The Compressed Baryonic Matter experiment

Estrellas de Neutrones en el laboratorio

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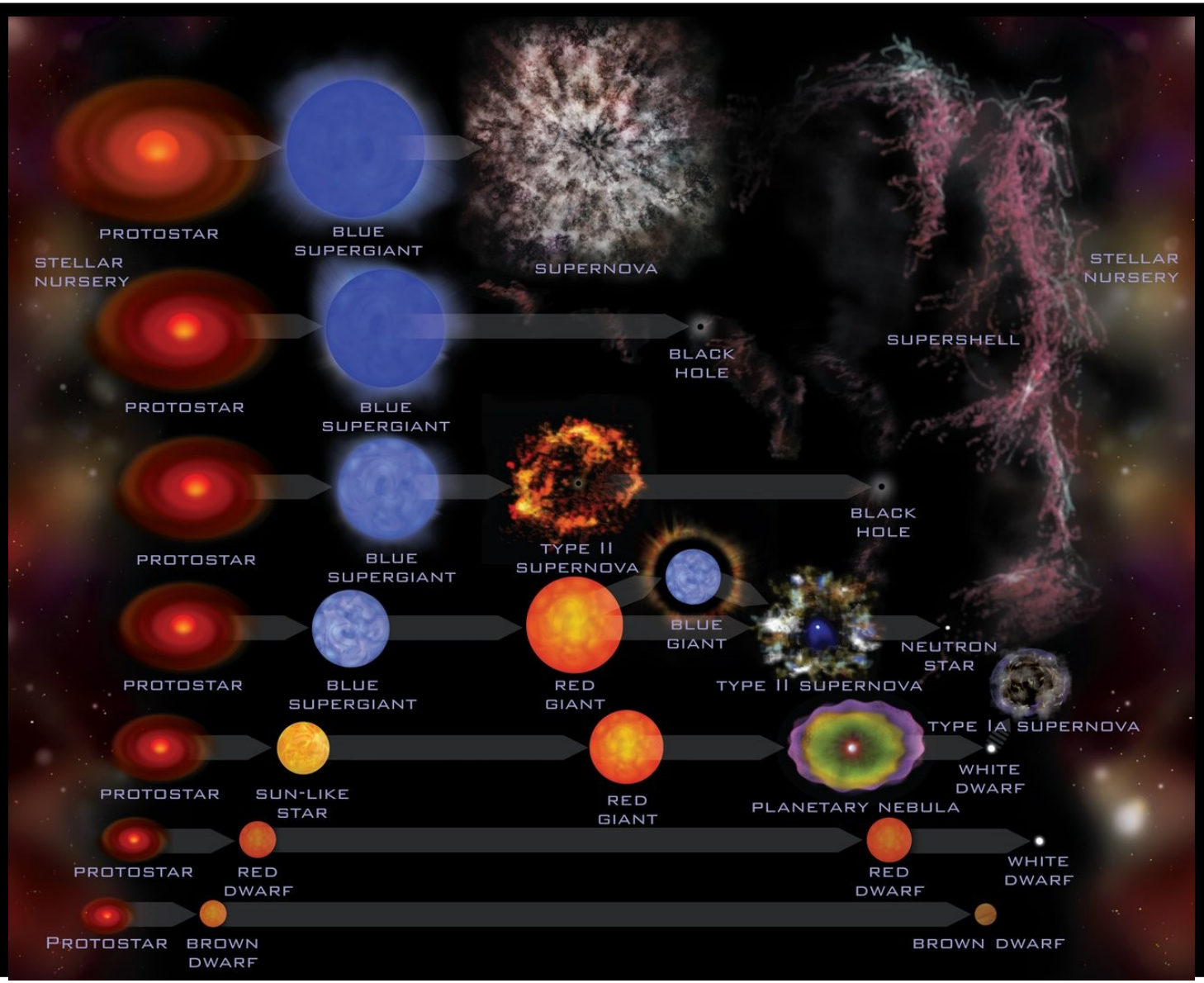
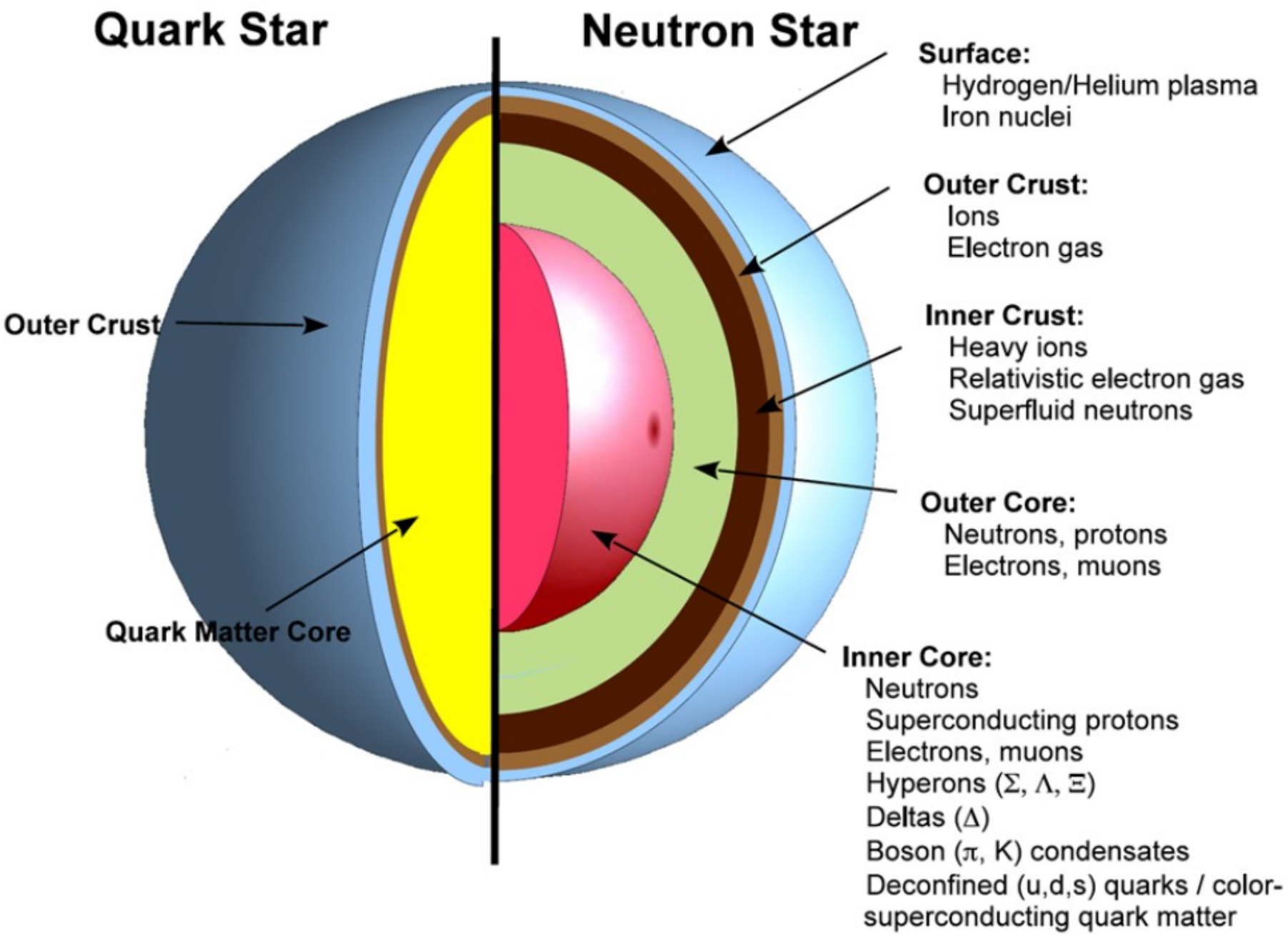
WUPPERTAL

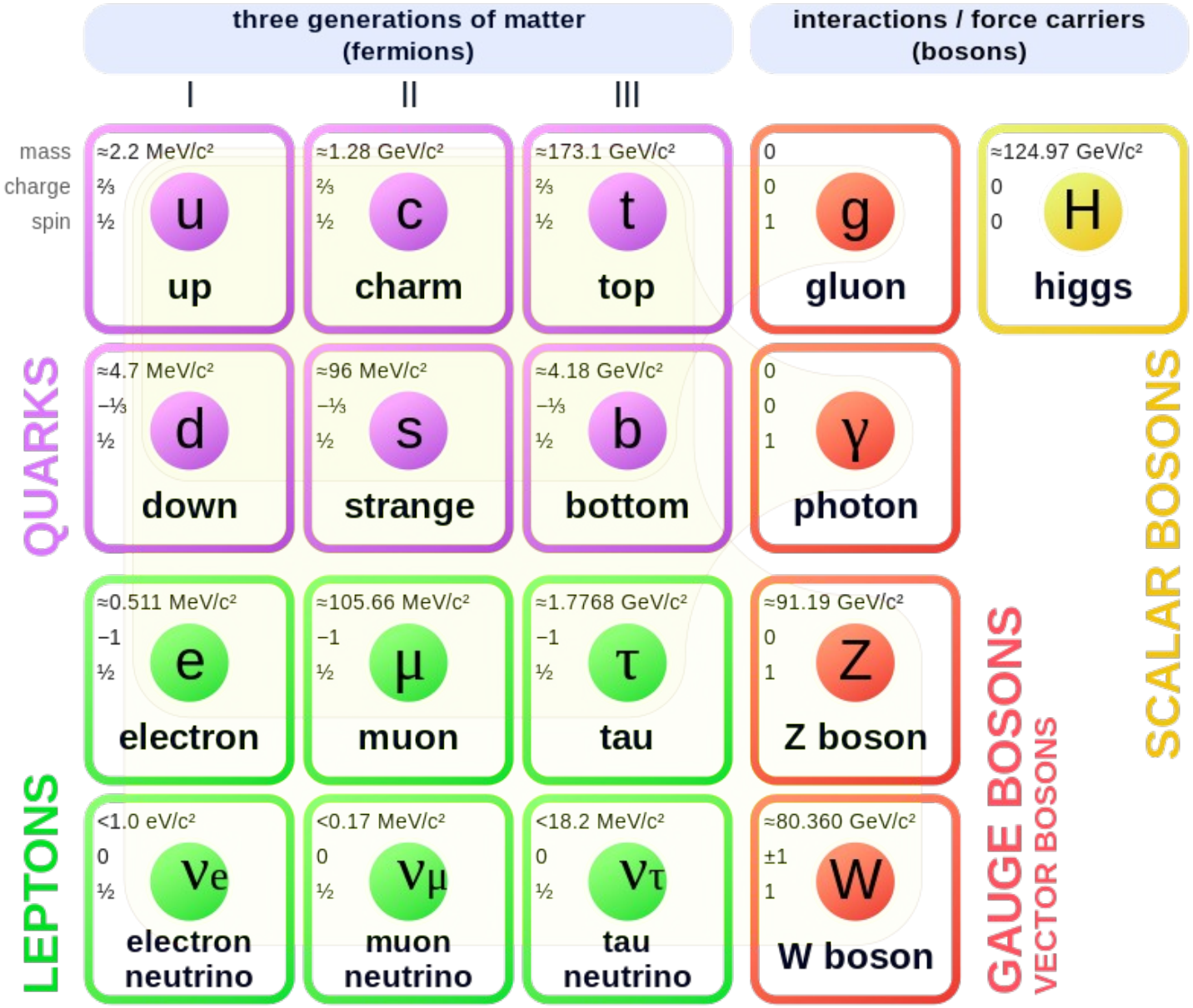
Evolución estelar



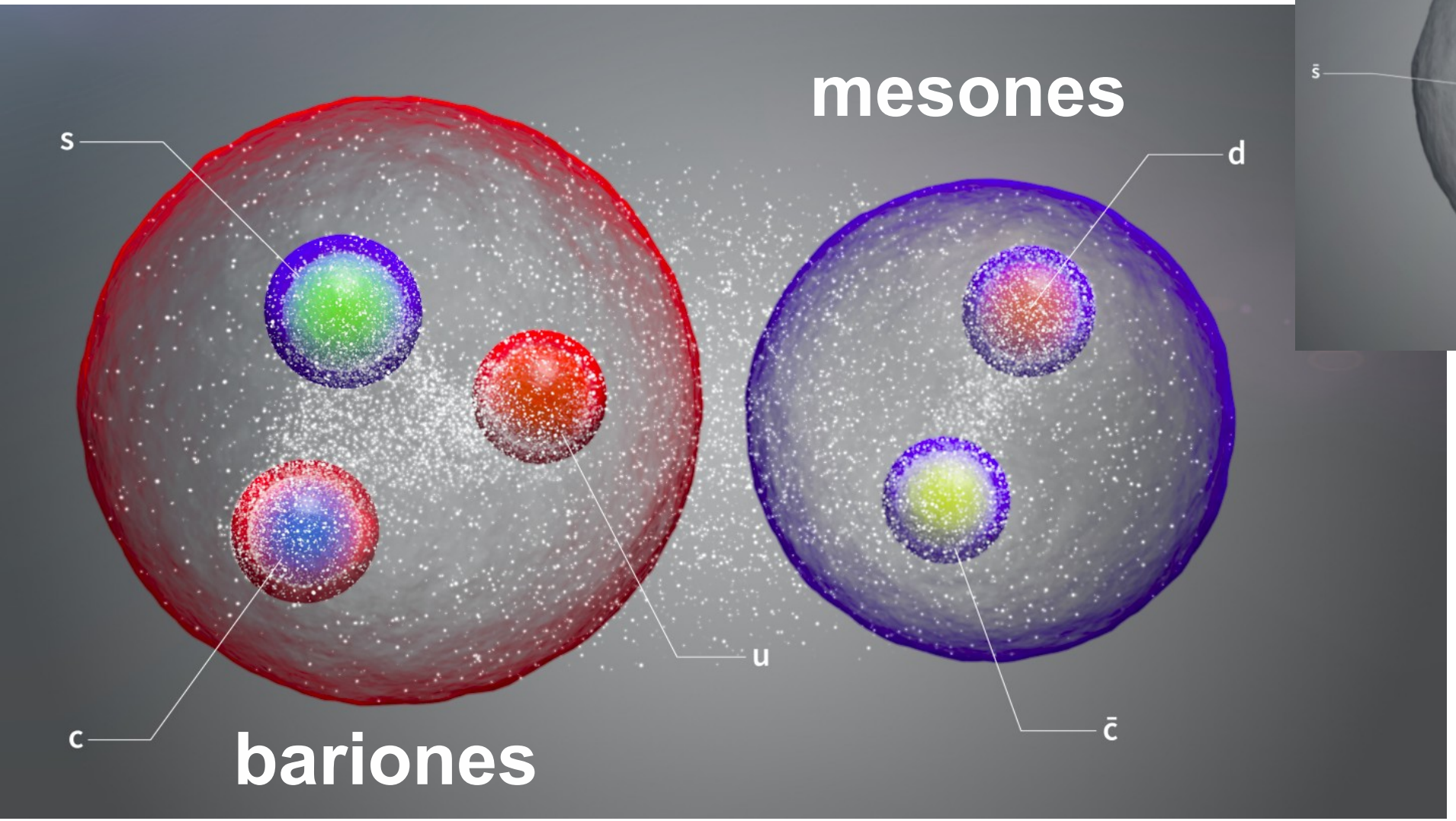
www.jpl.nasa.gov/infographics/stellar-evolution

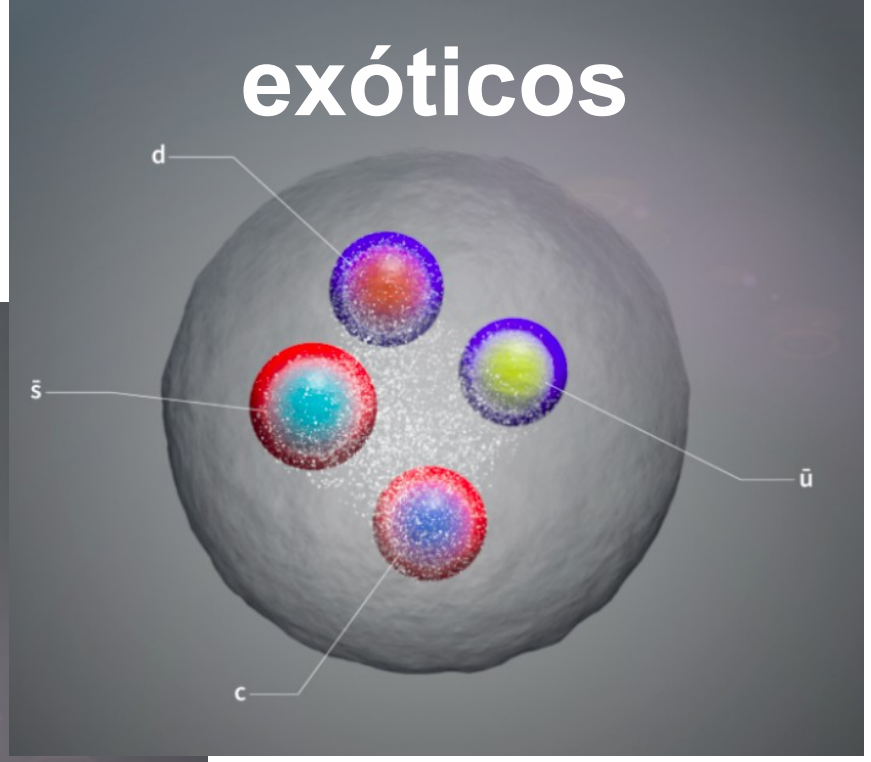

Quark Star
Neutron Star
Surface:
Hydrogen/Helium plasma
Iron nuclei
Outer Crust:
Ions
Electron gas
Inner Crust:
Heavy ions
Relativistic electron gas
Superfluid neutrons
Outer Core:
Neutrons, protons
Electrons, muons
Inner Core:
Neutrons
Superconducting protons
Electrons, muons
Hyperons (Σ, Λ, Ξ)
Deltas (Δ)
Boson (π, K) condensates
Deconfined (u,d,s) quarks / color-superconducting quark matter
Outer Crust
Quark Matter Core

Modelo estándar



Hadrones

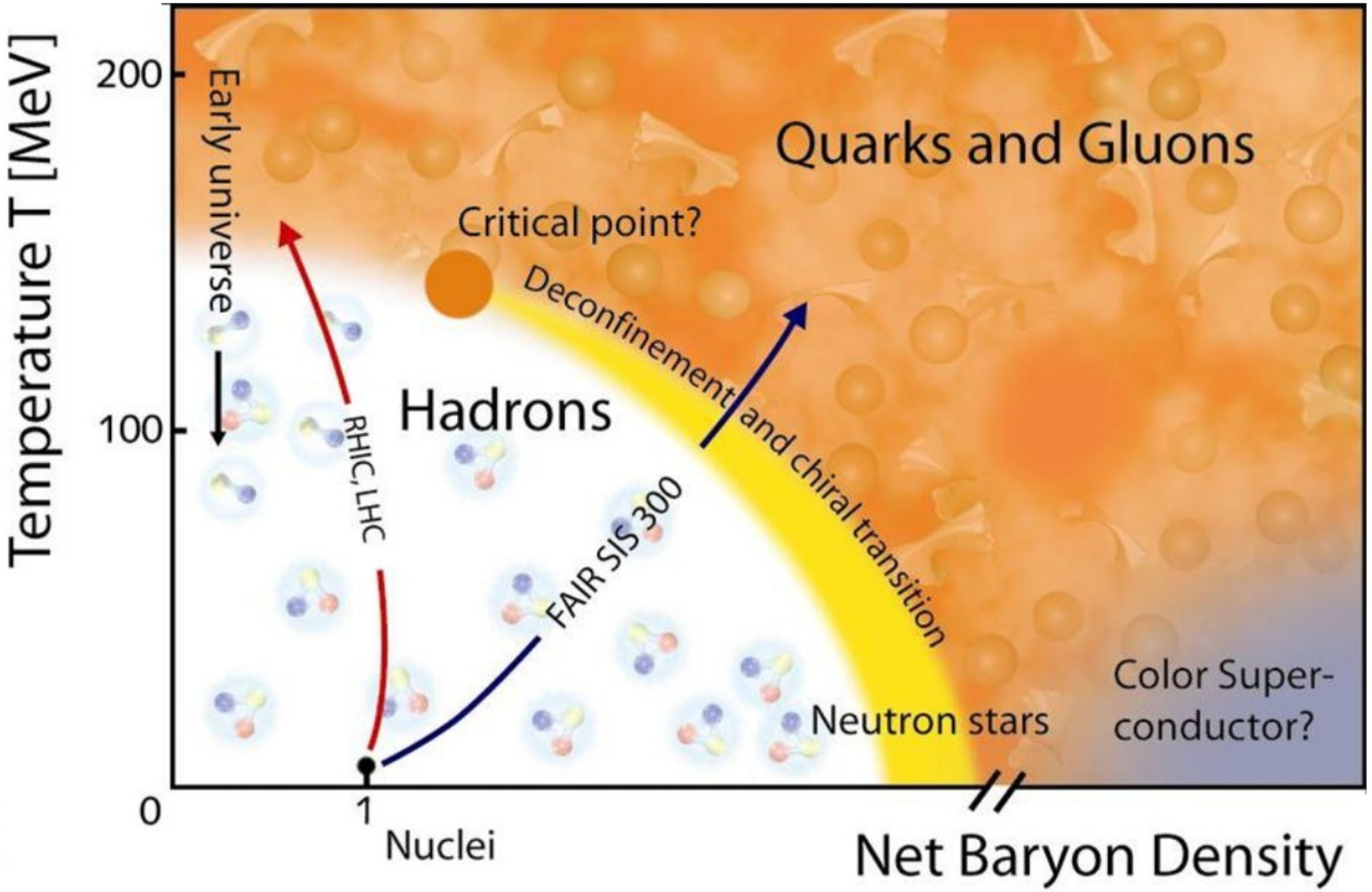


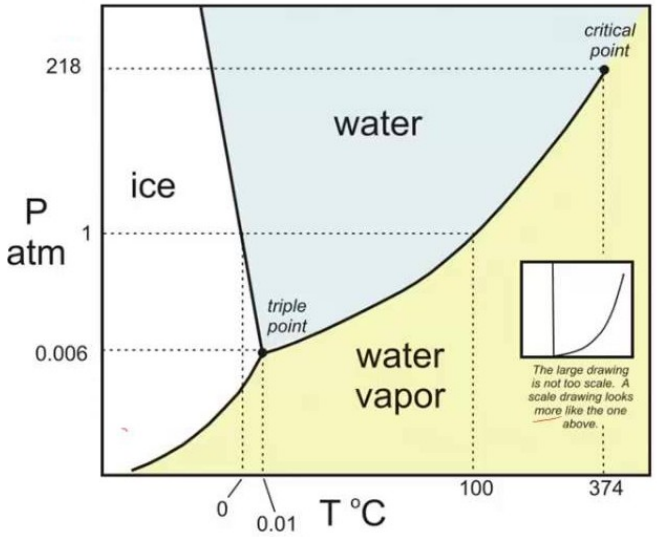


https://home.cern/news/news/physics/lhcb-discovers-three-new-exotic-particles

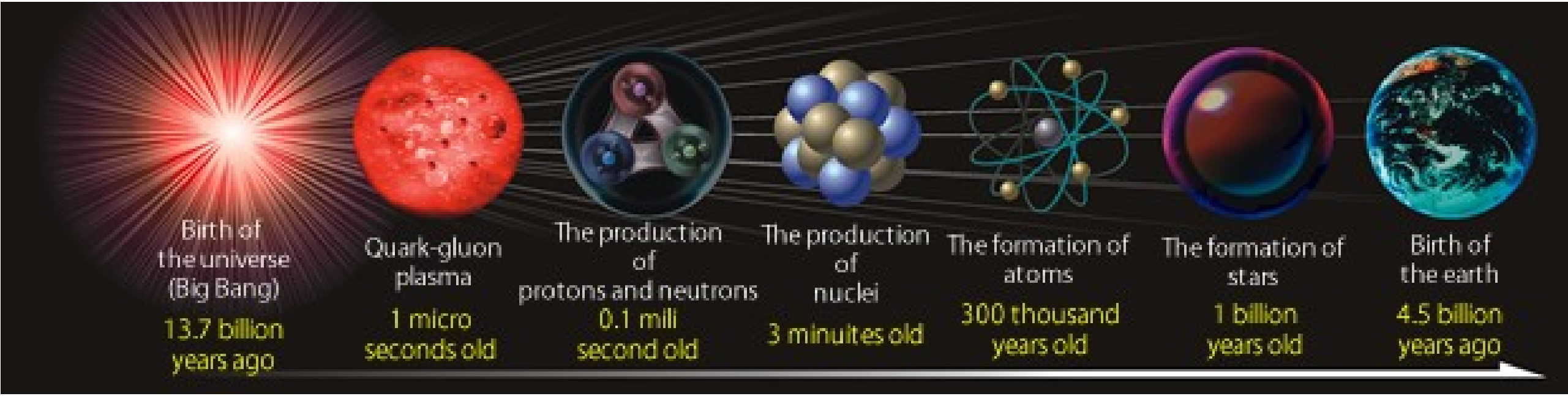
Hadrons			
Mesons Quark-antiquark states		**Baryons** Three-quark states	
π/ρ	$u\bar{d}/\bar{u}d/(u\bar{u}-d\bar{d})$	Proton(p), neutron(n)	uud, udd
η/φ	$(u\bar{u}-d\bar{d}+s\bar{s})$	Δ^{++}, Δ^{-}	uuu, ddd
$K^0, \bar{K}^0$	$d\bar{s}, \bar{d}s$	Λ^0	uds
K^+, K^-	$u\bar{s}, \bar{u}s$	Λ_c	udc
$D^0, \bar{D}^0$	$c\bar{u}, \bar{c}u$	Σ^0	uds
D^+, D^-	$c\bar{d}, \bar{c}d$	Σ^+, Σ^-	uus, dds
B^0, B_1^0	$d\bar{b}, \bar{s}b$	Ξ^0	uss
B^+, B^-	$u\bar{b}, \bar{u}b$	Ξ^-	dss
J/ψ	$c\bar{c}$	Ω^-	sss

Diagrama de fase de QCD





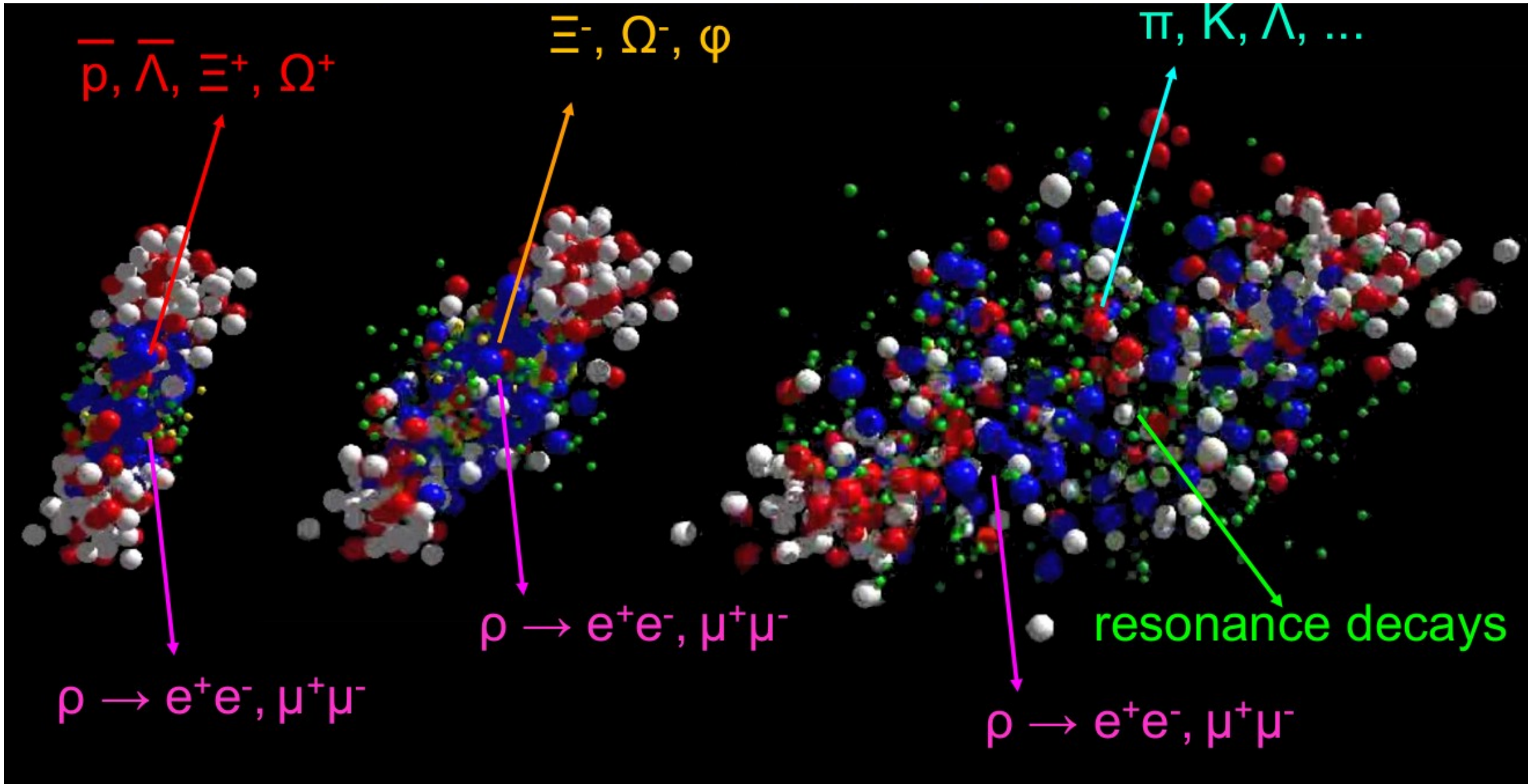
Universo temprano



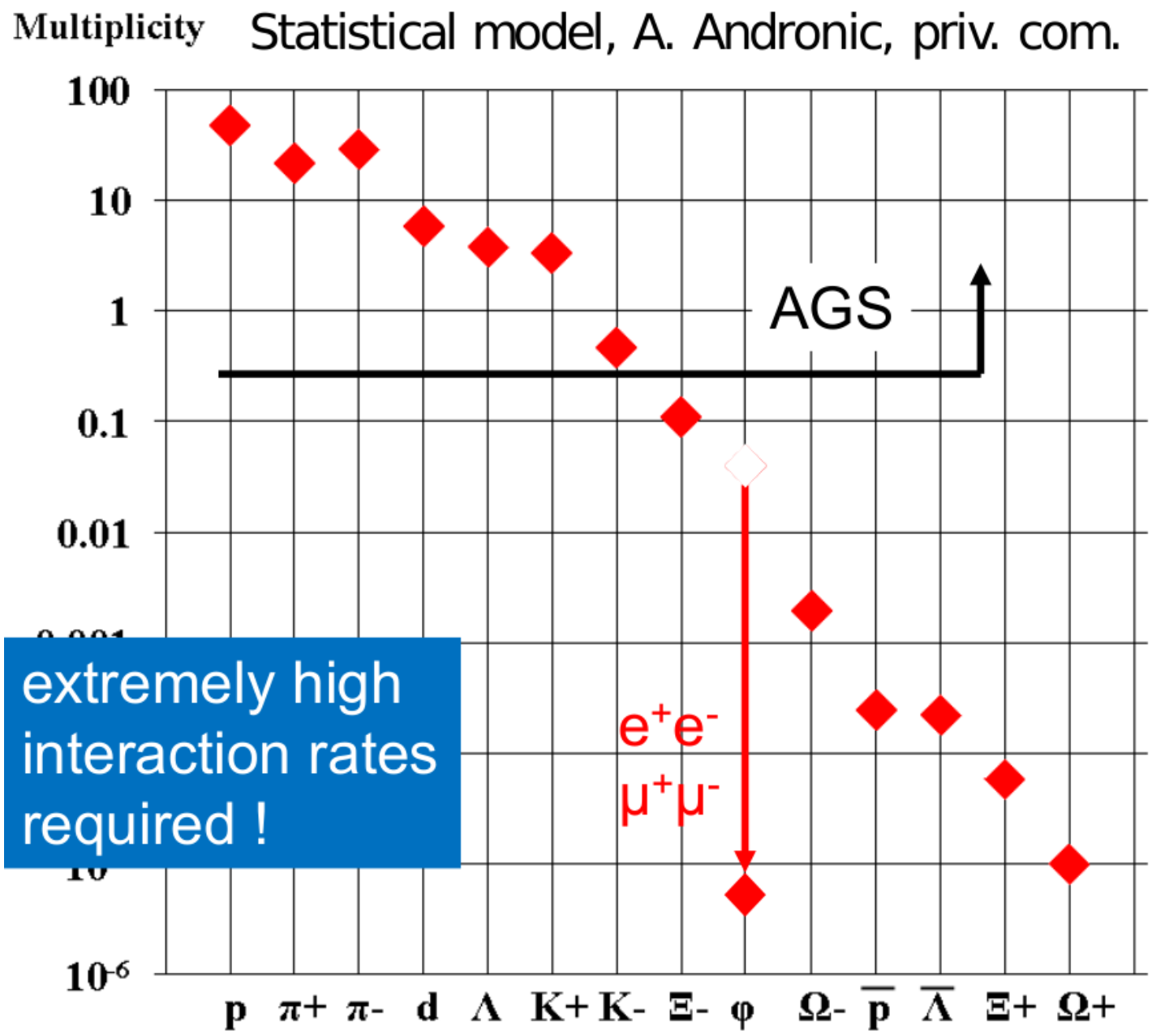
https://j-parc.jp/Hadron/en/index.html

¡Vamos al laboratorio!

Colisionando núcleos pesados

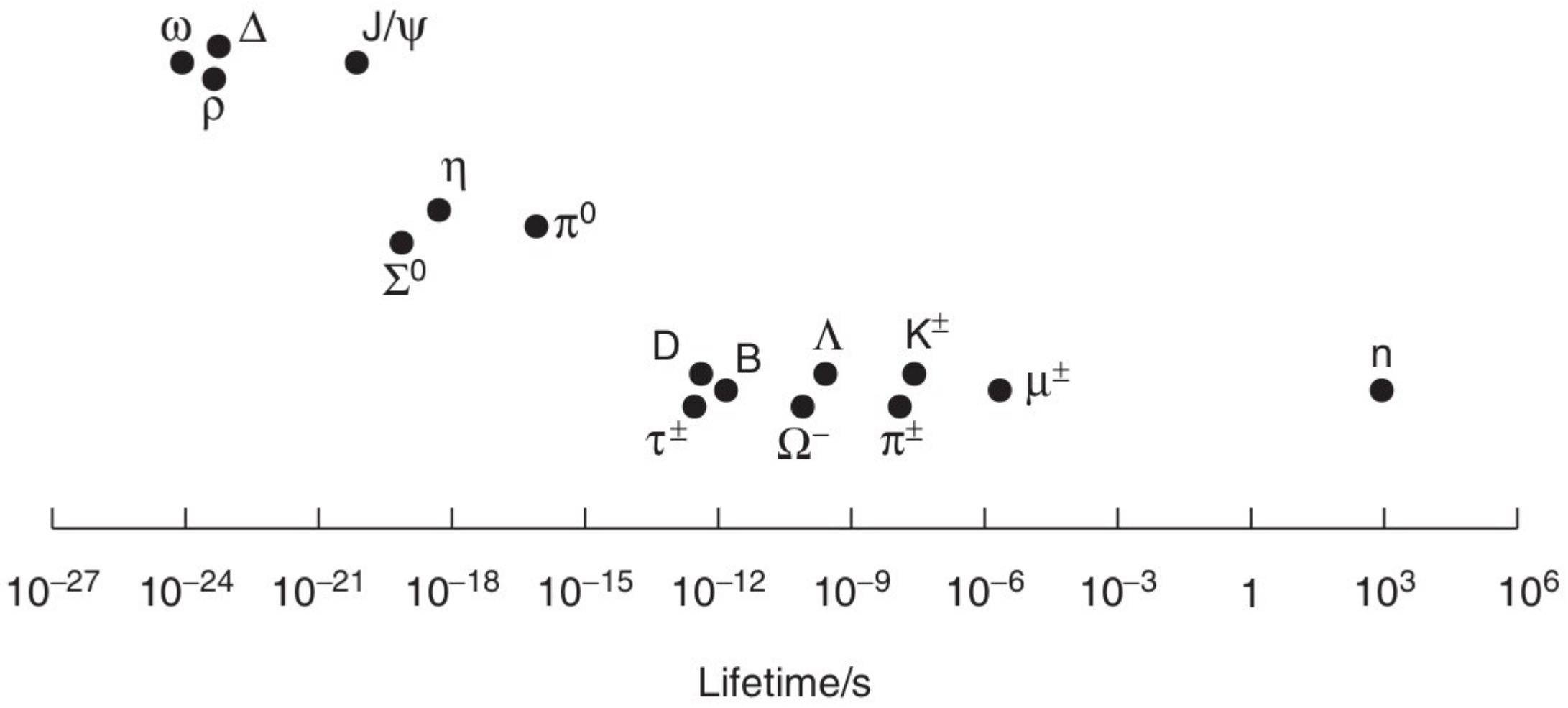


Multiplicidad

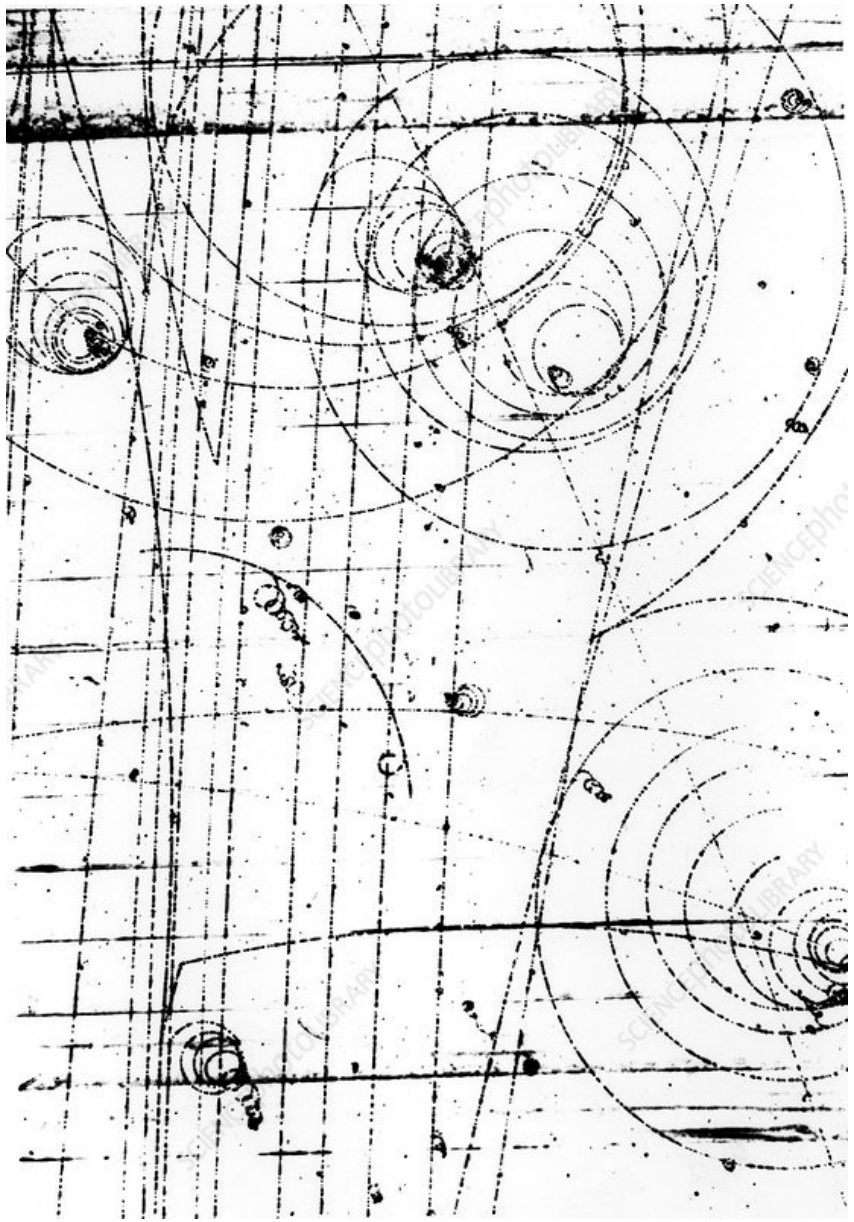


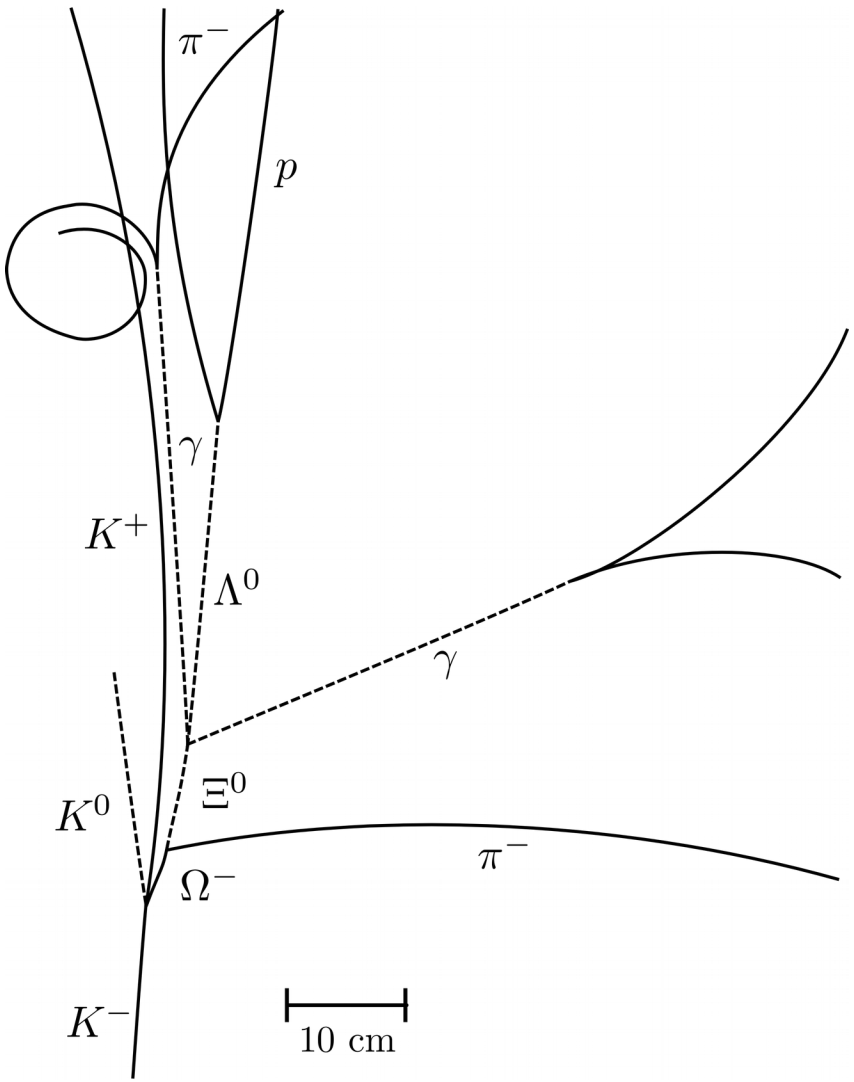
extremely high interaction rates required !

Tiempo de vida



Mensajeros

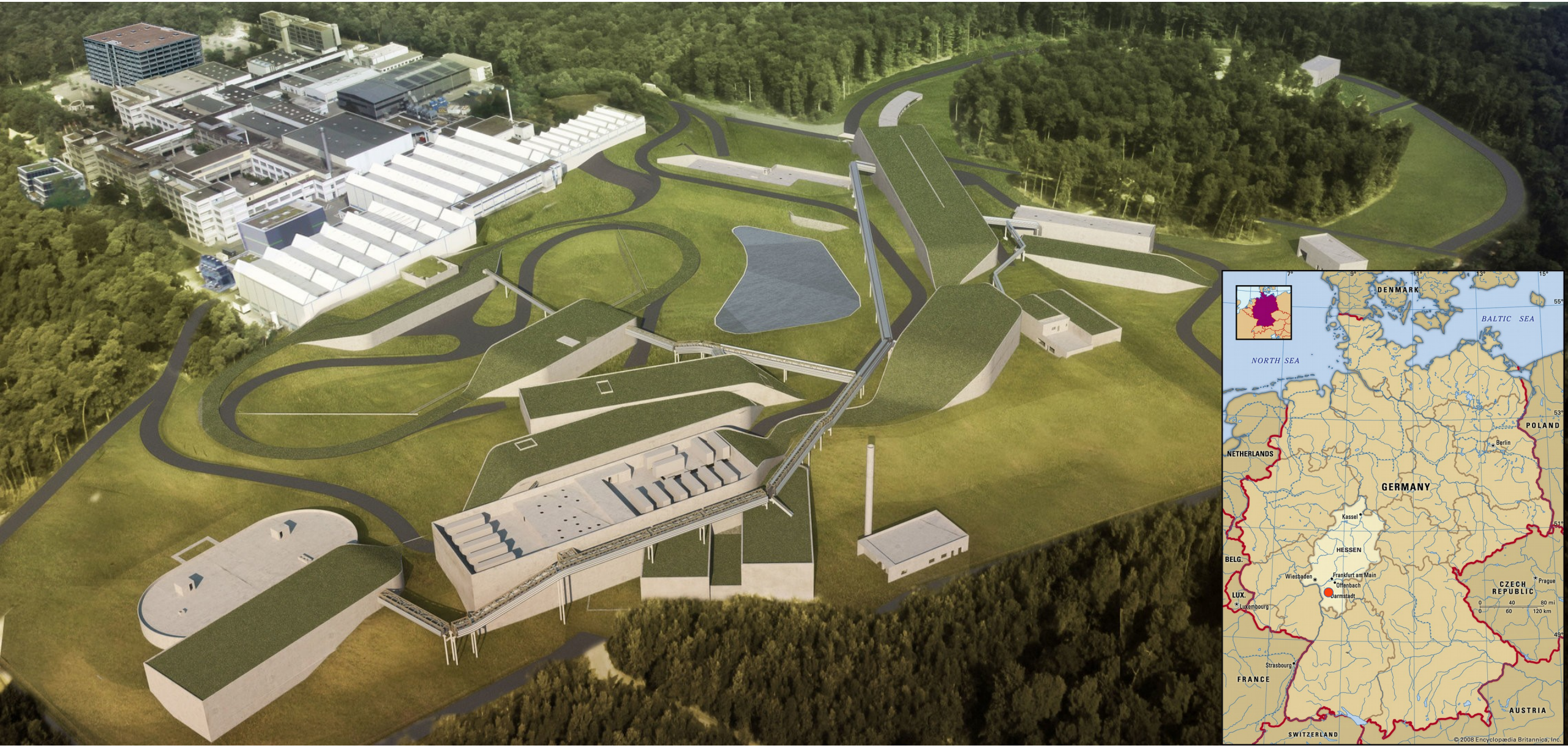




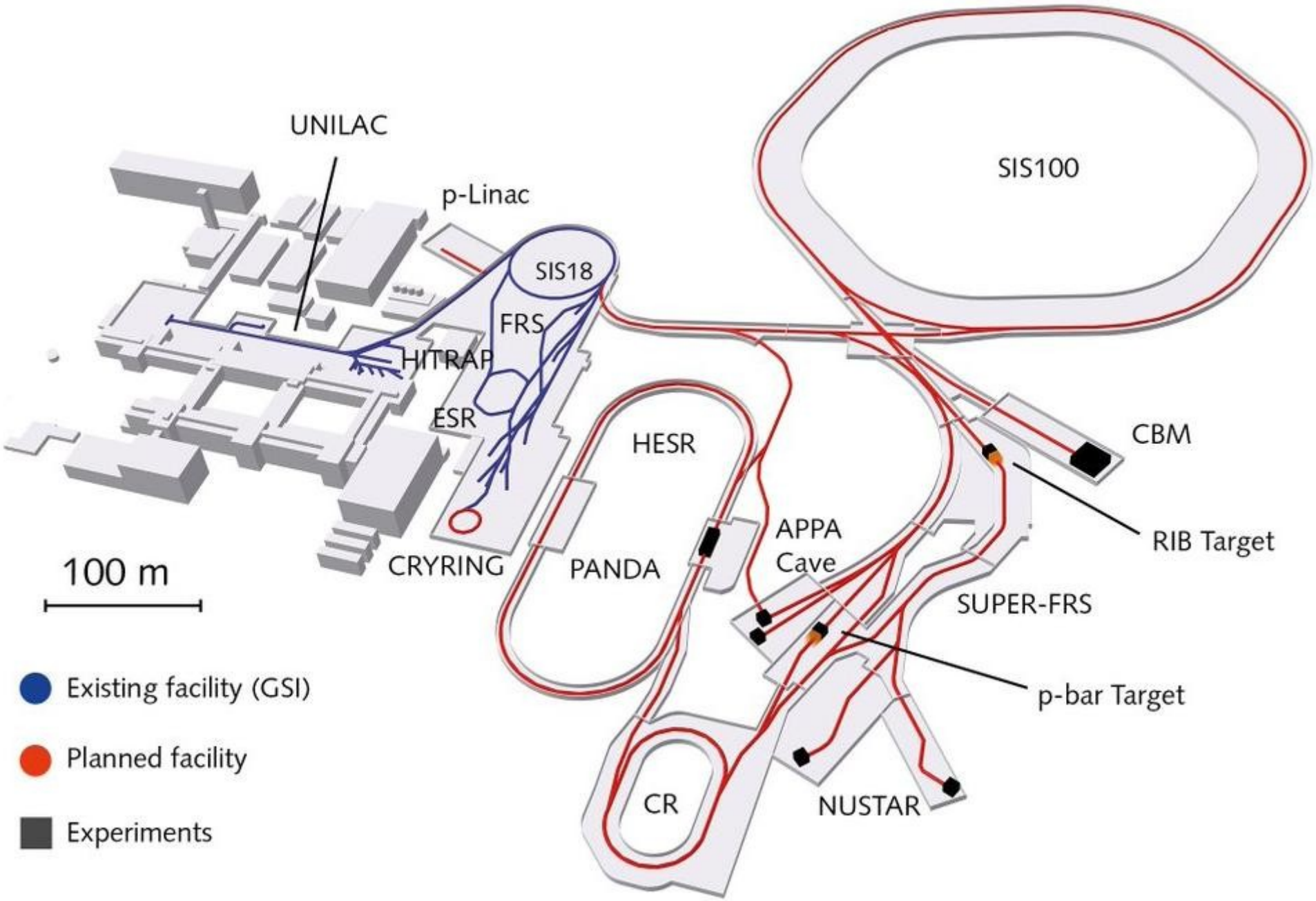
Requerimientos experimentales

- 10^5-10^7 interacciones Au + Au por segundo
- Medición de vértices con $\sigma \approx 50$ um
- Identificación de hadrones y leptones
- Detectores de respuesta rápida (10^{-9} – 10^{-10} s)
- Detectores inmunes a la radiación
- Electrónica de lectura automática
- Adquisición de datos de alta velocidad
- Selección *on-line* de eventos
- Reconstrucción 4D de eventos

CBM en FAIR (Facility for Antiproton and Ion Research)

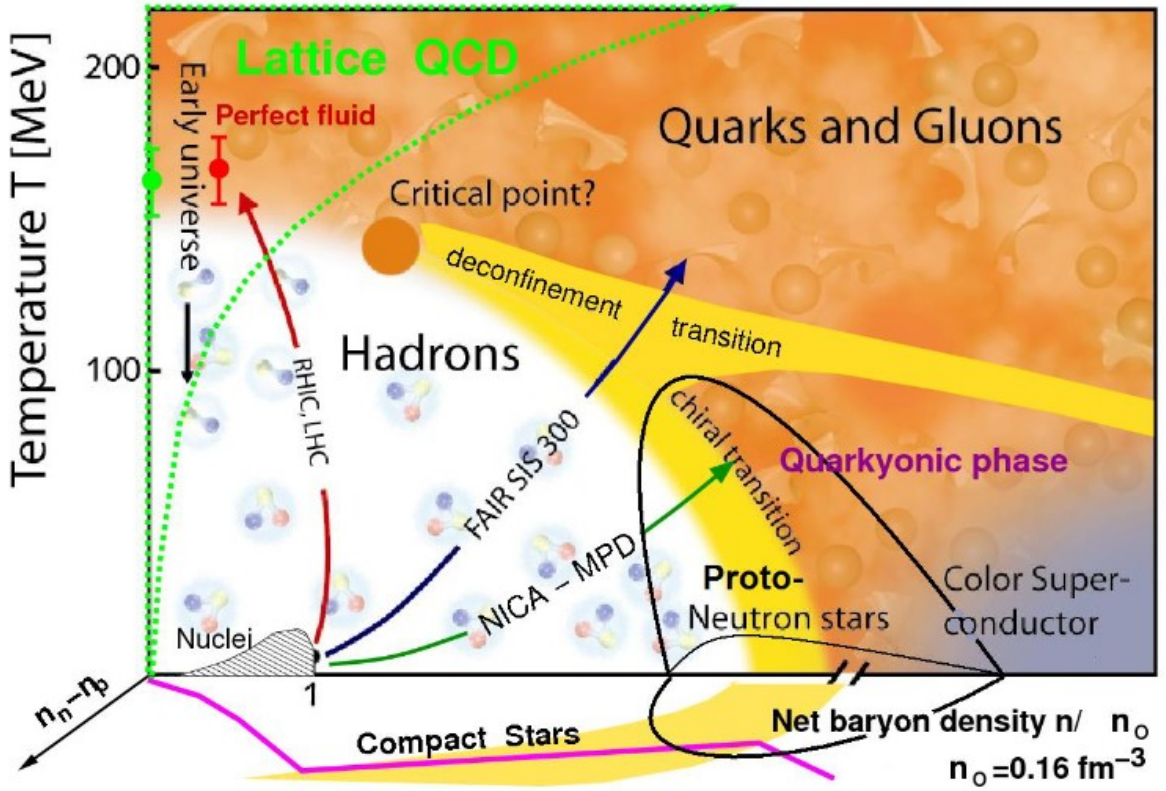


FAIR


UNILAC
p-Linac
SIS18
FRS
HITRAP
ESR
CRYRING
HESR
PANDA
SIS100
CBM
RIB Target
APPA
Cave
SUPER-FRS
p-bar Target
NUSTAR
CR
100 m
Existing facility (GSI)
Planned facility
Experiments

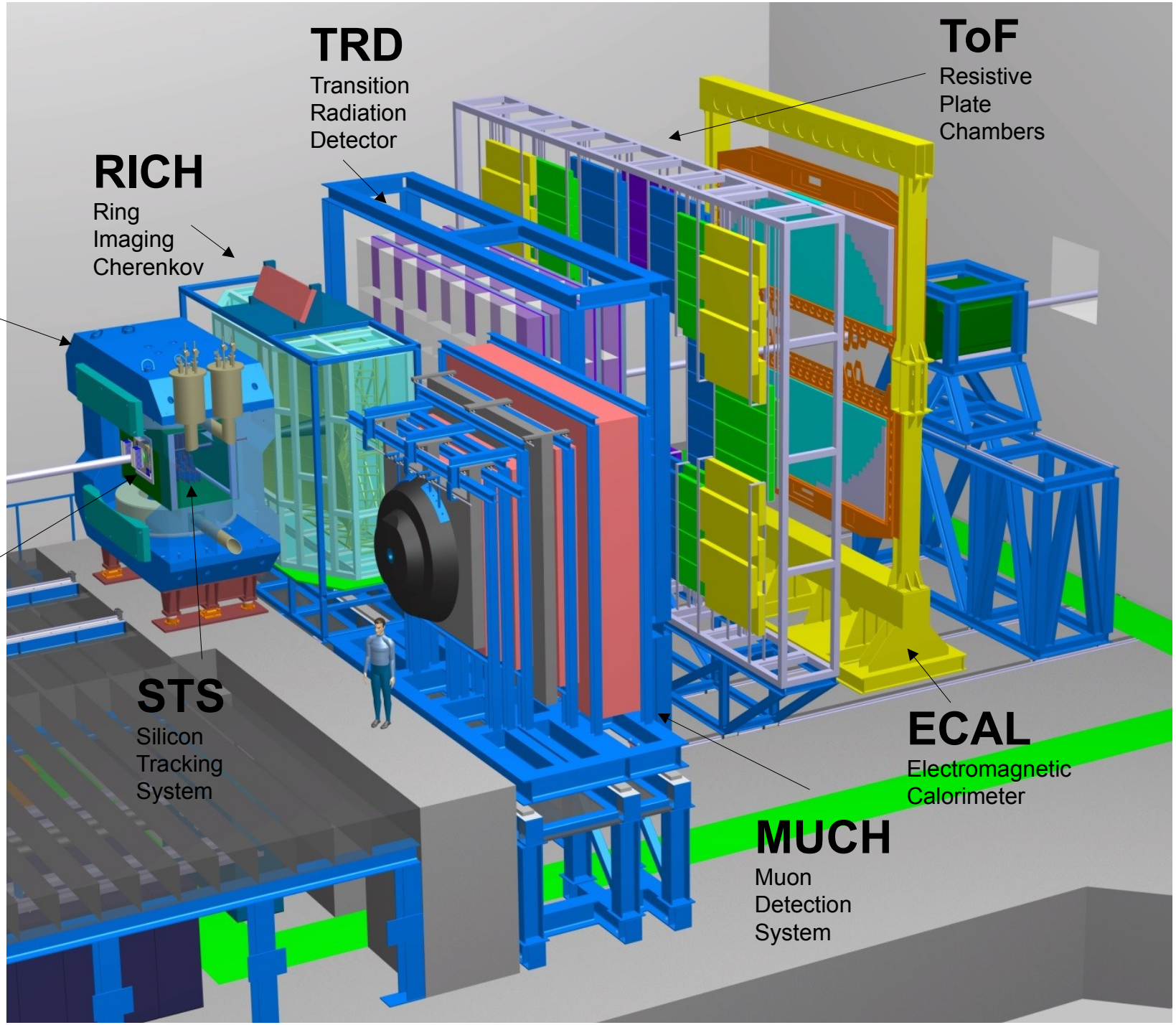
Objetivo de CBM

Explorar el diagrama de fase de QCD en la región de alta densidad bariónica usando colisiones núcleo-núcleo de alta energía.



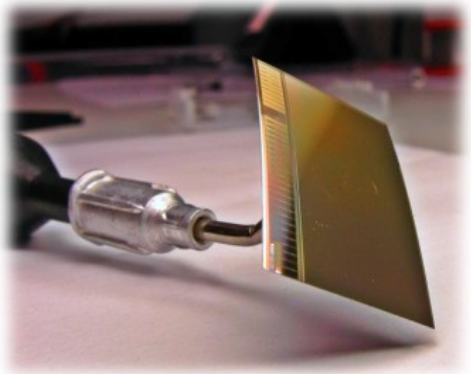
V. Friese. CBM: Experiment, Physics and Trigger. 2018

CBM


TRD
Transition
Radiation
Detector
ToF
Resistive
Plate
Chambers
RICH
Ring
Imaging
Cherenkov
Dipole
magnet
MVD
Micro
Vertex
Detector
STS
Silicon
Tracking
System
ECAL
Electromagnetic
Calorimeter
MUCH
Muon
Detection
System

Micro Vertex Detector (MVD)

Task: determination of secondary vertices of open charm decays ($\tau = 10^{-12}$-10^{-13} s)



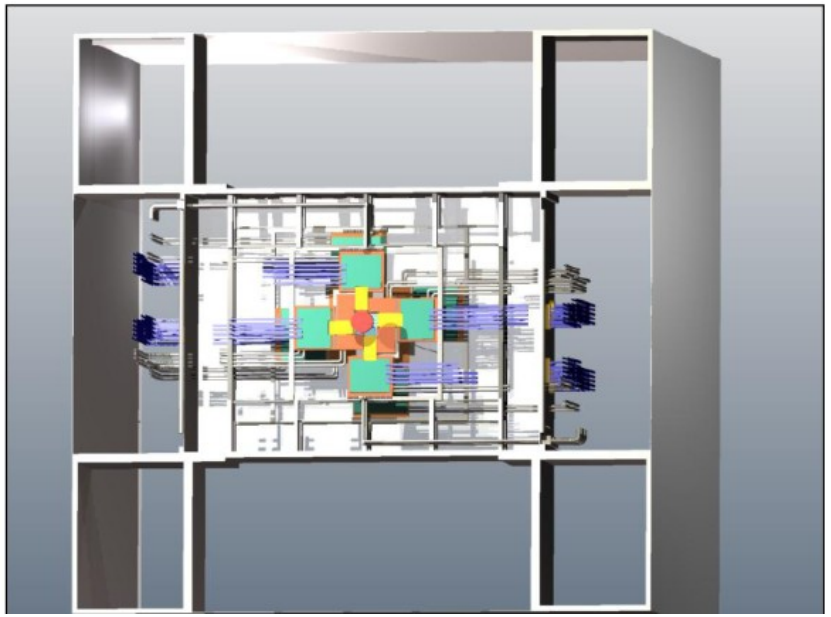
Monolithic Active Pixel Sensors (MAPS)

MIMOSA-26 :
600 kPixel, 10^4 frames/s, zero suppression
thinned to 50µm, at IKF Frankfurt

Micro Vertex Detector:

- Pixel size about 20x20 μm^2
- Position resolution σ = 4 µm
- Vertex resolution 50-100 µm (beam axis)
- Total material budget 300 – 500 µm silicon equivalent
- 3 stations at 5, 10, 15 cm from target

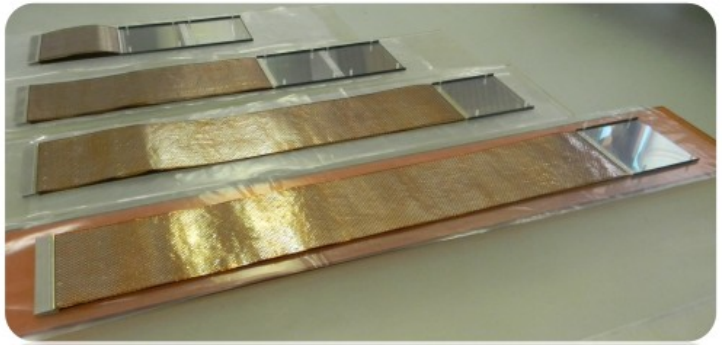
Univ. Frankfurt, IPHC Strasbourg



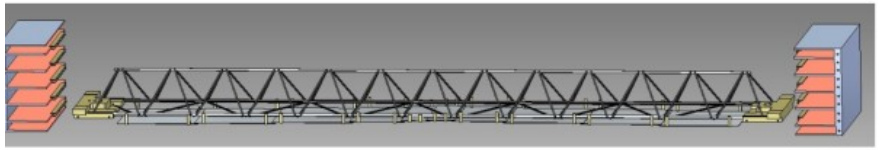
Silicon Tracking System (STS)

Silicon sensors:
double-sided micro-strips,
1024 strips on each side,
58 μm pitch, stereo angle 0°, 7.5°
width 60 mm, height 20, 40, 60 mm

Micro cables from sensors to FEBs

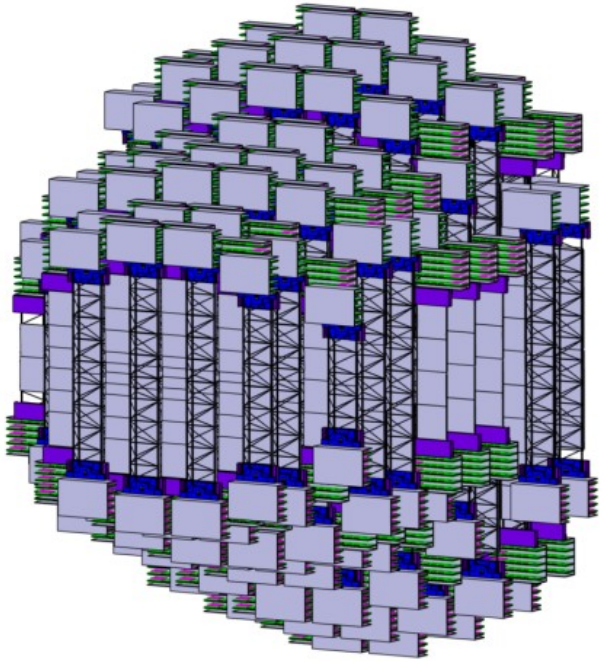


Light weight carbon fibre ladders

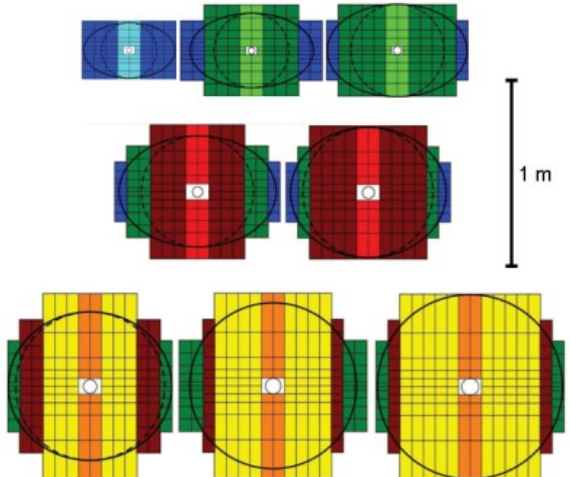


ASIC:
free streaming, hits with time stamp

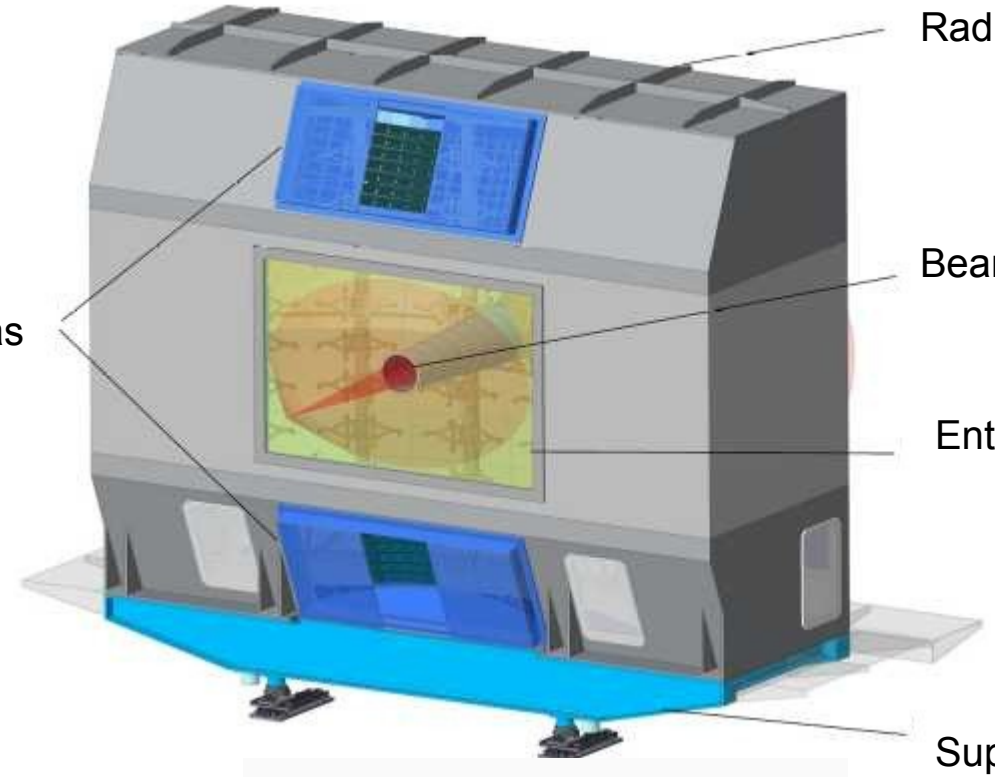
FEB cooling: CO_2



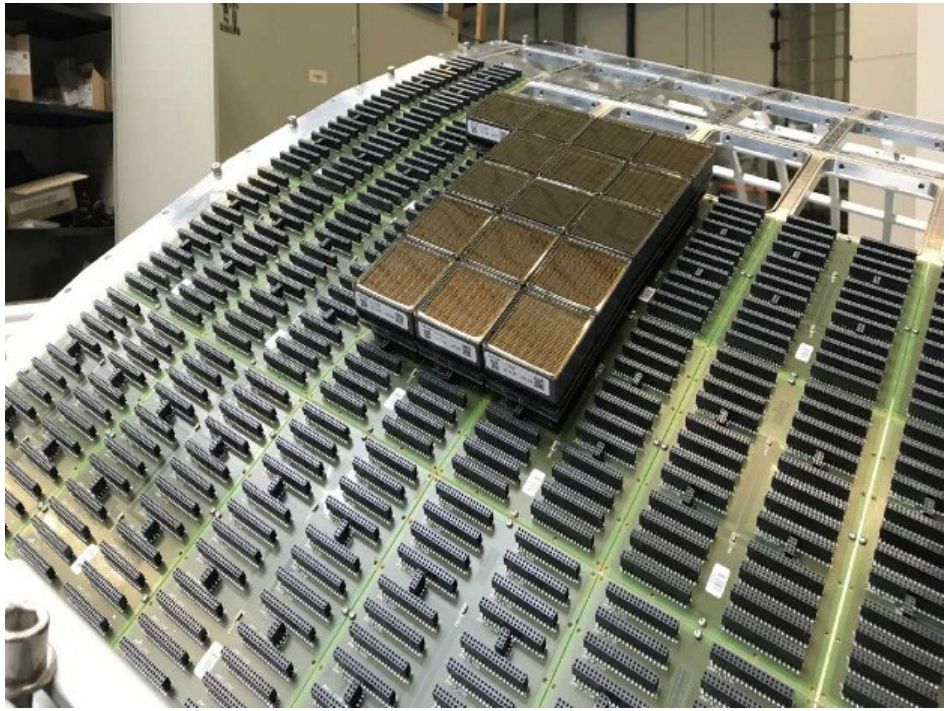
8 STS stations, distance from target 30–100 cm



Ring Imaging Cherenkov (RICH)



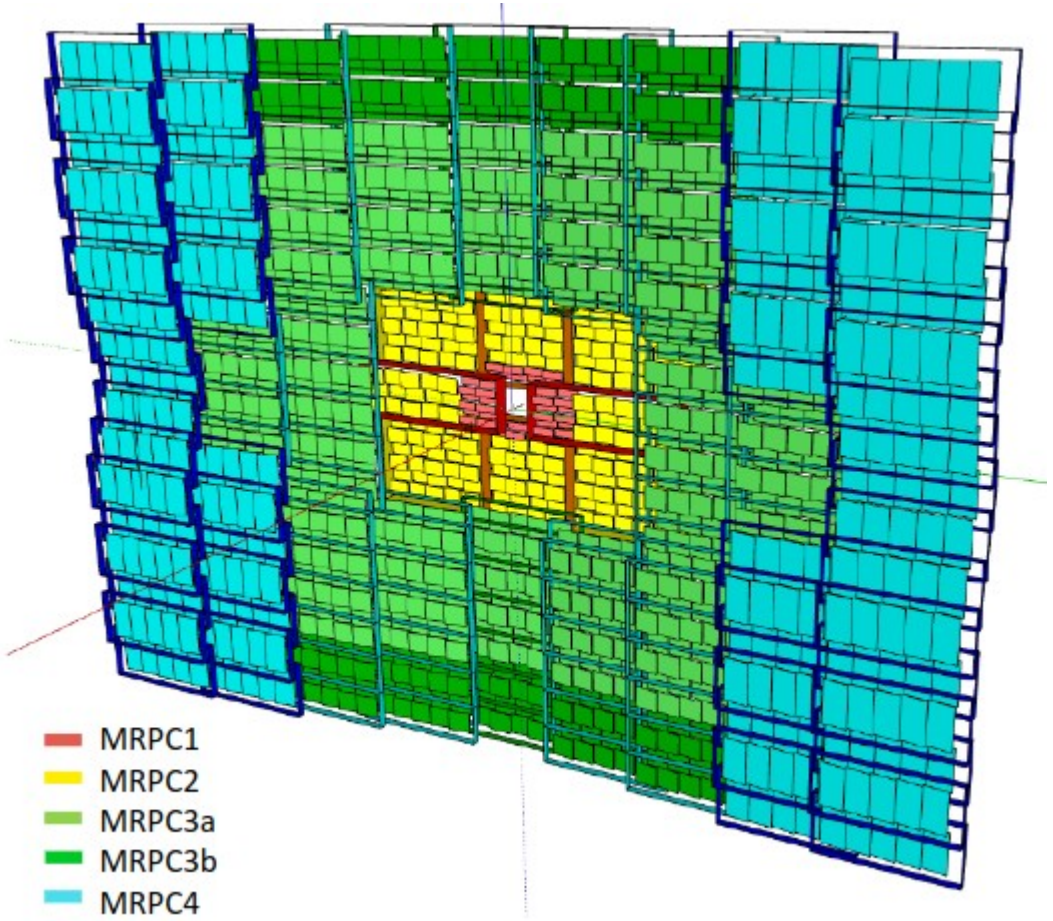
55000 channels
30 m³ CO2 gas
Multi-Anode PMTs

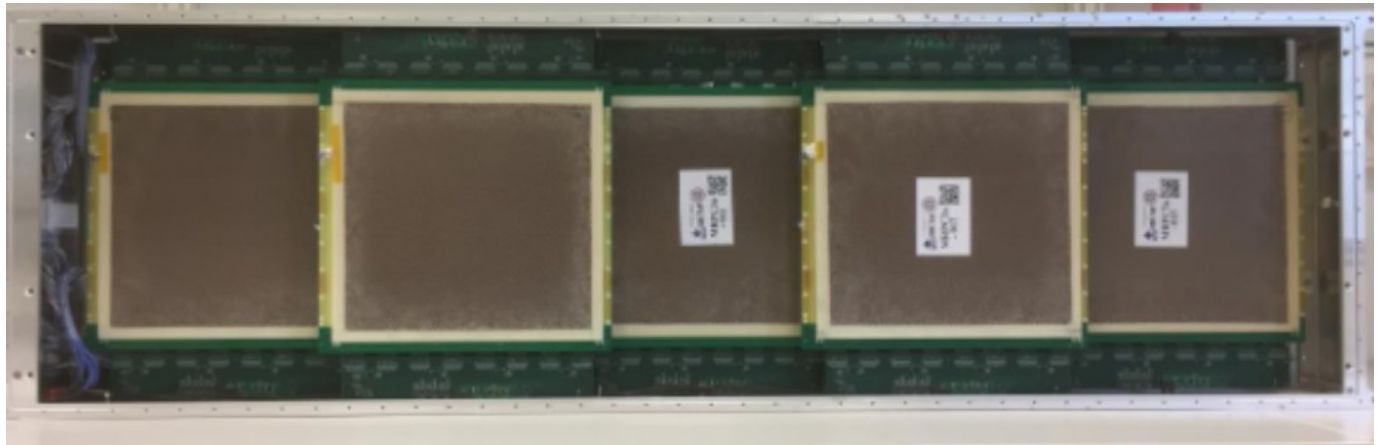


Time of Flight (ToF)

Counter properties

- Active area 300 – 864 cm^2
- Granularities 10 – 27 cm^2
- Low resistive glass
- Rate capability > 30 kHz/cm^2
- Time resolution about 50 ps
- Efficiencies above 95 %





Transition Radiation Detector (TRD)

General TRD layout

Four detector layers

Radiator: PE foam-foil arrangement

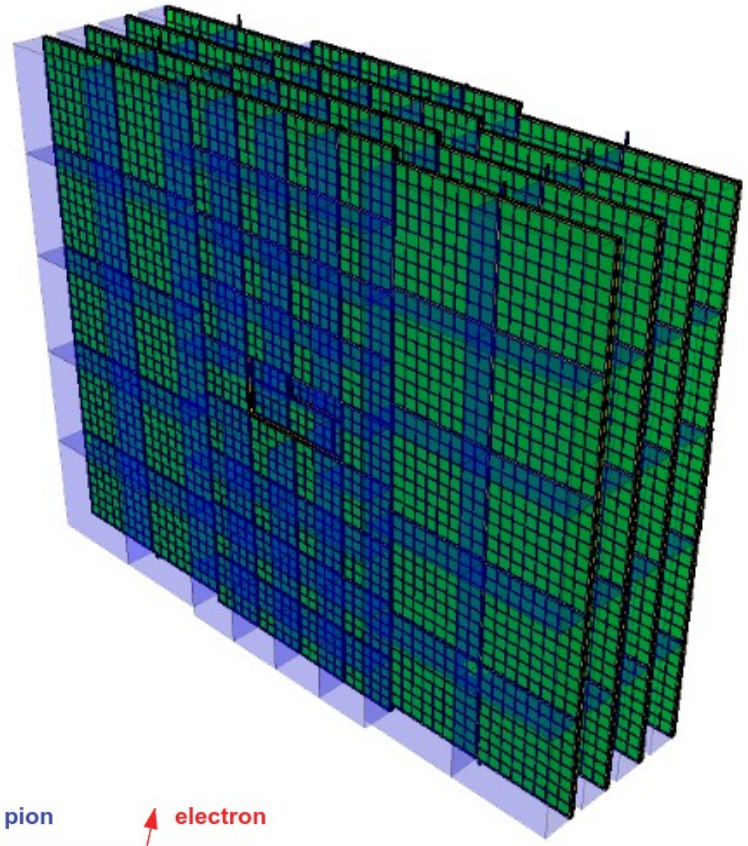
Readout: MWPCs (3.5 + 3.5 + 5.0 mm)

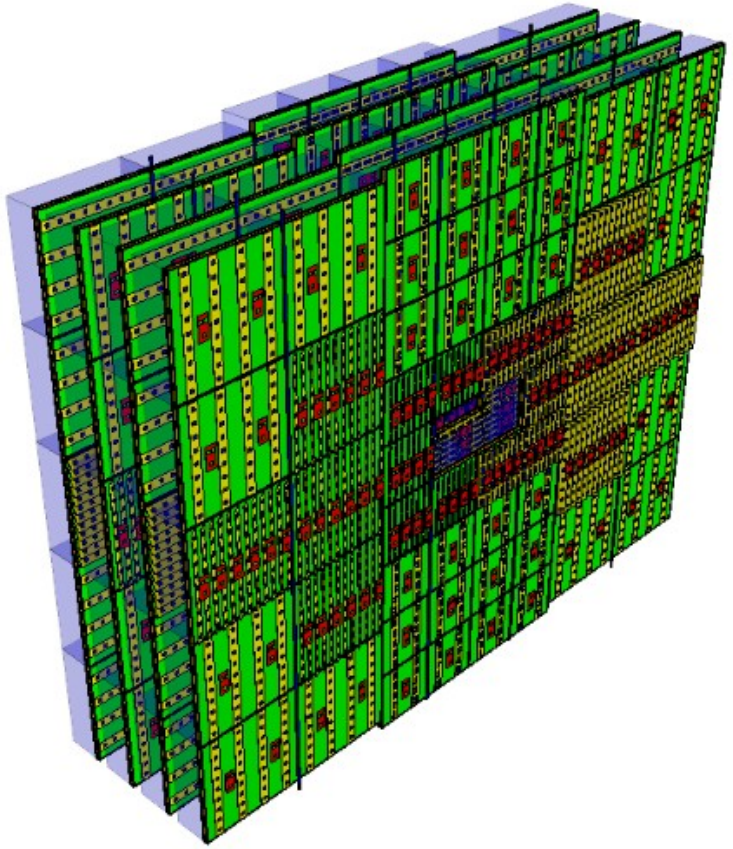
200 detector modules in total (radiator + MWPC
in two different sizes (57 × 57 cm² and 95 × 95

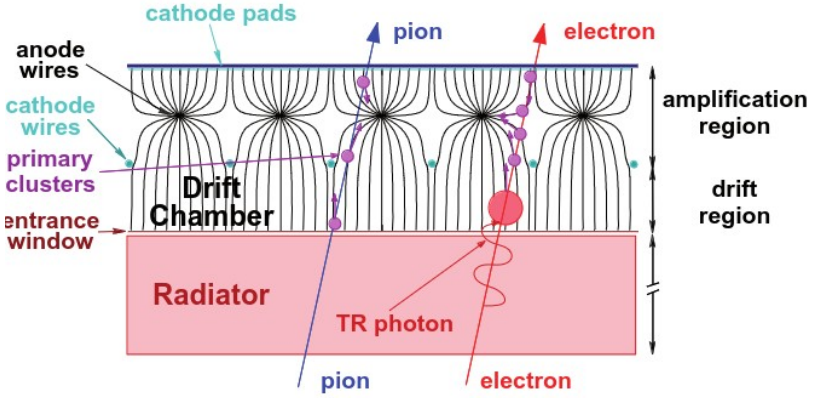
Six different pad plane layouts
(pad areas between 1 cm² and 11 cm²)

Readout with online data reduction
+ feature extraction (SPADIC)

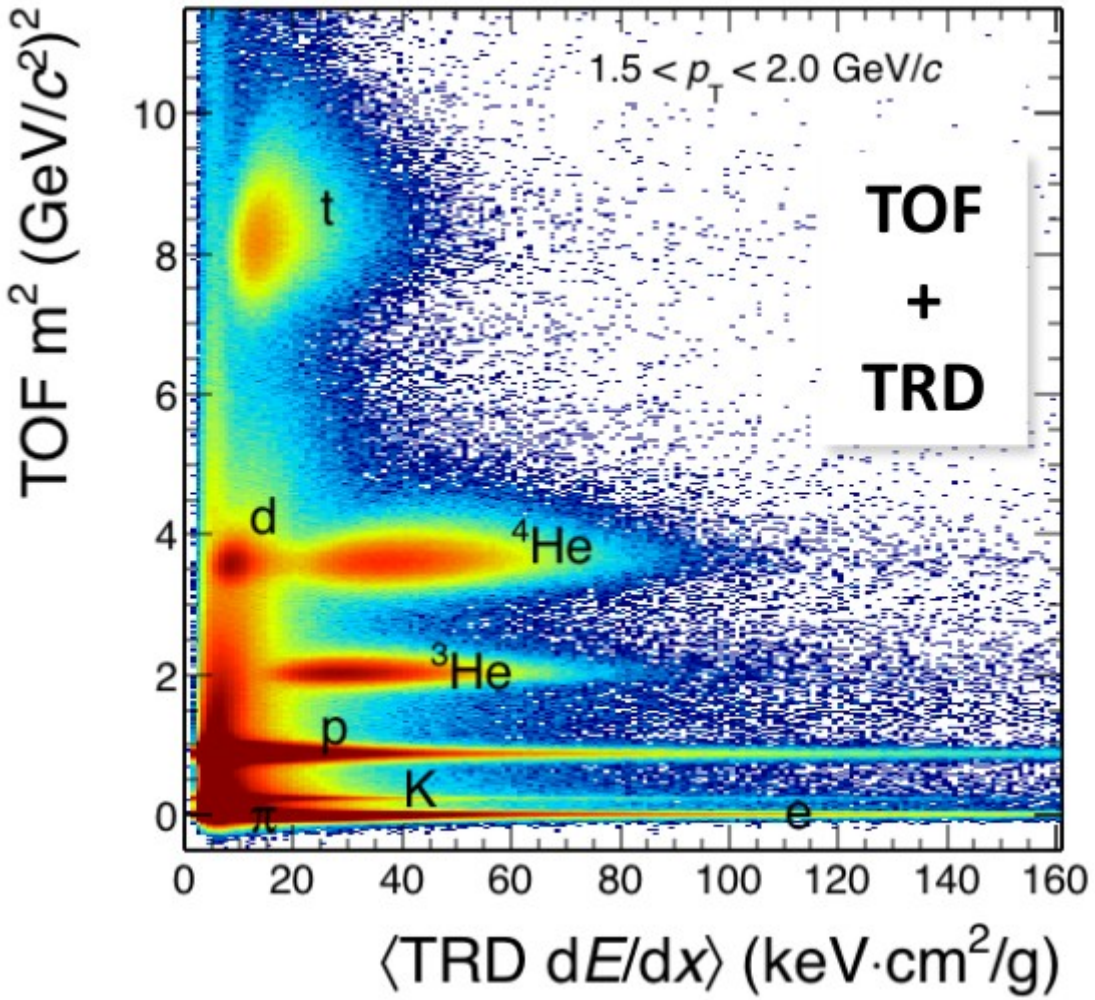
Movable along beam direction
to fit TRD into different CBM setups

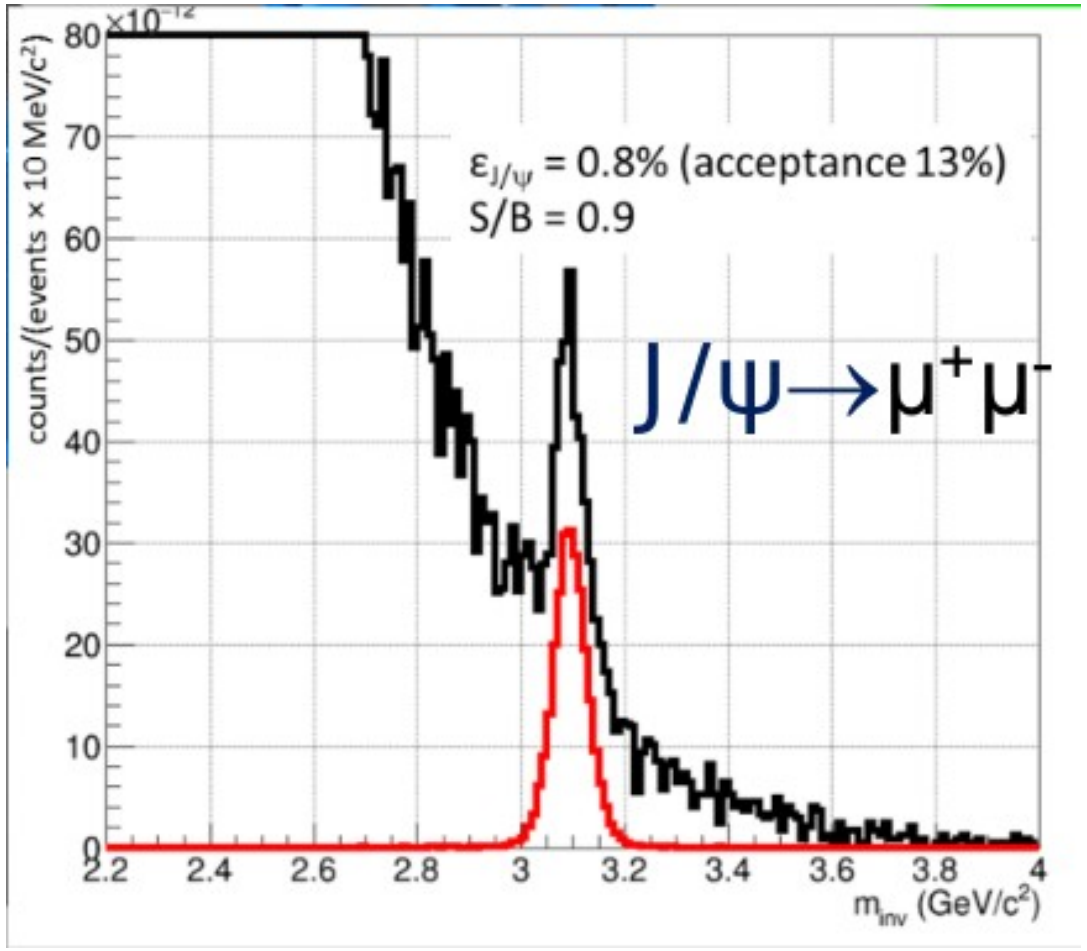




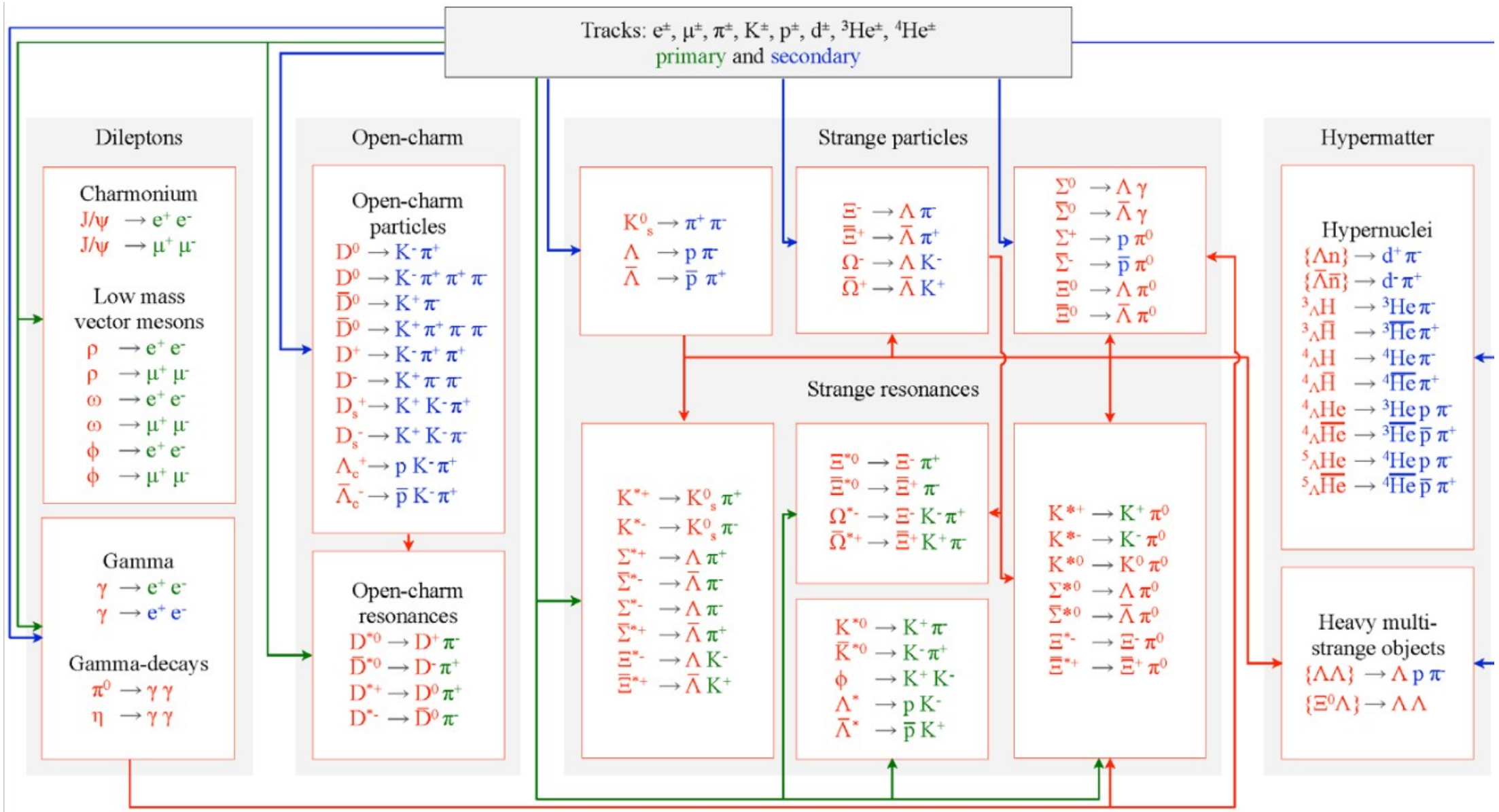


Identificación de partículas



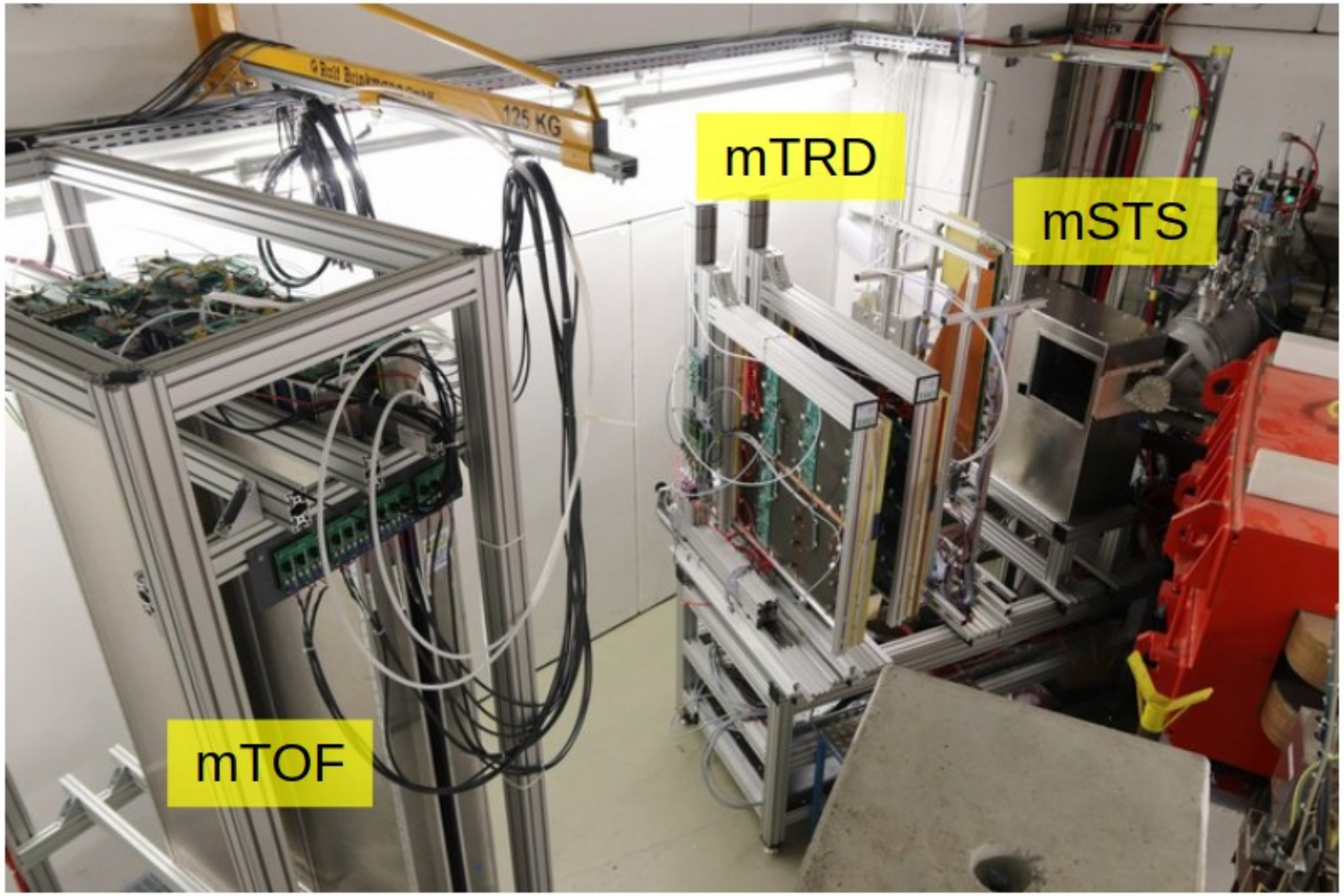


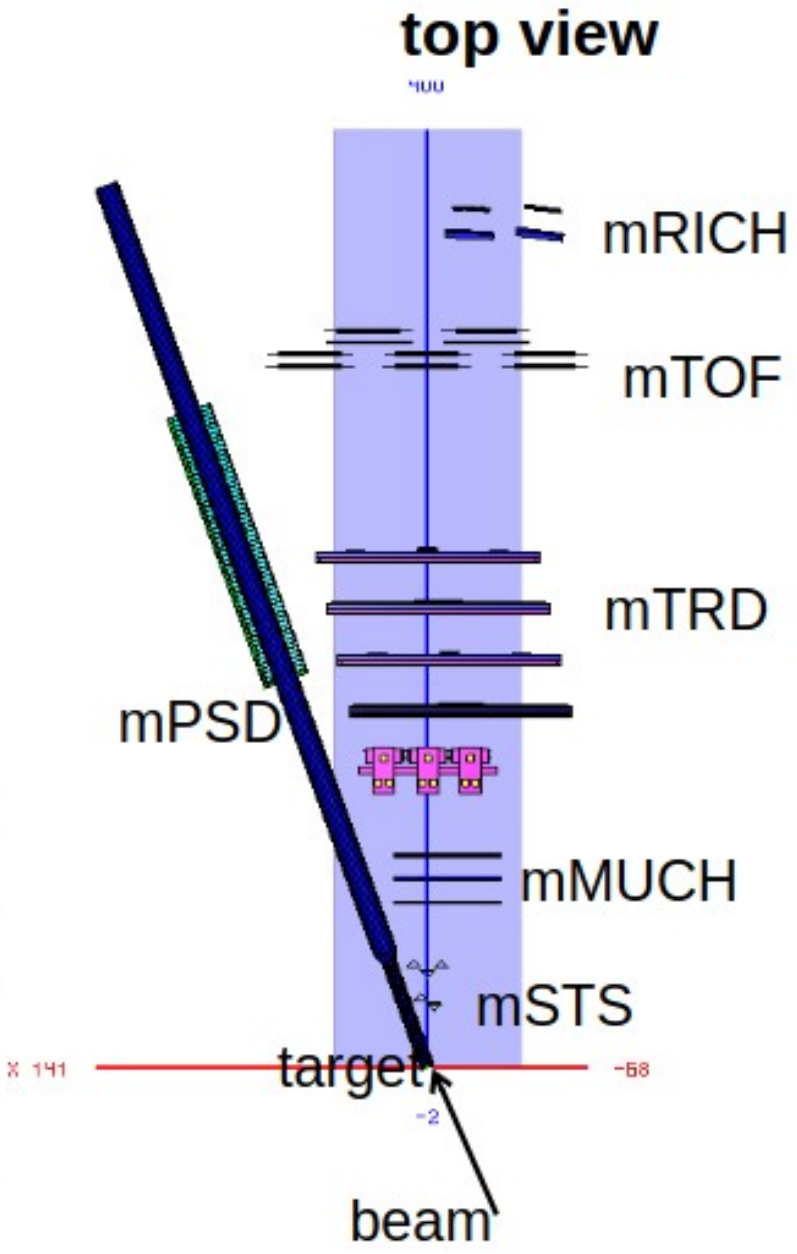
Identificación de partículas en CBM



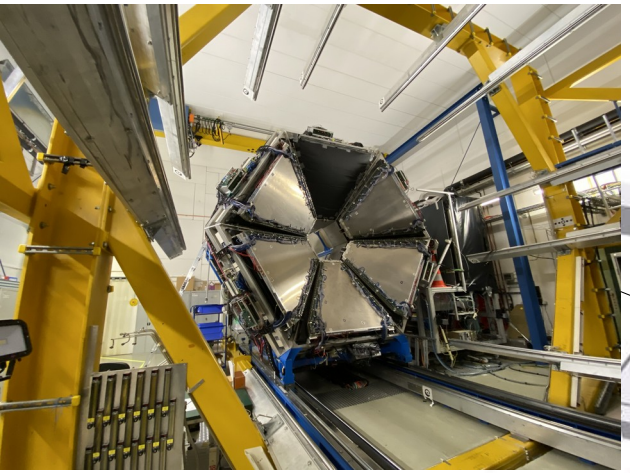
Estado actual

Prueba de concepto: mCBM

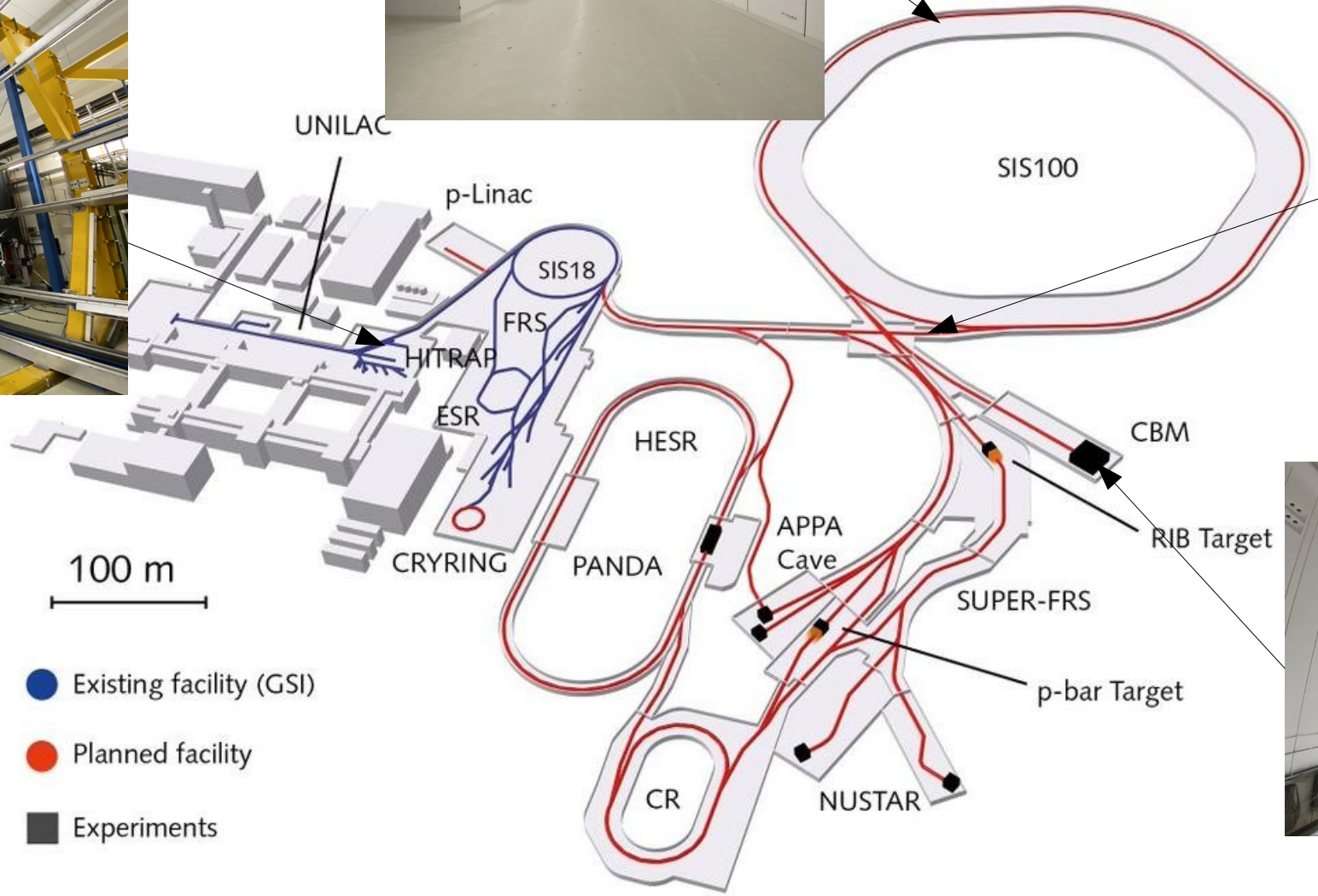




Estructura civil



HADES



Colaboración CBM

Croatia:
Split Univ.

China:
CCNU Wuhan
Tsinghua Univ.
USTC Hefei
CTGU Yichang

Czech Republic:
CAS, Rez
Techn. Univ.Prague

France:
IPHC Strasbourg

Hungary:
KFKI Budapest
Budapest Univ.

Germany:
Darmstadt TU
FAIR
Frankfurt Univ. IKF
Frankfurt Univ. FIAS
Frankfurt Univ. ICS
GSI Darmstadt
Giessen Univ.
Heidelberg Univ. P.I.
Heidelberg Univ. ZITI
HZ Dresden-Rossendorf
KIT Karlsruhe
Münster Univ.
Tübingen Univ.
Wuppertal Univ.
ZIB Berlin

India:
Aligarh Muslim Univ.
Bose Inst. Kolkata
Panjab Univ.
Rajasthan Univ.
Univ. of Jammu
Univ. of Kashmir
Univ. of Calcutta
B.H. Univ. Varanasi
VECC Kolkata
IOP Bhubaneswar
IIT Kharagpur
IIT Indore
Gauhati Univ.

Korea:
Pusan Nat. Univ.

Poland:
AGH Krakow
Jag. Univ. Krakow
Silesia Univ. Katowice
Warsaw Univ.
Warsaw TU

Romania:
NIPNE Bucharest
Univ. Bucharest

Ukraine:
T. Shevchenko Univ. Kiev
Kiev Inst. Nucl. Research

Colaboración CBM

Gracias!

From neutron stars to heavy ion collisions

Crab-Nebula (Supernova 1054)

Temperature
T < 20 MeV

Core density
$\rho < 10\ \rho_0$

Lifetime
$\Delta t \sim$ infinity

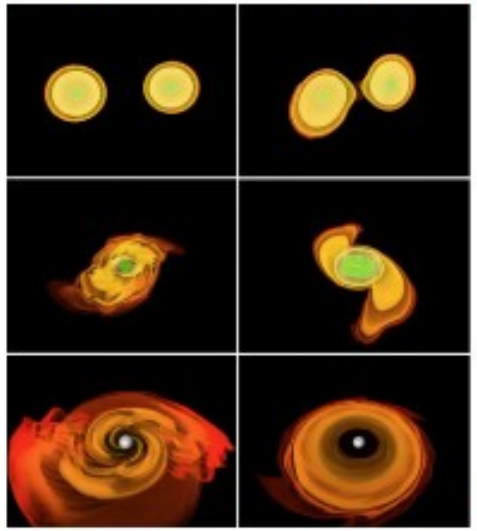
Crab pulsar T = 33.4 ms, Mass ~ 1.5 $M_\odot$
B0531+21

Neutron star merger (simulation)

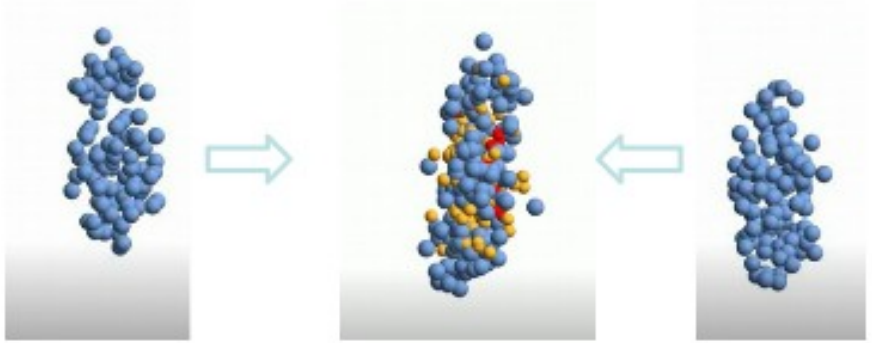
Temperature
T < 70 MeV

Core density
$\rho \sim 2\text{-}6\ \rho_0$

Reactiontime
$\Delta t \sim 10$ms



Relativistic nucleus-nucleus collision SIS100



Temperature
T < 120 MeV

Density
$\rho < 8\ \rho_0$

Reaction time
$\Delta t \sim 10^{-23}$ s

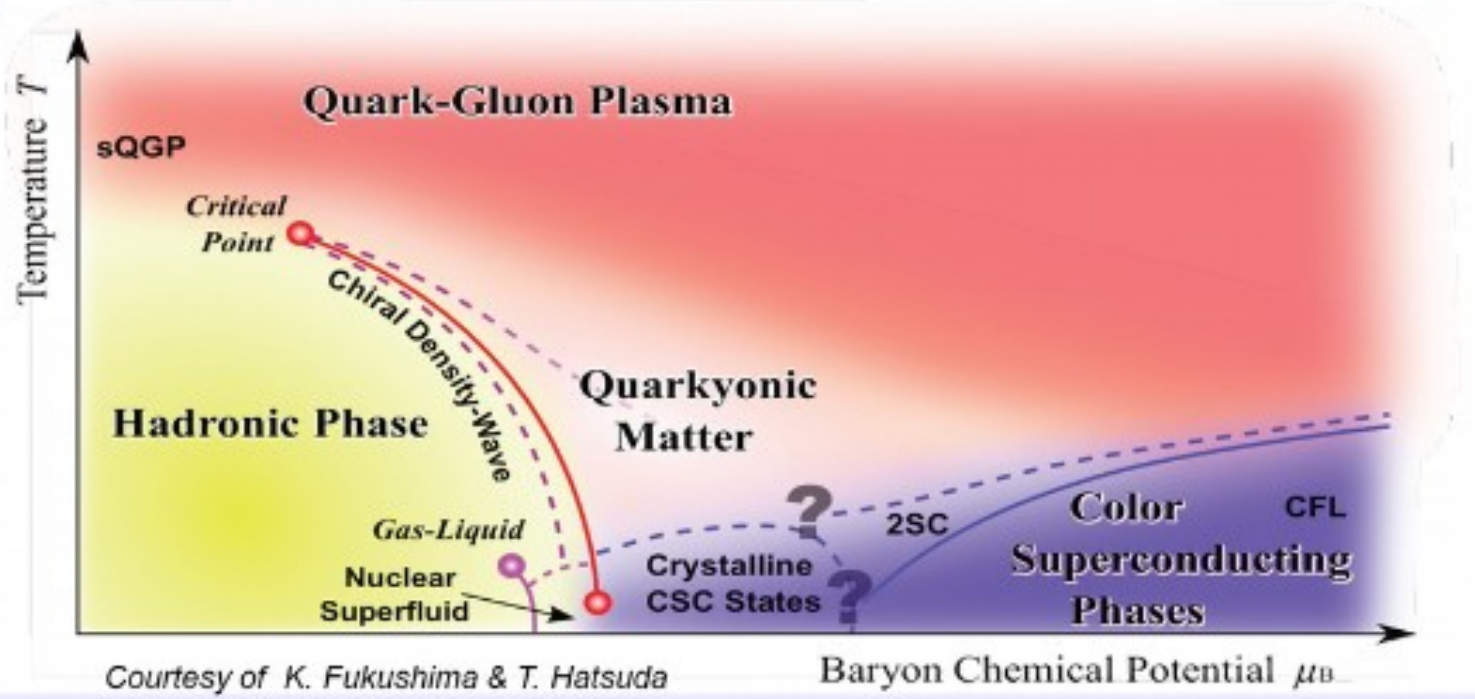
Max Planck Institute for Gravitational Physics

Topics:

- QCD equation of state
- Search for exotic phases and 1st order phase transition
- Critical endpoint
- Chiral symmetry restoration at high μ_B

CBM Probes:

- Collective Flow → nuclear matter EoS
- Event-by-Event fluctuations → critical endpoint
- Strangeness → signature of deconfinement
- (multi)-strange Hypernuclei → strange dimension of chart of nuclei
- Charm → early stages of collision, Debye-screening
- Dileptons



Courtesy of K. Fukushima & T. Hatsuda

10% most central Au+Au collisions at 6 and 10 A GeV

Particle (mass MeV/c^2)	Multi-plicity 6 A GeV	Multi-plicity 10 A GeV	decay mode	BR	ε (%)	yield (s^{-1}) 6 A GeV	yield (s^{-1}) 10 A GeV	yield in 10 weeks 6 A GeV	yield in 10 weeks 10 A GeV	IR MHz
K^+ (494)	12.5	20	-	-	31	$3.9\cdot10^{5}$	$6.2\cdot10^{5}$	$2.4\cdot10^{12}$	$3.7\cdot10^{12}$	1
K^- (494)	1.4	3	-	-	27	$3.8\cdot10^{4}$	$8.1\cdot10^{4}$	$2.3\cdot10^{11}$	$4.8\cdot10^{11}$	1
ρ (770)	5	9	L^+L^-	$4.7\cdot10^{-5}$	4.6	1.1	2.0	$6.5\cdot10^{6}$	$1.2\cdot10^{7}$	1
ω (782)	3.3	6	L^+L^-	$7.1\cdot10^{-5}$	5.2	1.2	2.2	$7.4\cdot10^{6}$	$1.3\cdot10^{7}$	1
φ (1020)	0.07	0.12	L^+L^-	$3\cdot10^{-4}$	6.0	$1.3\cdot10^{-1}$	$2.2\cdot10^{-1}$	$7.6\cdot10^{5}$	$1.3\cdot10^{6}$	1
Λ (1115)	10.4	17.4	$p\pi^-$	0.64	18	$1.2\cdot10^{5}$	$2.0\cdot10^{5}$	$7.2\cdot10^{11}$	$1.2\cdot10^{12}$	1
$\bar{\Lambda}$ (1115)	$4.6\cdot10^{-4}$	0.034	$\bar{p}\pi^+$	0.64	11	1.1	81.3	$6.6\cdot10^{6}$	$2.2\cdot10^{8}$	10
Ξ^- (1321)	0.054	0.222	$\Lambda\pi^-$	1	6	$3.2\cdot10^{3}$	$1.3\cdot10^{4}$	$1.9\cdot10^{10}$	$7.8\cdot10^{10}$	10
Ξ^+ (1321)	$3.0\cdot10^{-5}$	$5.4\cdot10^{-4}$	$\Lambda\pi^+$	1	3.3	$9.9\cdot10^{-1}$	17.8	$5.9\cdot10^{6}$	$1.1\cdot10^{8}$	10
Ω^- (1672)	$5.8\cdot10^{-4}$	$5.6\cdot10^{-3}$	ΛK^-	0.68	5	17	164	$1.0\cdot10^{8}$	$9.6\cdot10^{8}$	10
Ω^+ (1672)	-	$7\cdot10^{-5}$	ΛK^+	0.68	3	-	0.86	-	$5.2\cdot10^{6}$	10
J/ψ (3097)	-	$1.74\cdot10^{-7}$	L^+L^-	0.06	5	-	$5.2\cdot10^{-4}$	-	3100	10
${}^{3}_{\Lambda}H$ (2993)	$4.2\cdot10^{-2}$	$3.8\cdot10^{-2}$	${}^{3}He\pi^-$	0.25	19.2	$2\cdot10^{3}$	$1.8\cdot10^{3}$	$1.2\cdot10^{10}$	$1.1\cdot10^{10}$	10
${}^{4}_{\Lambda}He$ (3930)	$2.4\cdot10^{-3}$	$1.9\cdot10^{-3}$	${}^{3}He p\pi^-$	0.32	14.7	110	87	$6.6\cdot10^{8}$	$5.2\cdot10^{8}$	10

https://j-parc.jp/Hadron/en/index.html