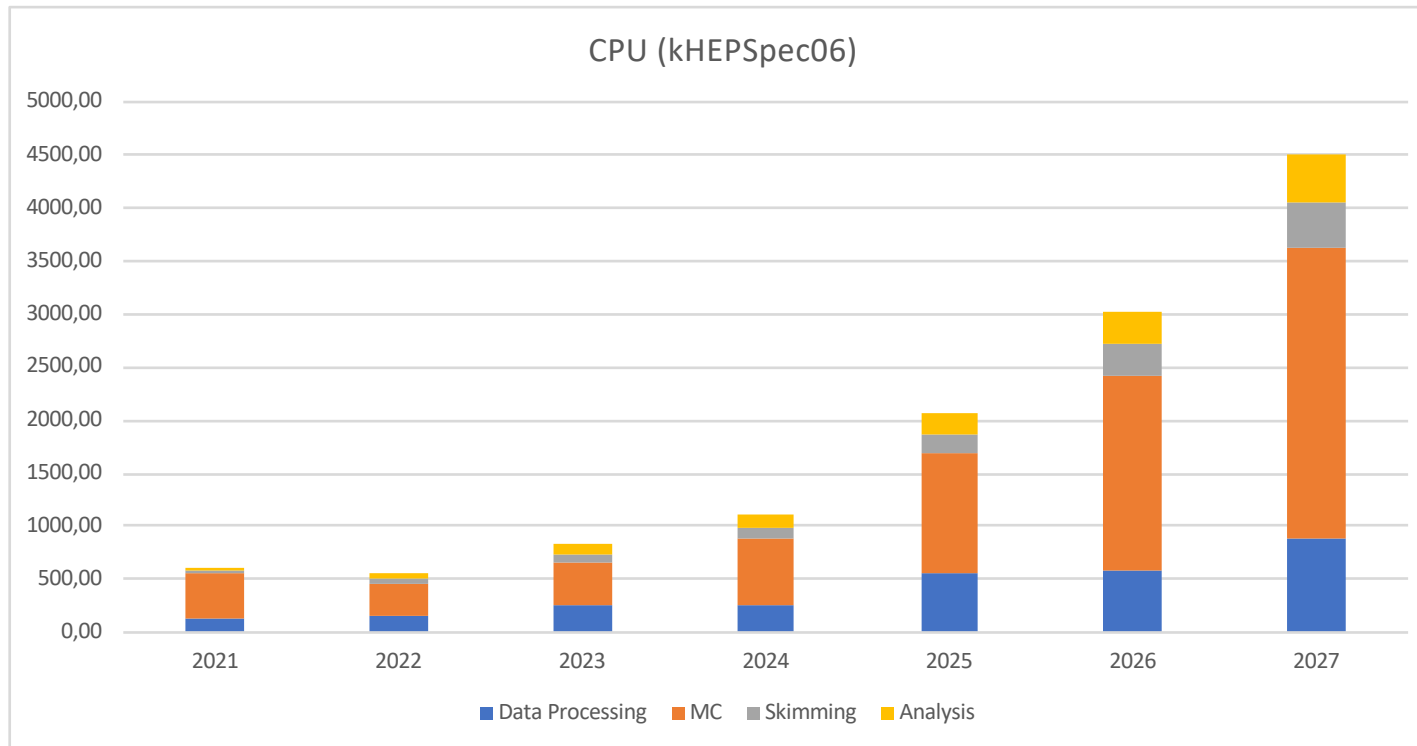
→



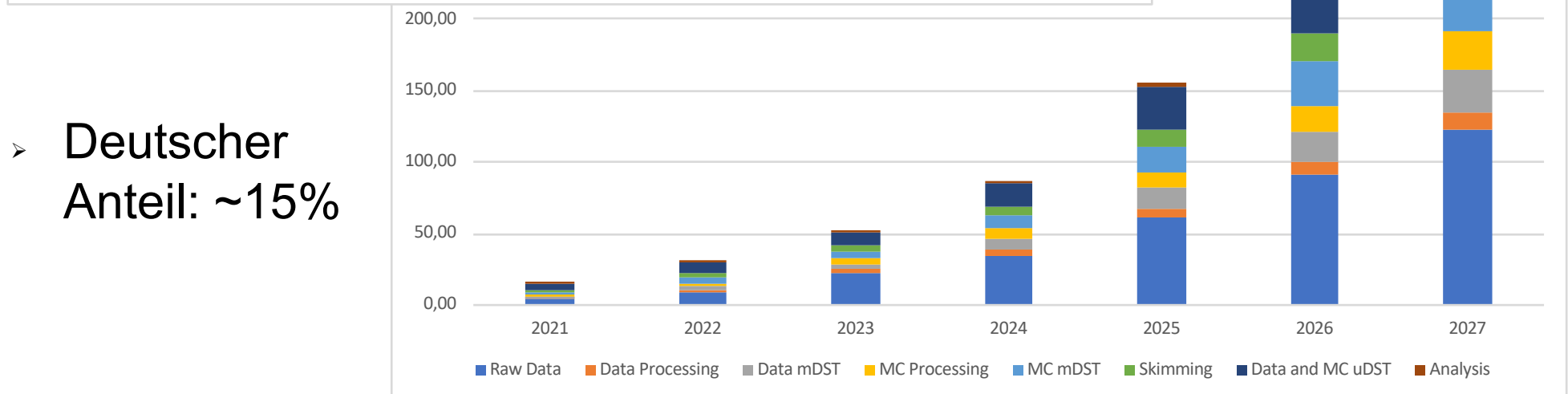
- Analyse in Python

- Integration der Experimentsoftware in Jupyter

# Belle II Ressourcen



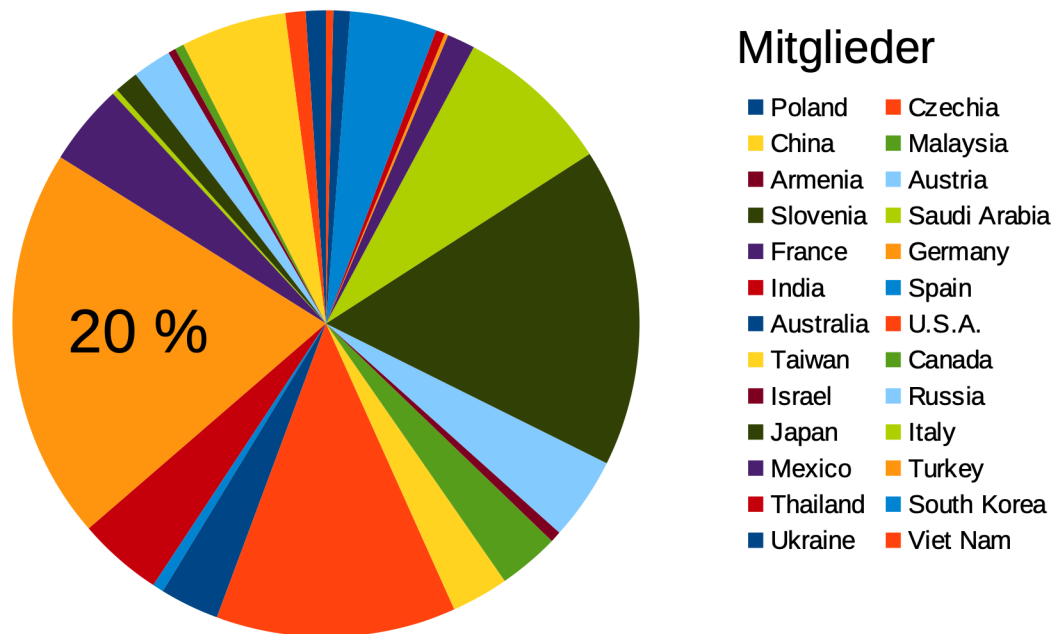
Private Abschätzung



➤ Deutscher Anteil: ~15%

# Belle II Deutschland

- Institute: Bonn, DESY, Gießen, Göttingen, Heidelberg, HLL, Jülich, KIT, LMU, Mainz, MPP, TUM



- Sites: DESY, GridKa, MPP (LMU über COBaLD/TARDIS), Collaborative Services am DESY
- **Führende Rolle in der Softwareentwicklung**

(Theoretical Particle Physics)

Disclaimer: not a full picture...

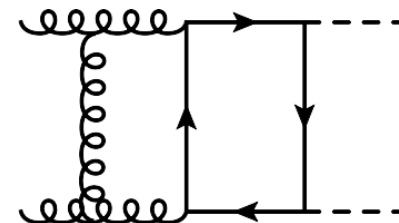
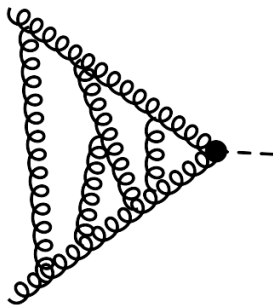
# Computing in theoretical particle physics

Many different applications with different demands on computer hardware.

Typical workflow/tasks:

- generation of amplitudes,
- processing of amplitudes (integral families, asymptotic expansions etc.)
- reduction to so-called master integrals
- analytic computation of master integrals
- numerical computation of master integrals
- real radiation/phase space integration
- ...

application (examples)	RAM	#cores (CPU)	#cores (GPU)	storage	parallelization	comments
Redution to master integrals	O(1TB)	O(20)	-	O(100GB) to O(2TB)	yes	Fast local disks necessary, e.g. NVME
Numerical evaluation of loop integrals	O(256GB)	O(10)	2-4 per node O(10-100) nodes	O(10GB)	yes	
Real radiation	O(10GB)	O(50.000)- O(100.000)	-	O(1-2TB)	yes	



# Theoretical Particle Physics

## Computing Needs

up to  $\sim 100.000$  cores  
for certain calculations

Typically done at  
HPC centers

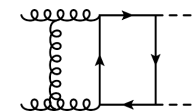
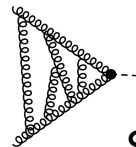
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Slide from Matthias Steinhauser, KIT

## Challenge: Data Storage and Management

Datasets approaching size of several PB

Long term storage strategy?

Data Management and availability at analysis sites?

## A Summary

### FAIR

- Becoming operational in the HL-LHC timeframe
- FAIR Tier-0 in Germany at GSI
- Tight integration of Online Computing and Tier-0
- Resources: ~3M HS06 + online,  
170PB disk, 38PB tape/year (single replica)

### Belle II

- Resources at HL-LHC timeframe:  
~3-4M HS06, ~300PB disk
- German membership ~20%,  
strong German computing contribution

### (Theoretical Particle Physics)

- HPC for computation; main challenge data storage and management

#### Common

Leading  
German role in  
software  
development