



Status of FAIR and PANDA

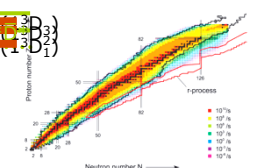
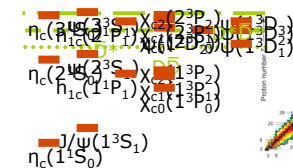
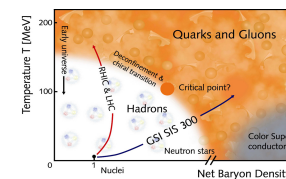


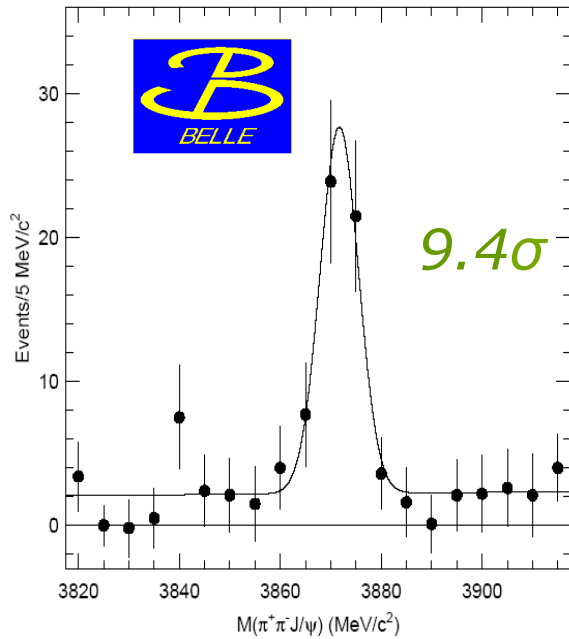
*Klaus Peters on behalf of **FAIR** and the **PANDA** Collaboration*
GSI Darmstadt and Goethe U Frankfurt
Erlangen, July 24, 2013



criteria of stability can be derived from extreme (exotic) structures

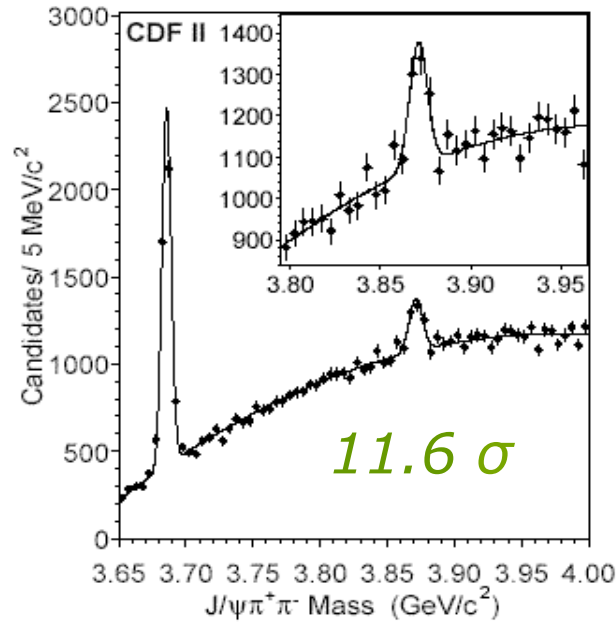
→ properties of the binding



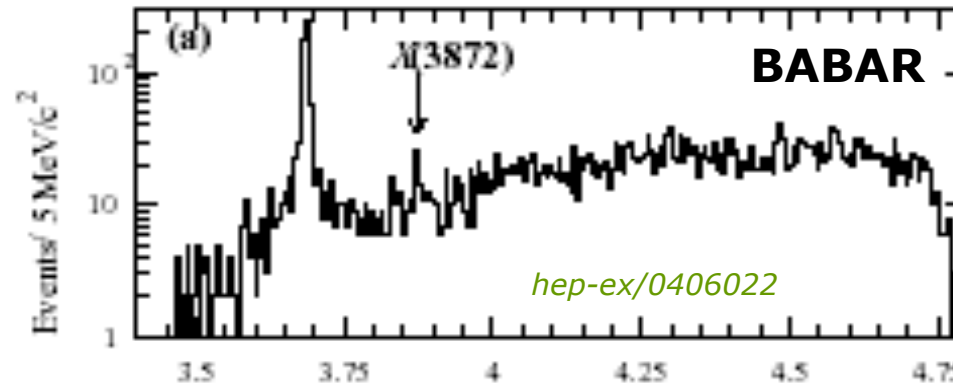
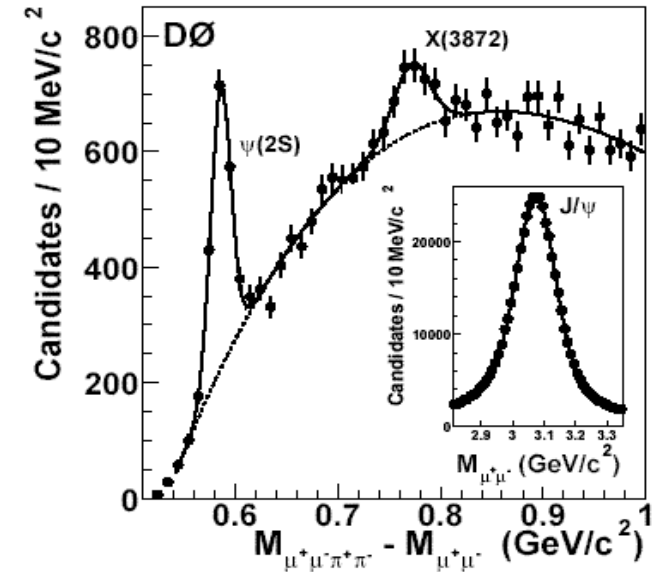


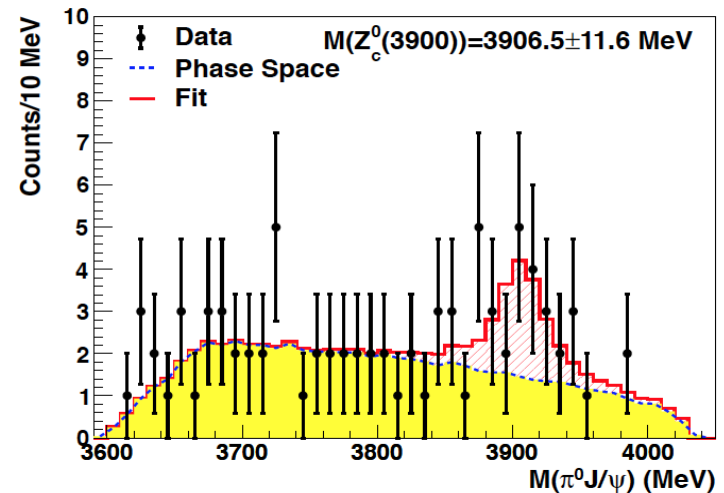
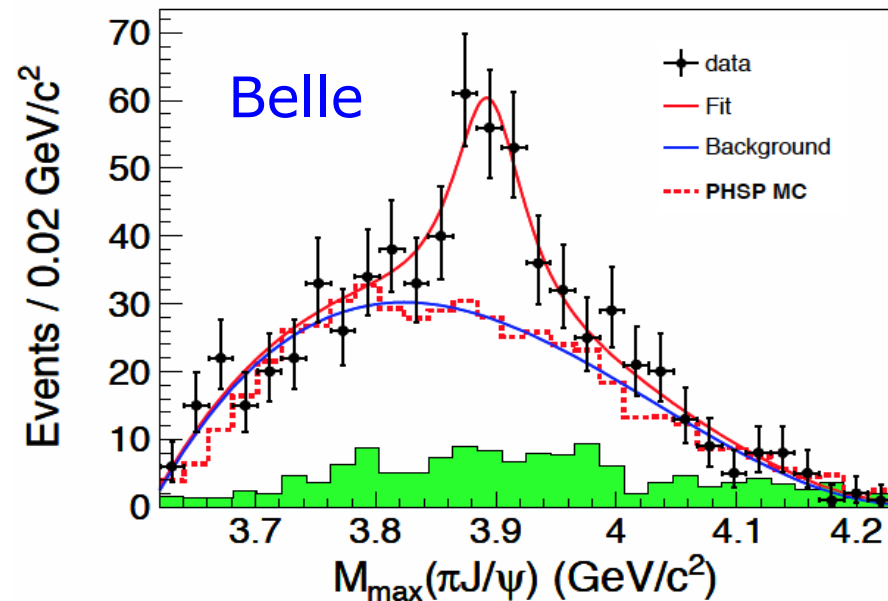
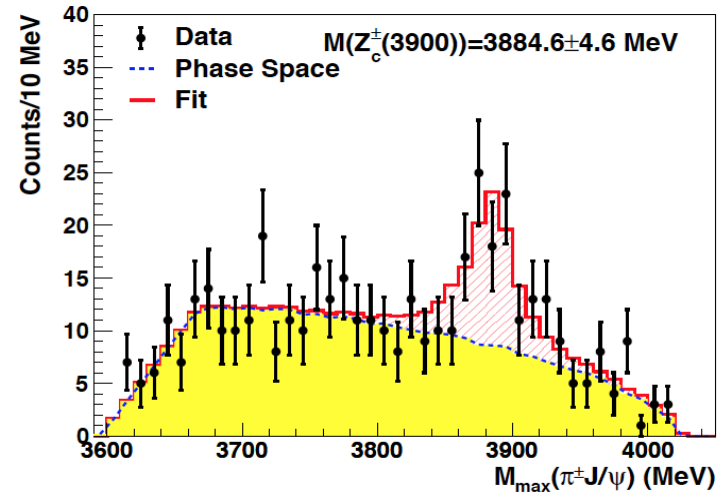
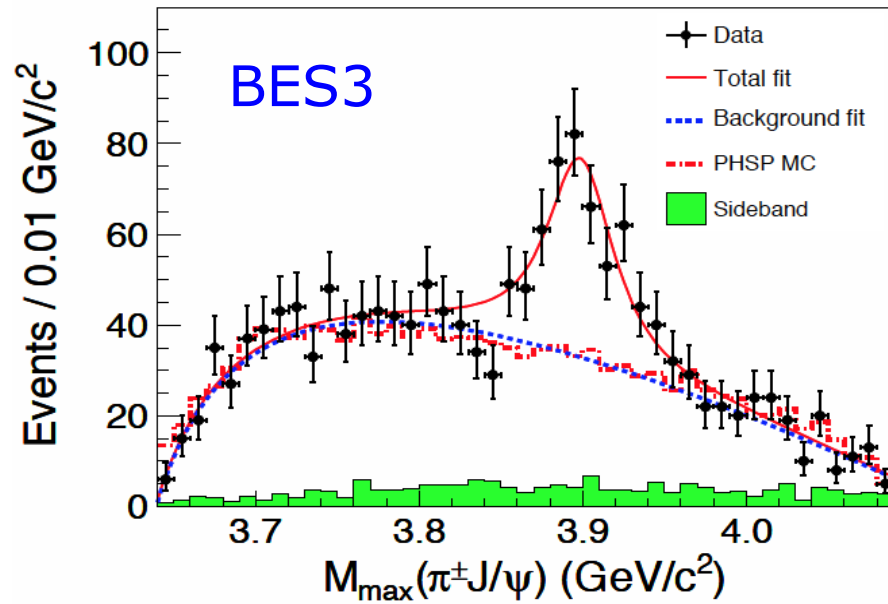
Phys. Rev. Lett. 91(2003)262001
152 Mill. BB

hep-ex/0312021

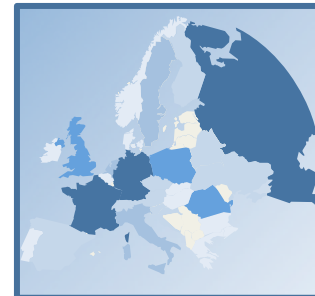
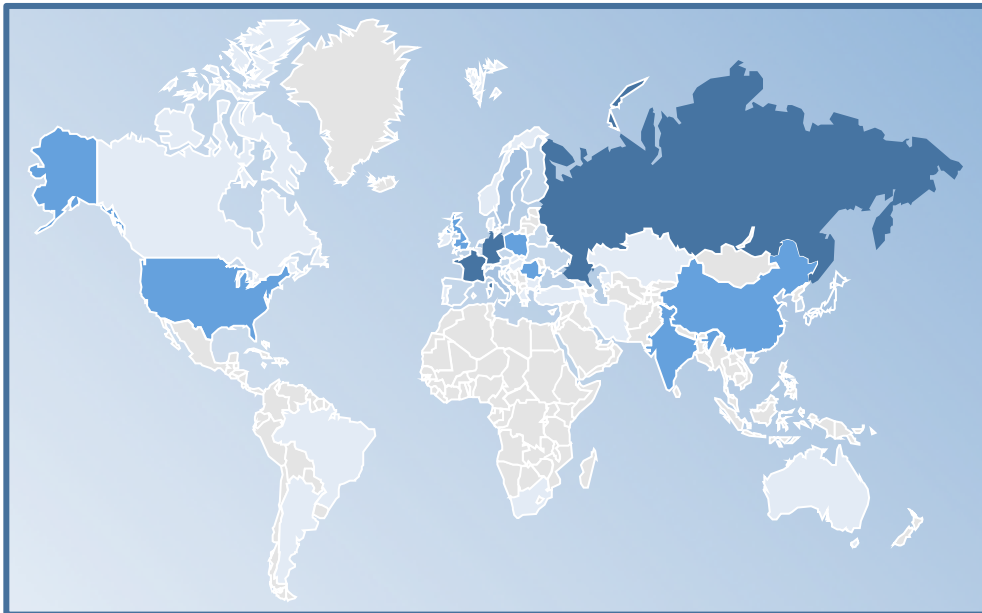


hep-ex/0405004





more than 2'000 Scientists
hundreds of institutions



42 countries Worldwide
27 countries in Europe

Nuclear Structure & Astrophysics
(Rare-isotope beams)

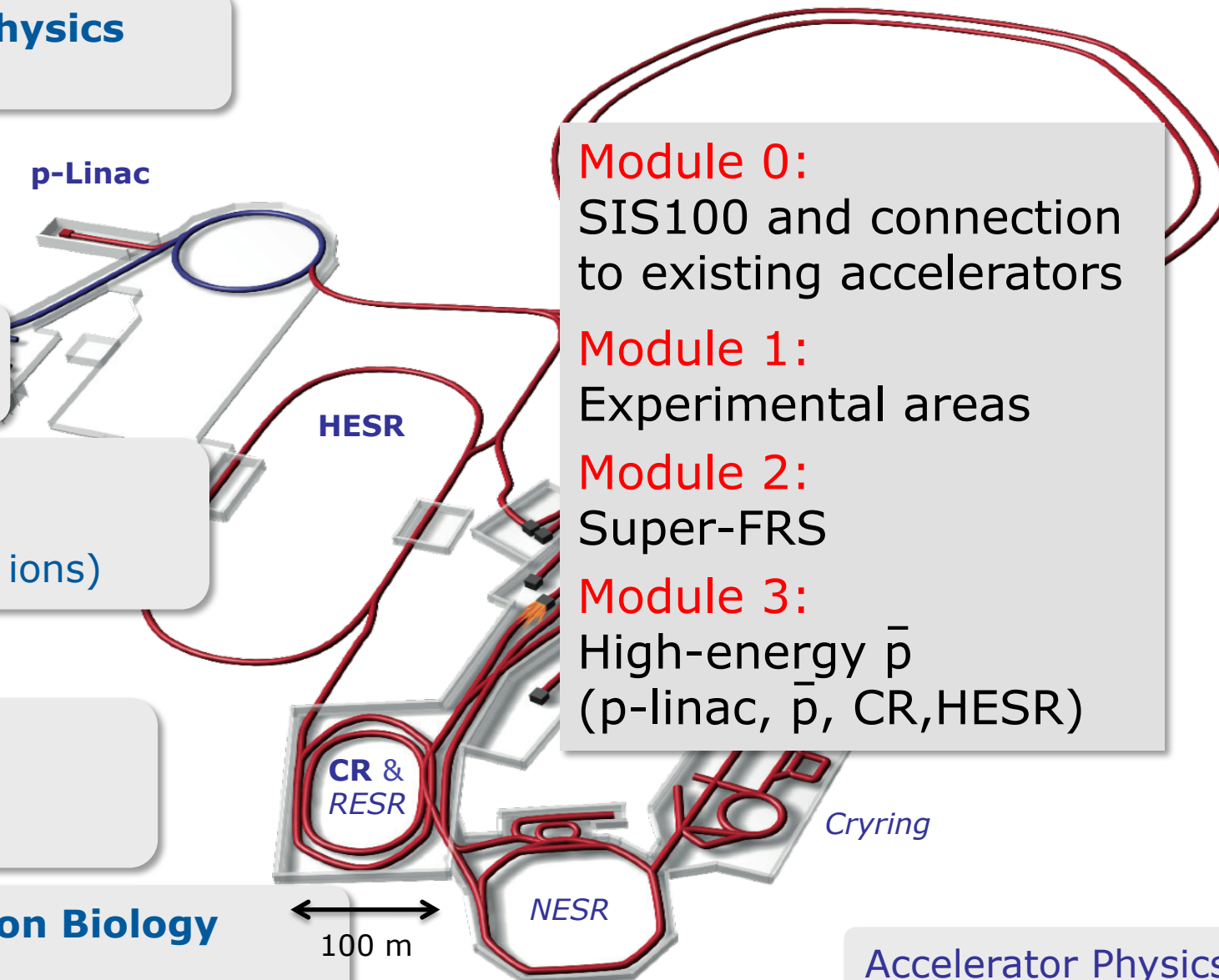
Hadron Physics
(Stored and cooled
14 GeV/c anti-protons)

QCD-Phase Diagram
(HI beams 2 to 45 GeV/u)

**Fundamental Symmetries
& Ultra-High EM Fields**
(Antiprotons & highly stripped ions)

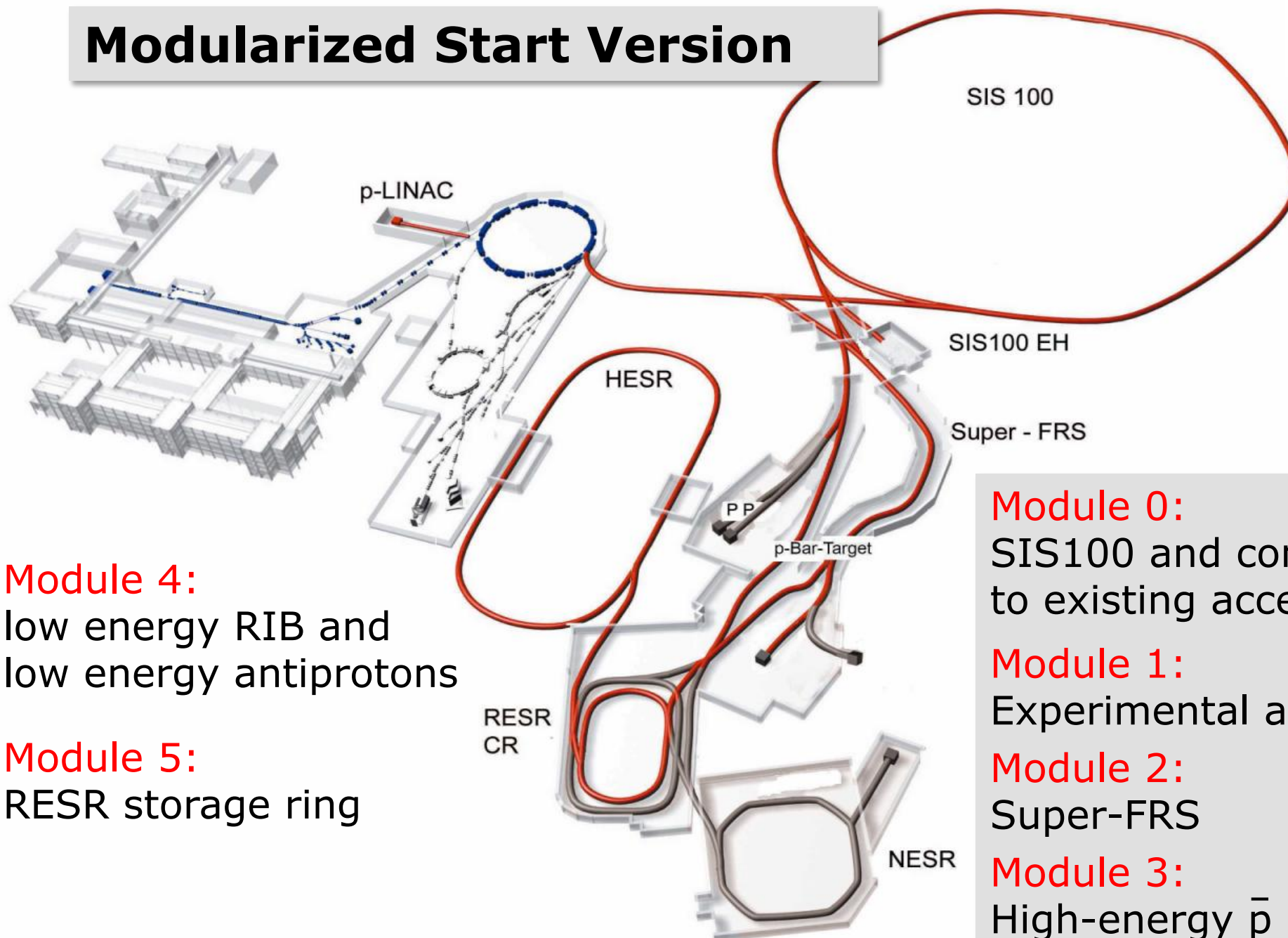
Dense Bulk Plasmas
(Ion-beam bunch compression
& petawatt-laser)

Materials Science & Radiation Biology
(Ion & antiproton beams)



Accelerator Physics

Modularized Start Version



Module 4:
low energy RIB and
low energy antiprotons

Module 5:
RESR storage ring

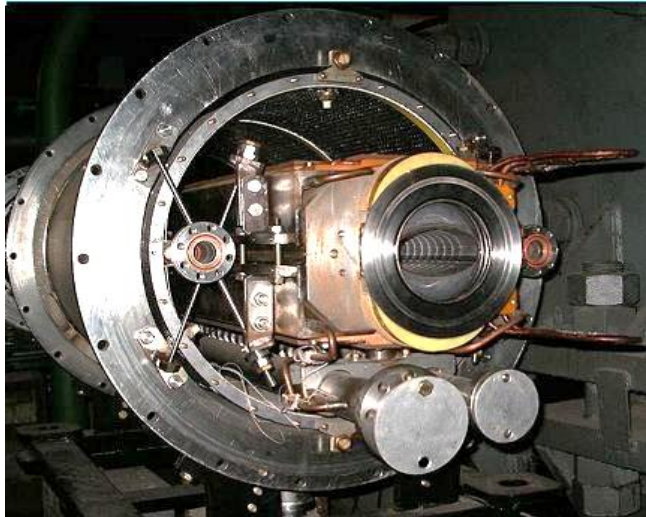
Module 0:
SIS100 and connection
to existing accelerators

Module 1:
Experimental areas

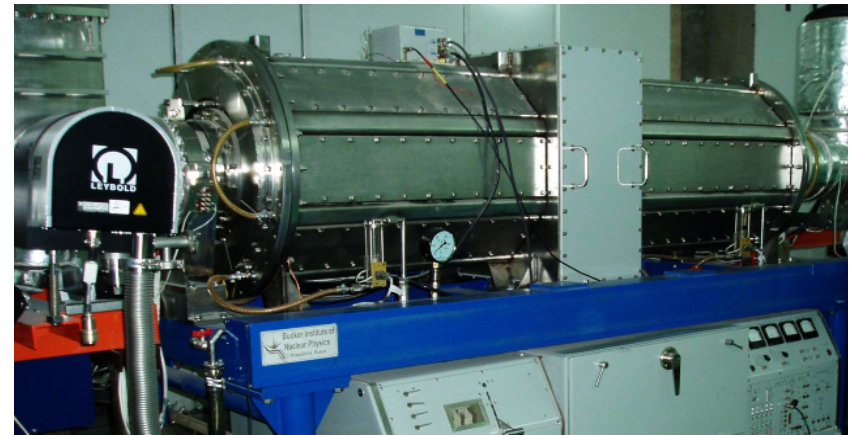
Module 2:
Super-FRS

Module 3:
High-energy \bar{p}
(p-linac, \bar{p} , CR, HESR)

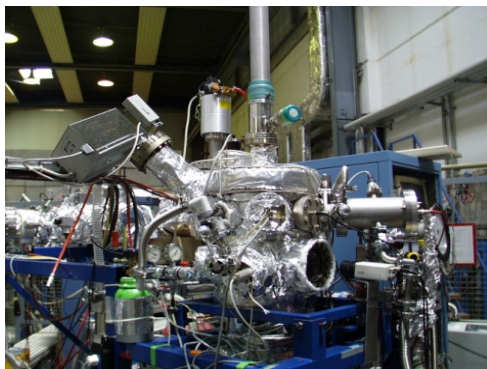
Fast cycling superconducting magnets
 $dB/dt \sim 4T/s$



High gradient, variable frequency
Ferrite & MA loaded cavities



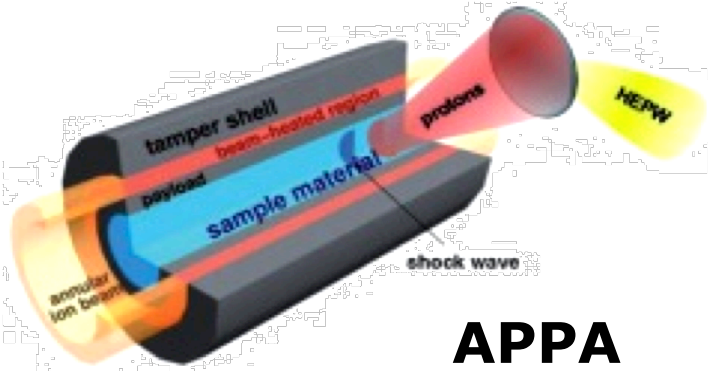
Extremely high vacuum $\sim 10^{-13}$ mbar



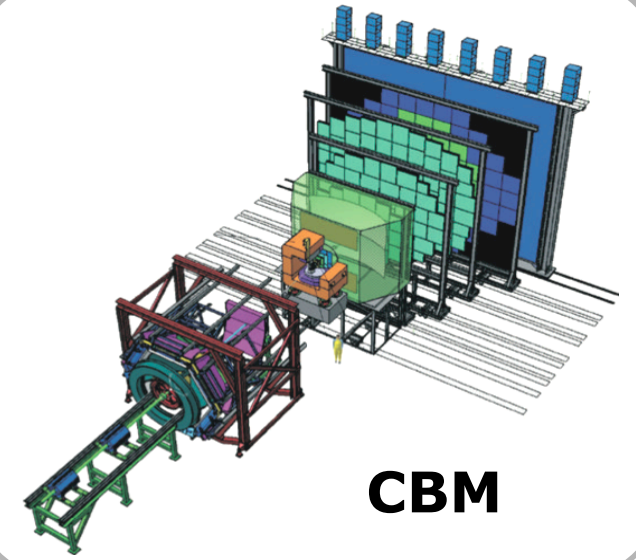
Electron & stochastic cooling



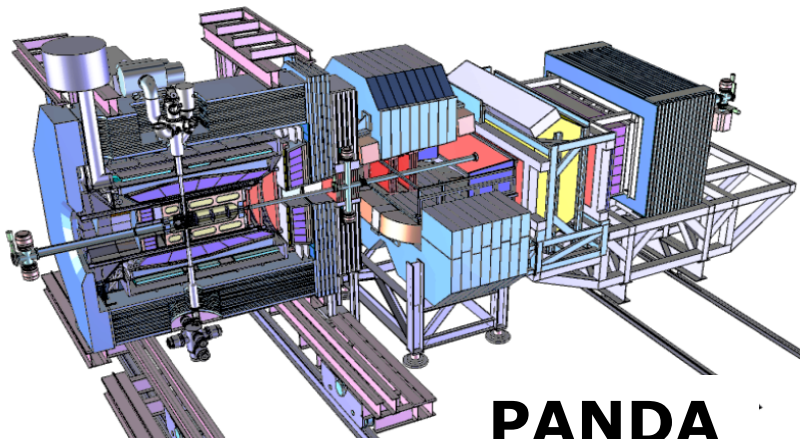
FAIR Experiments



APPA



CBM



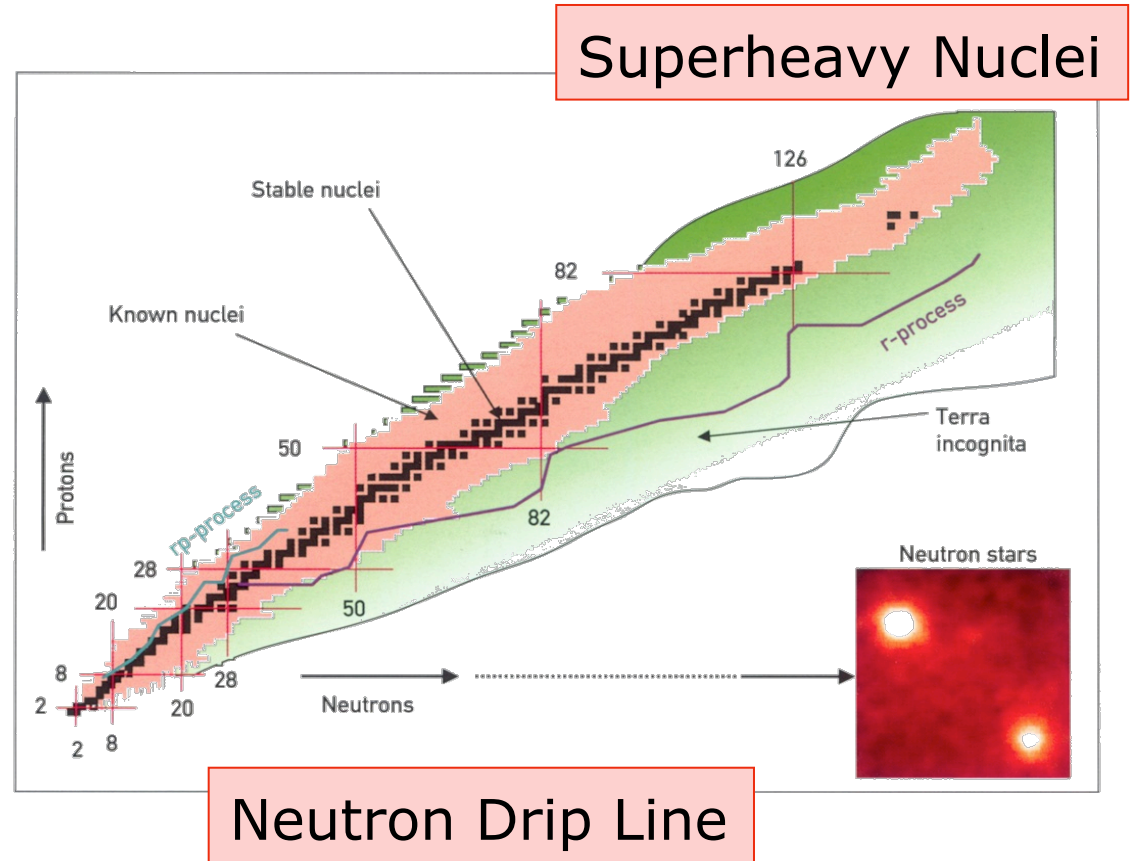
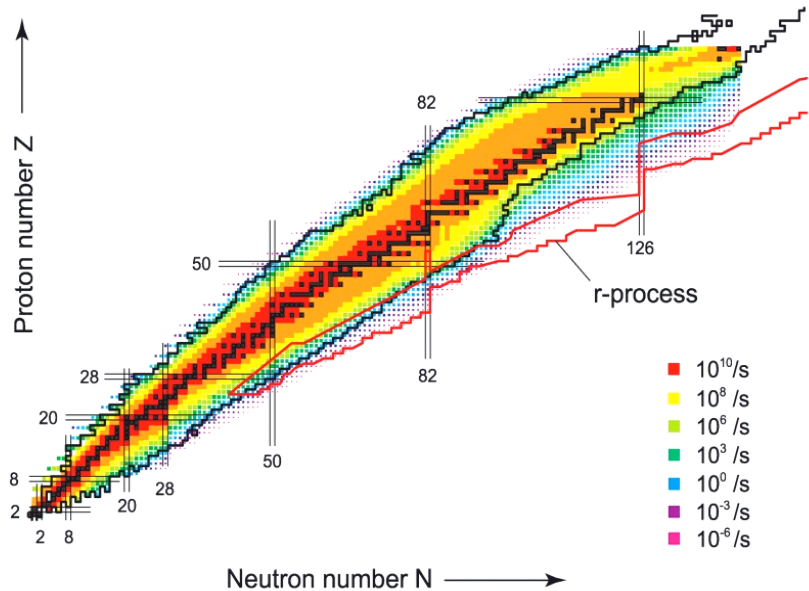
PANDA



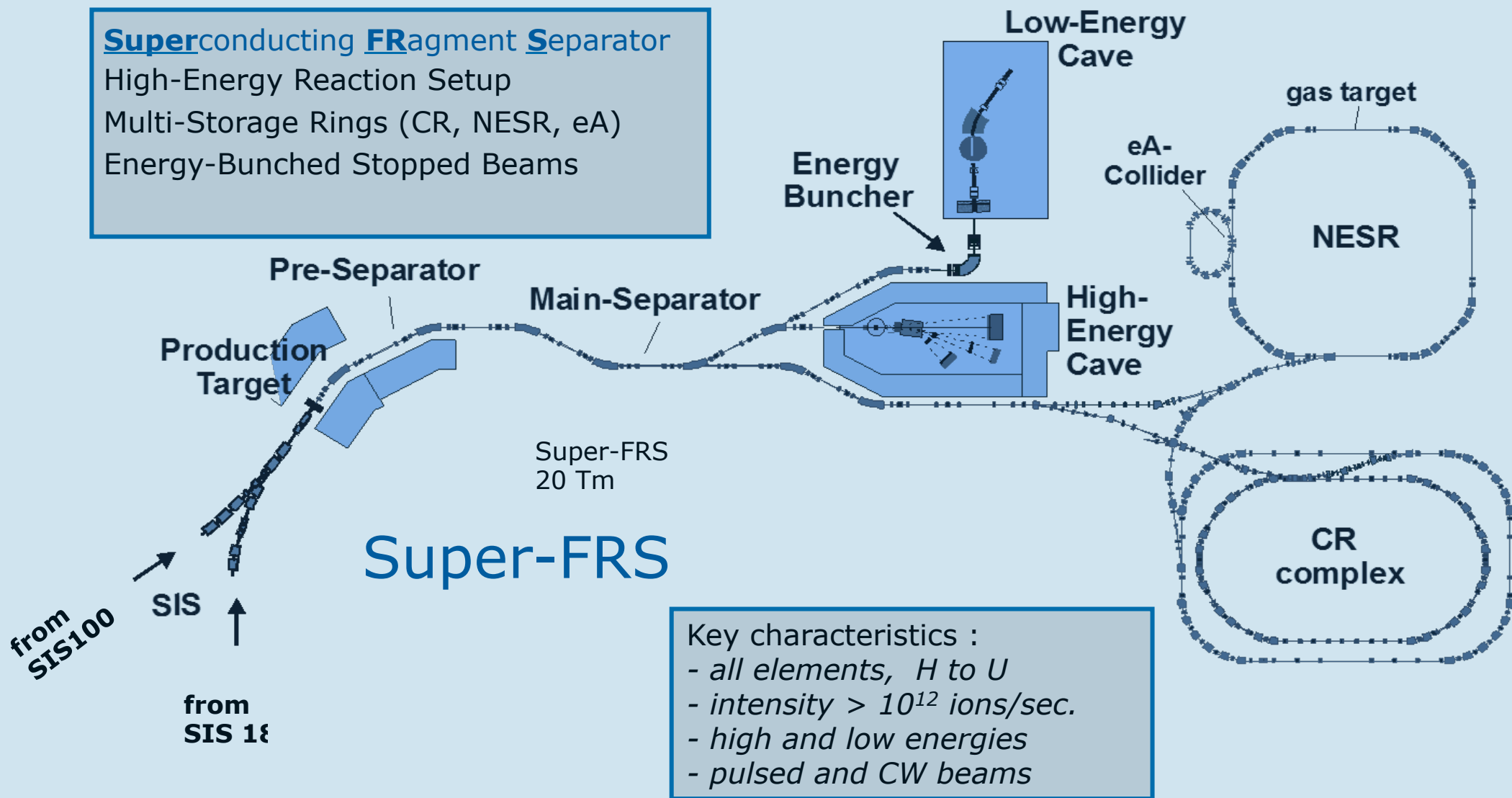
Super-FRS

NuSTAR

- How Are Elements Made ?
- Structure of exotic nuclei far off stability ?
- Nuclear synthesis in stars and star explosions
- Fundamental interactions and symmetries



Superconducting FRagment Separator
 High-Energy Reaction Setup
 Multi-Storage Rings (CR, NESR, eA)
 Energy-Bunched Stopped Beams

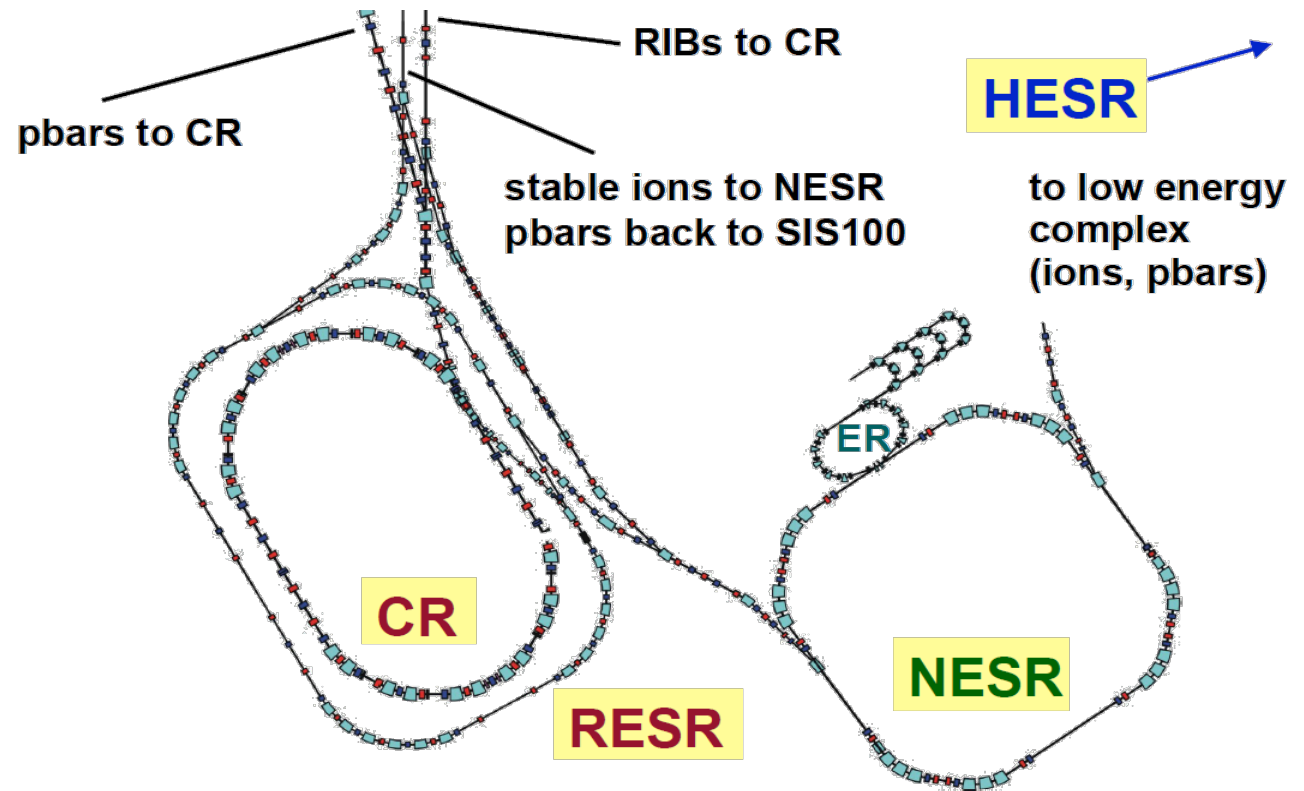


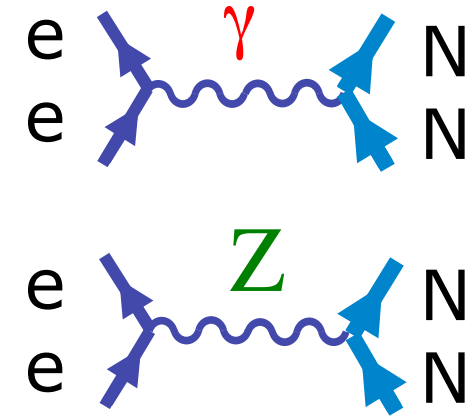
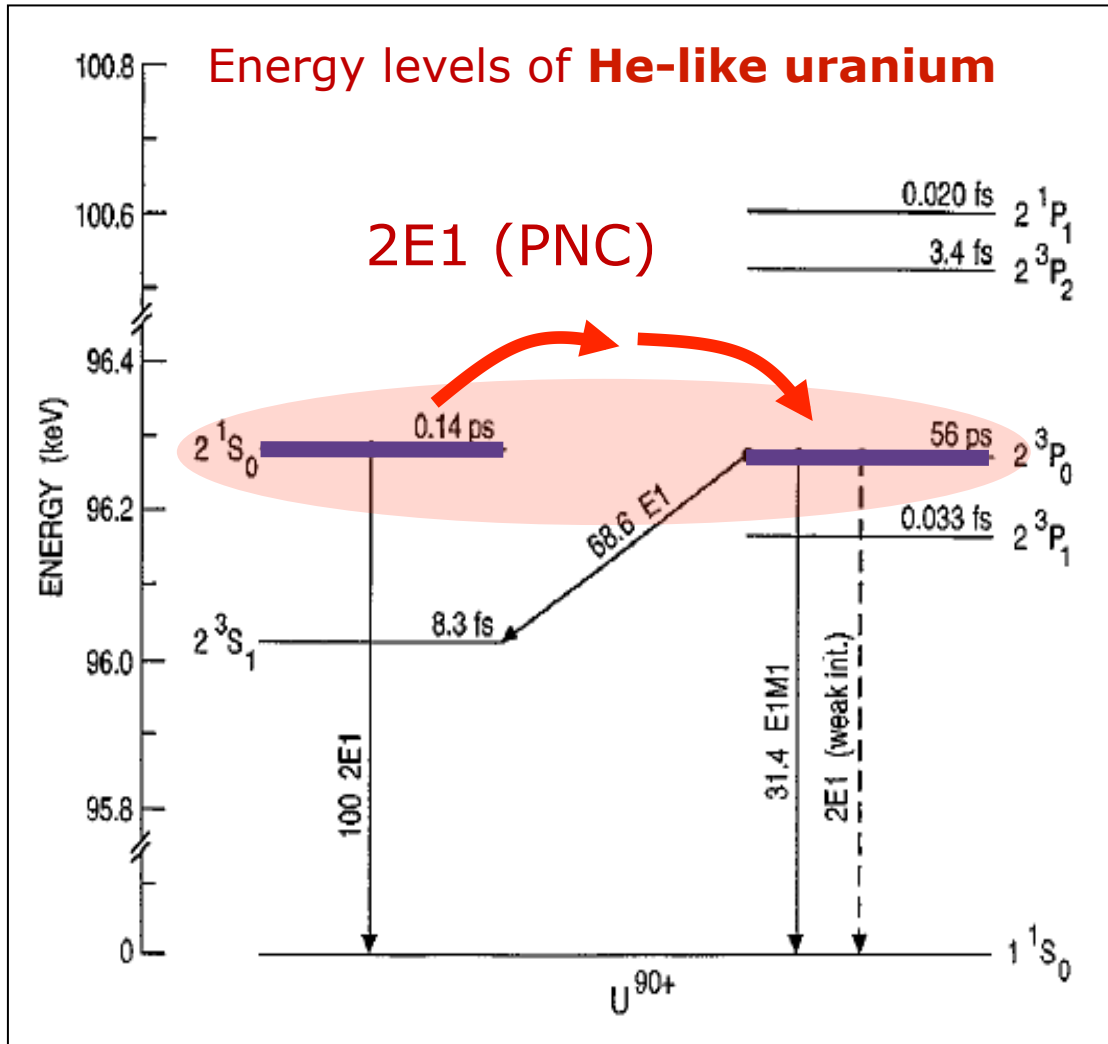
Key characteristics :

- all elements, H to U
- intensity $> 10^{12}$ ions/sec.
- high and low energies
- pulsed and CW beams

- very broad program
too broad to be summarized here
- SPARC and HedgeHob
are two important projects here

apart from
PLASMA cave
important rings
will be
RESR and NESR
(Module 5/6)



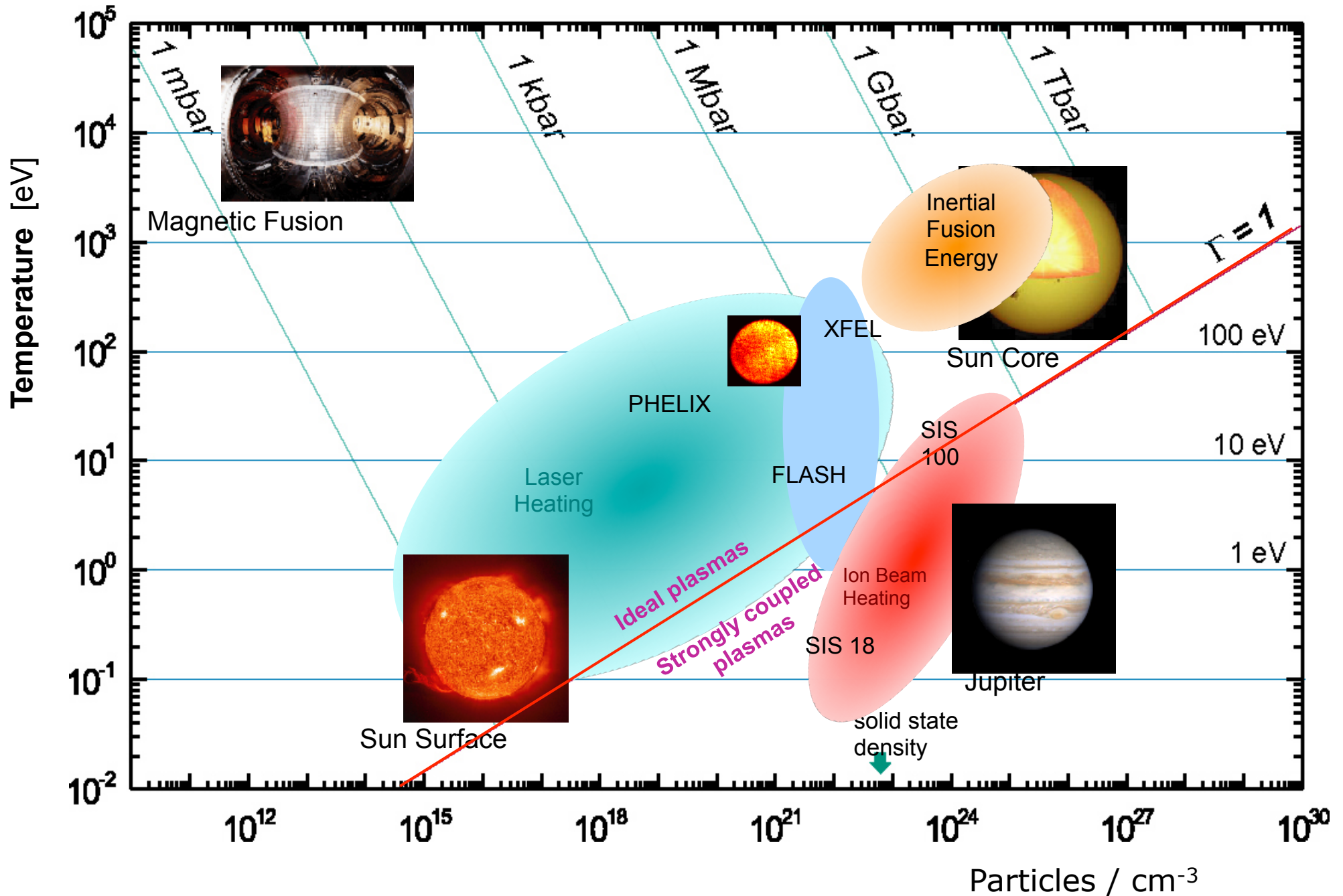


Mixing coefficient for states with opposite parities:

$$\eta = \frac{\langle \psi_S | G_F / 2\sqrt{2} Q_W \rho_N \gamma_5 | \psi_P \rangle}{E_S - E_P}$$

Select case with small splitting!

To “compete” with spontaneous decay channels, one needs to induce a two-photon PNC transition by polarized light with intensity $10^{20}\ W/cm^2$



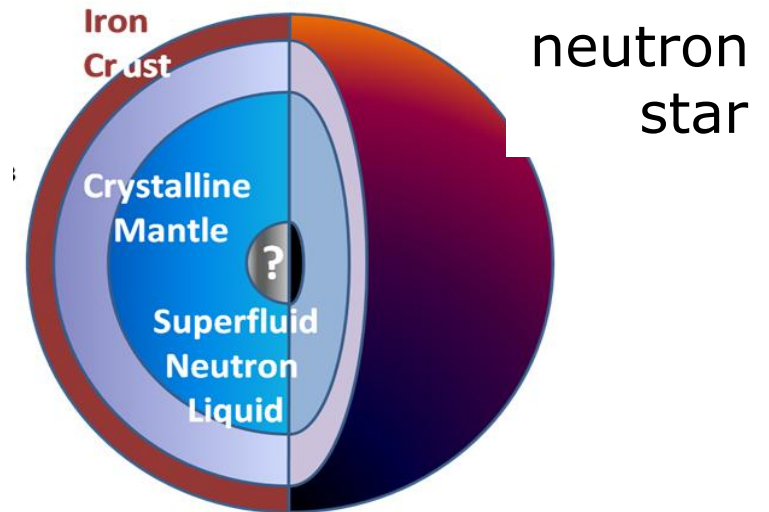
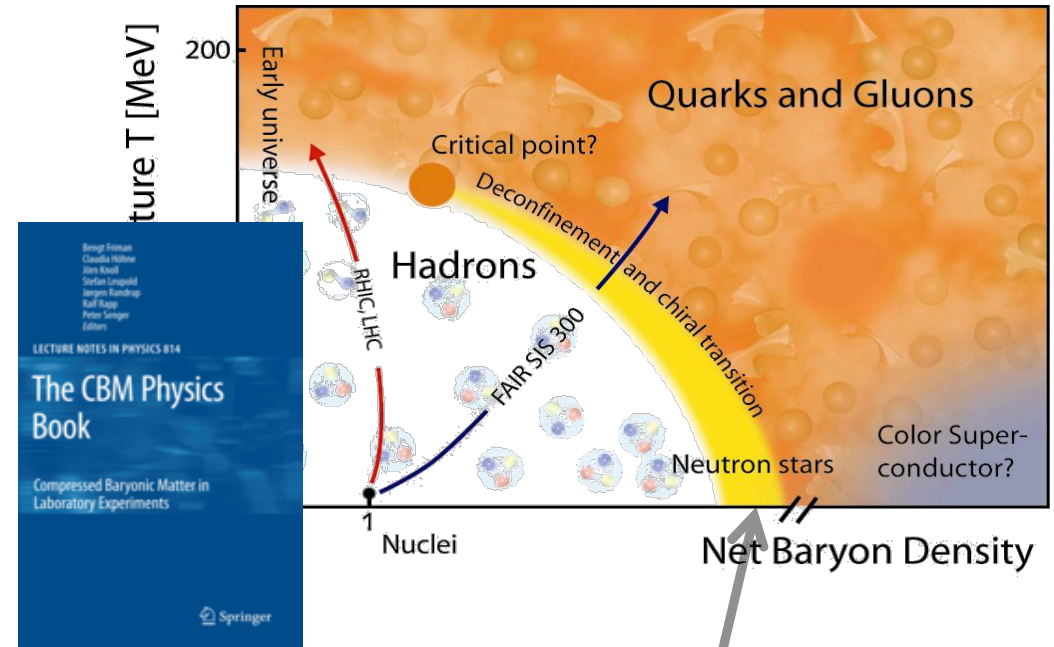
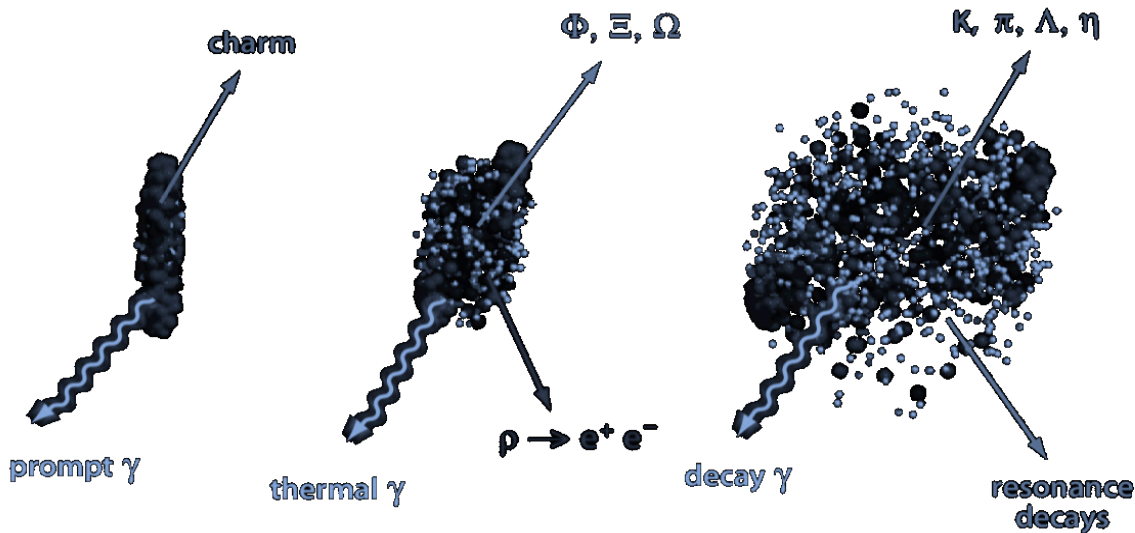
Nuclear Equation-of-state at high density

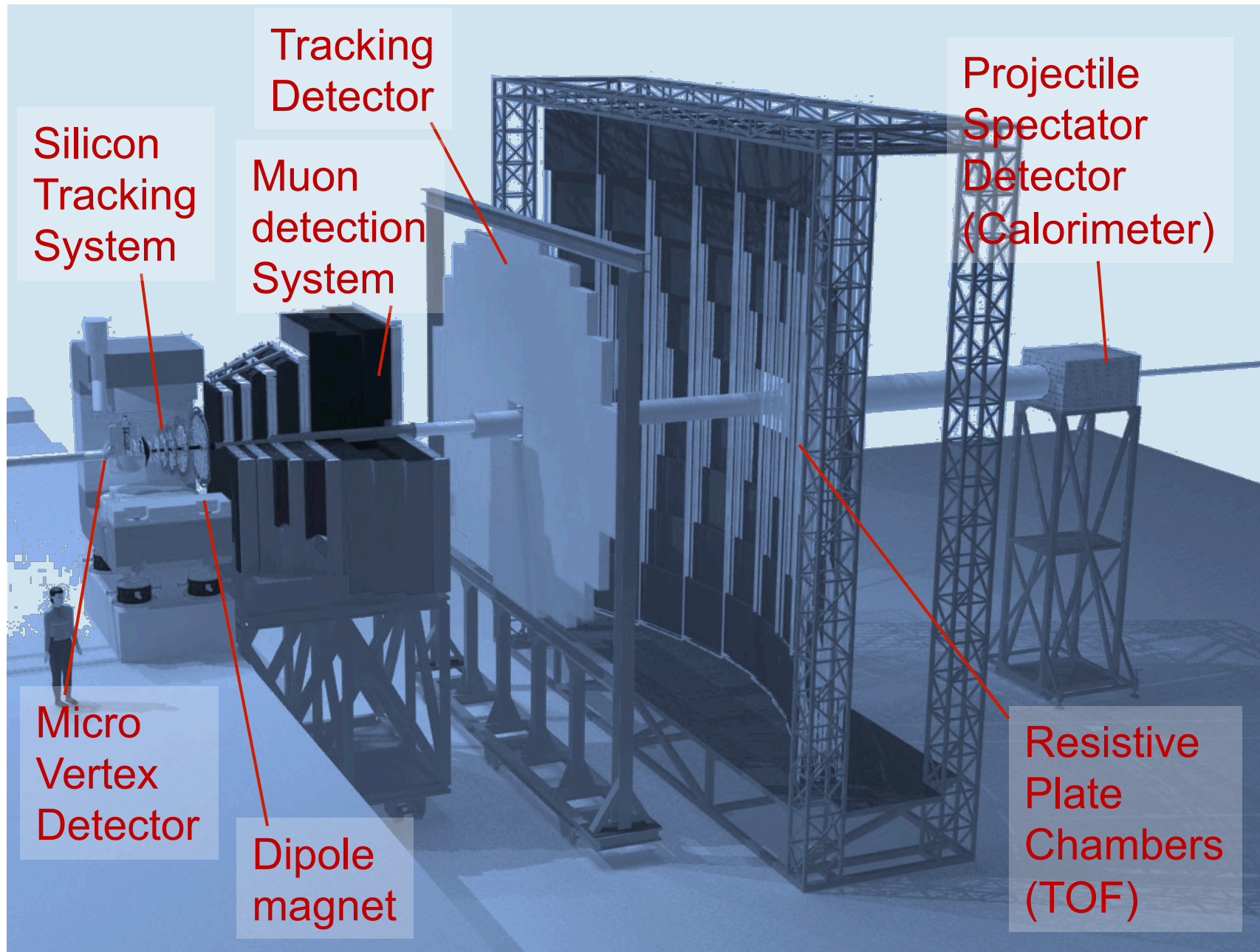
Search for phase transitions

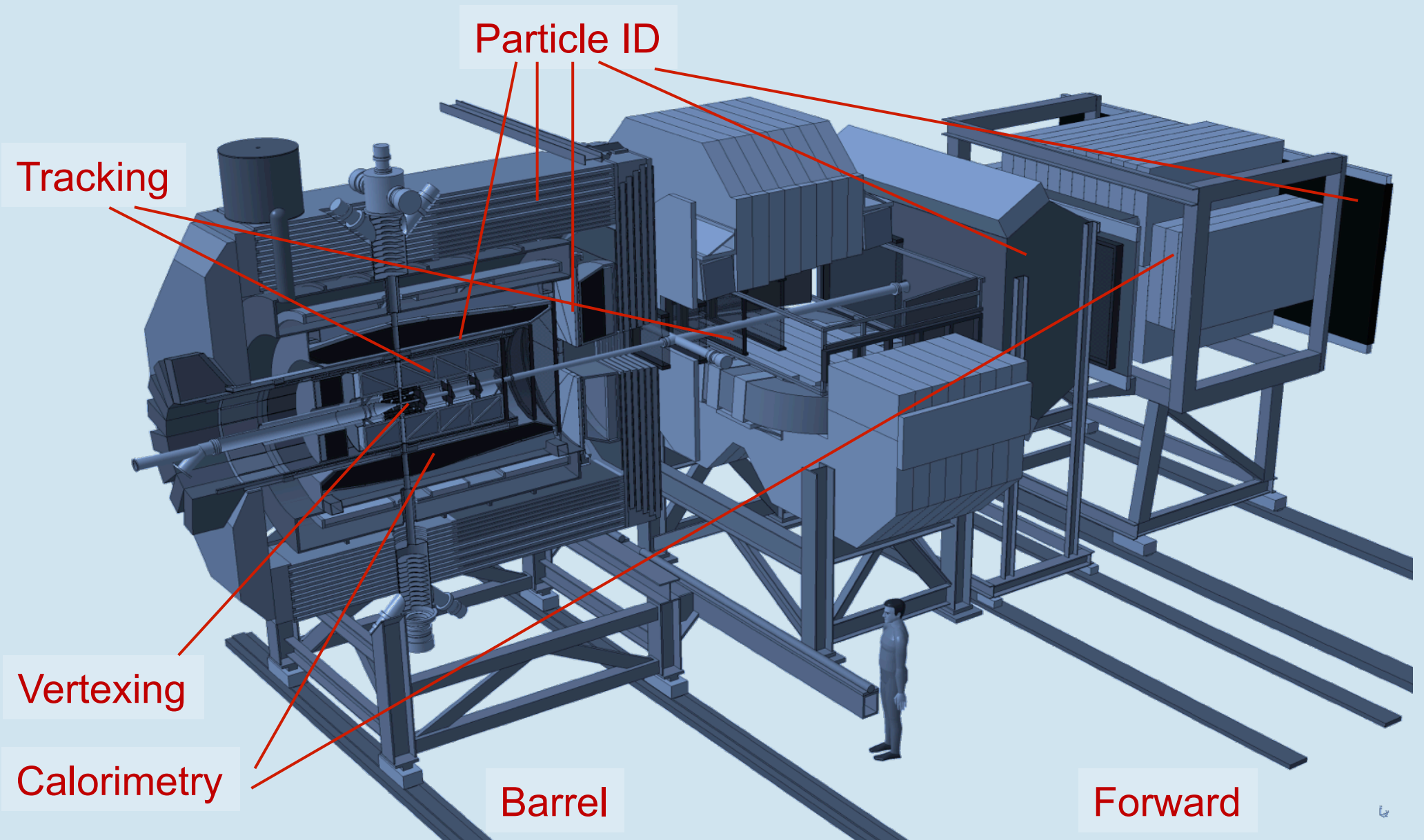
Search for the QCD critical endpoint

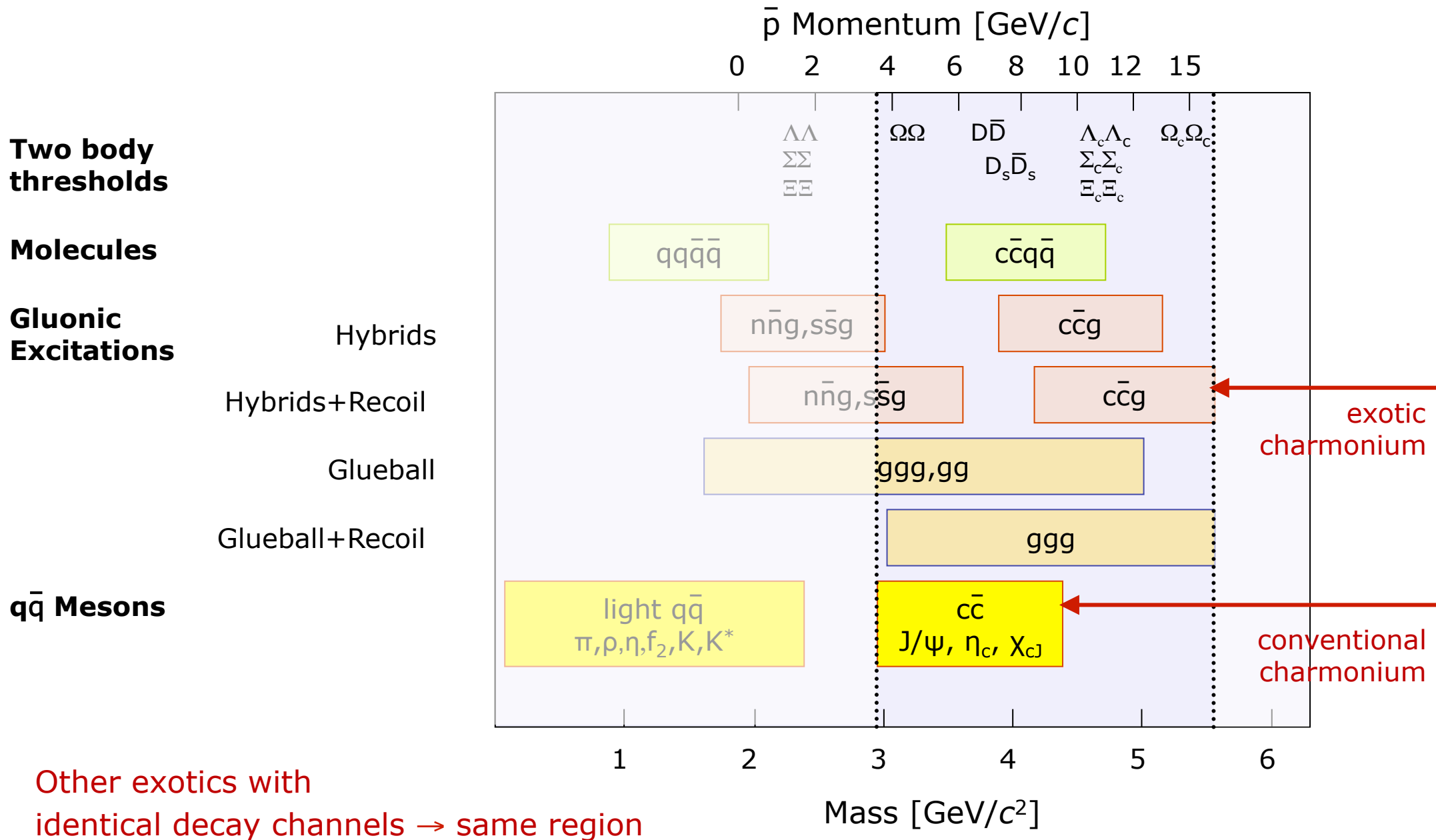
Study Chiral symmetry restoration and the origin of the hadron mass

Observables



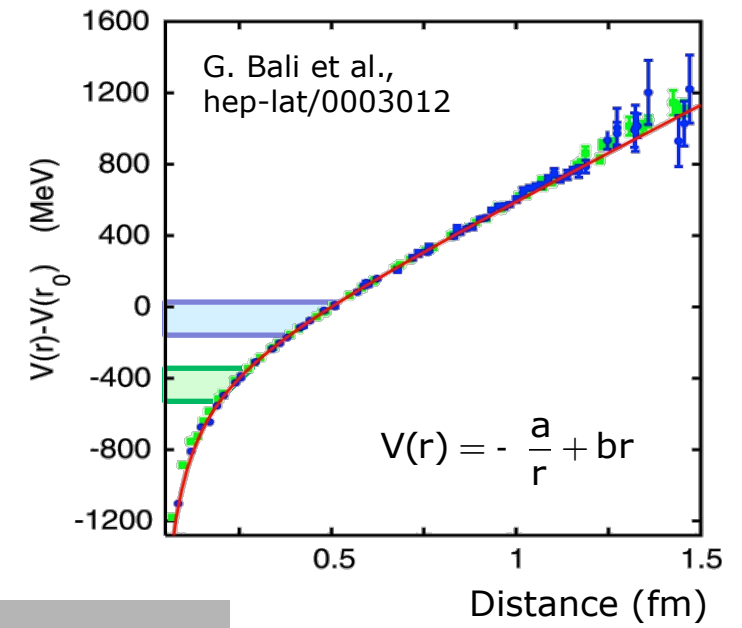
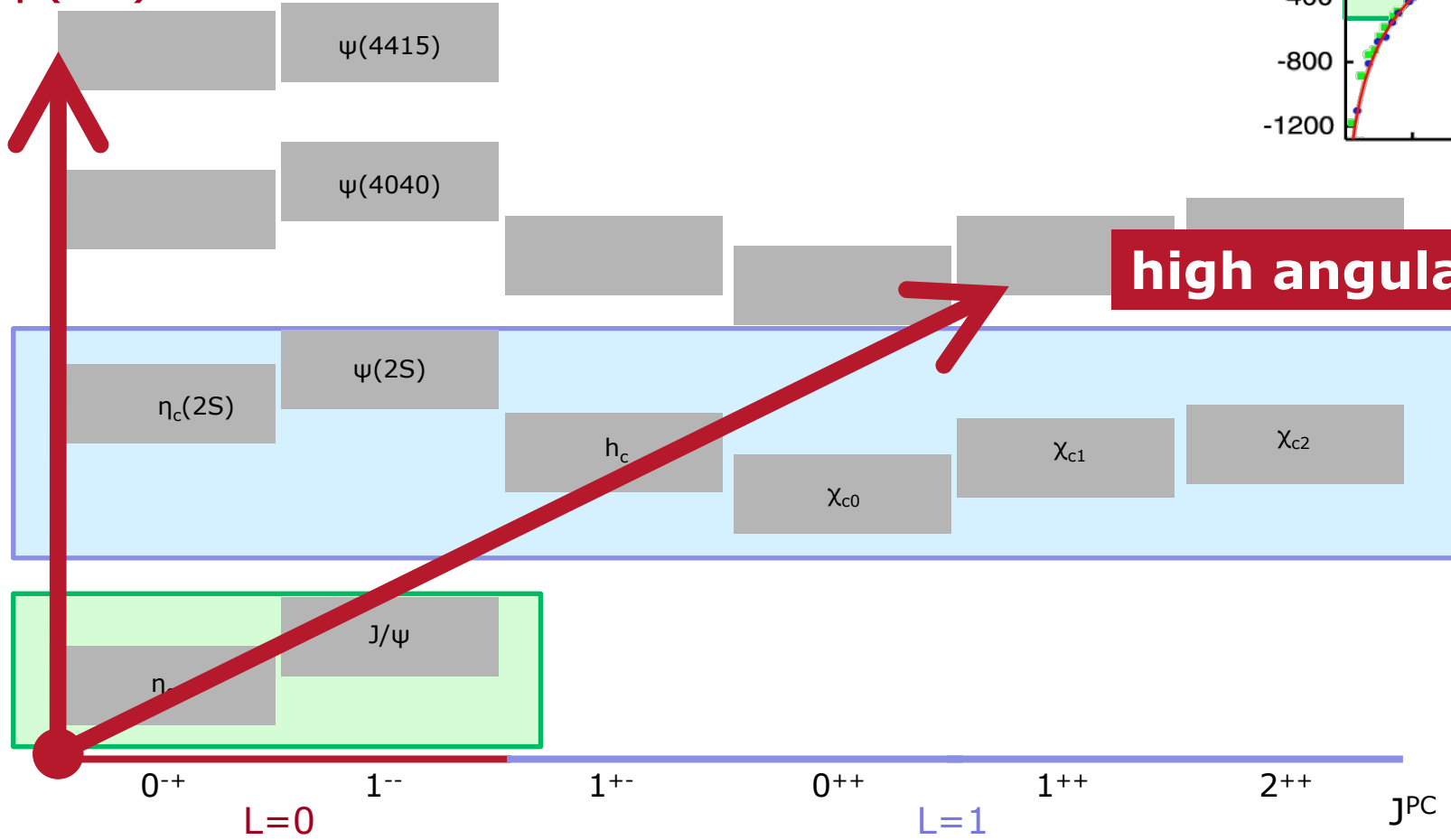






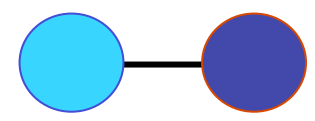
radial excitations

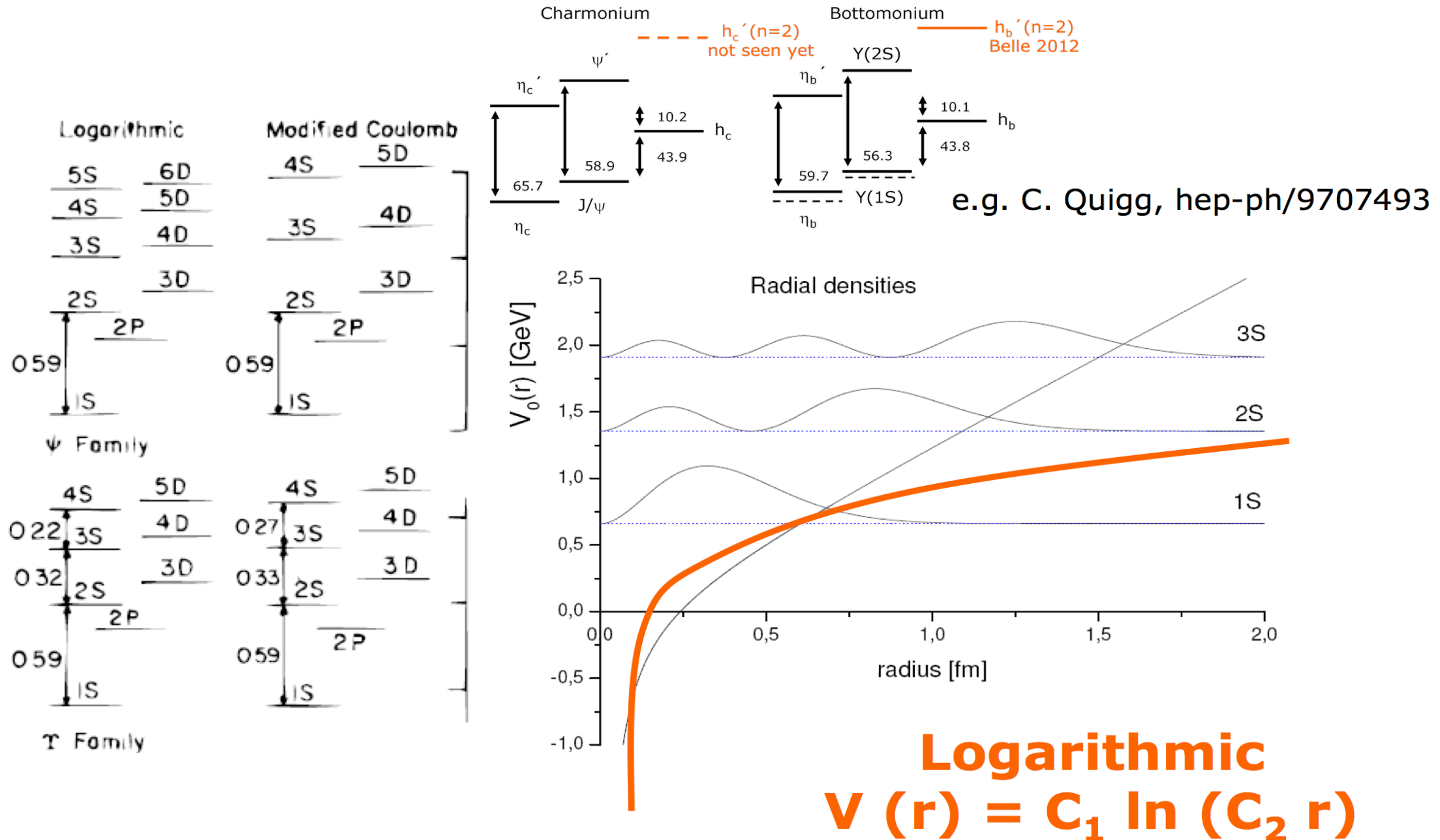
S-States
 $\eta_c(nS)$
 $\psi(nS)$



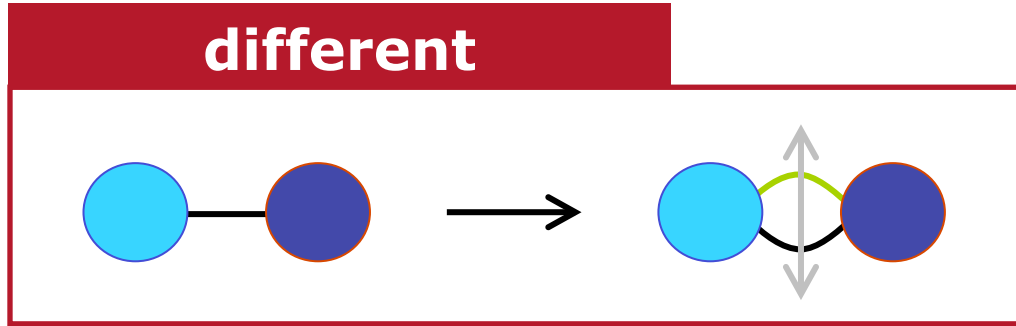
high angular momentum

P, D, F, ...
 States

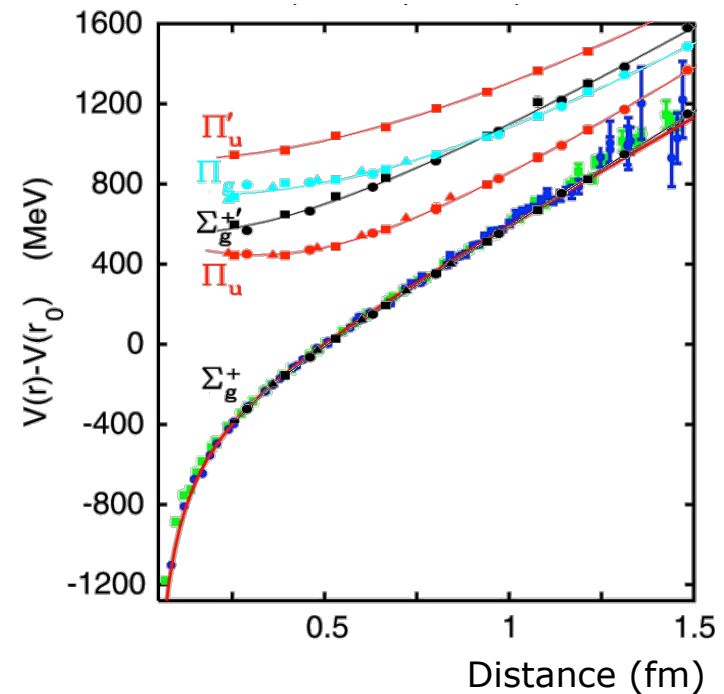
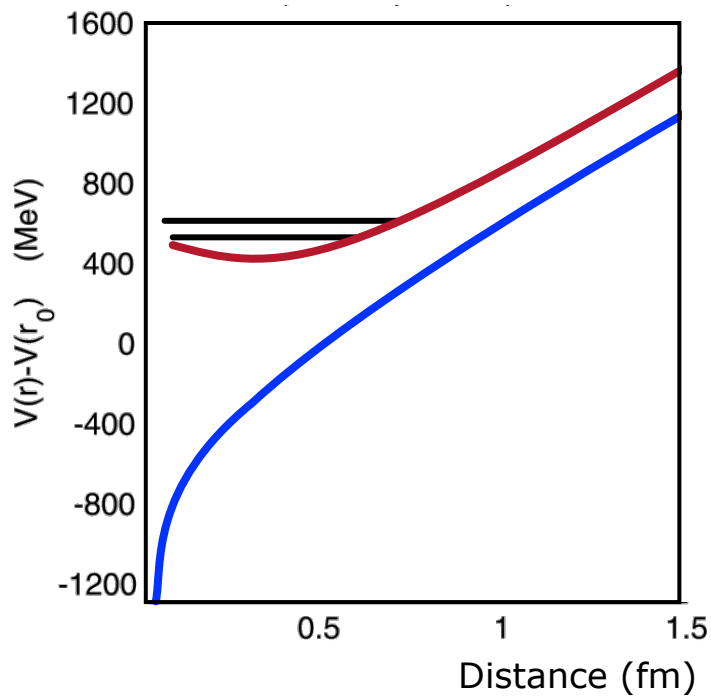




e.g. C. Quigg, hep-ph/9707493

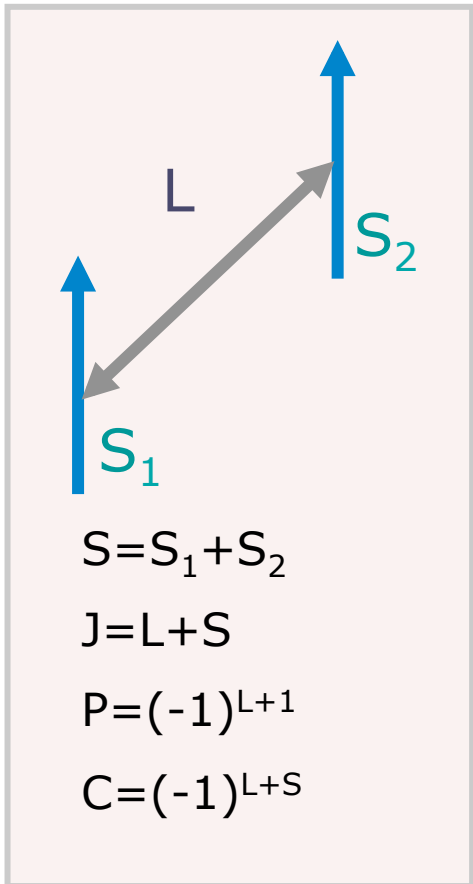


K.J. Juge, J. Kuti, C. Morningstar
 hep/lat 9709131



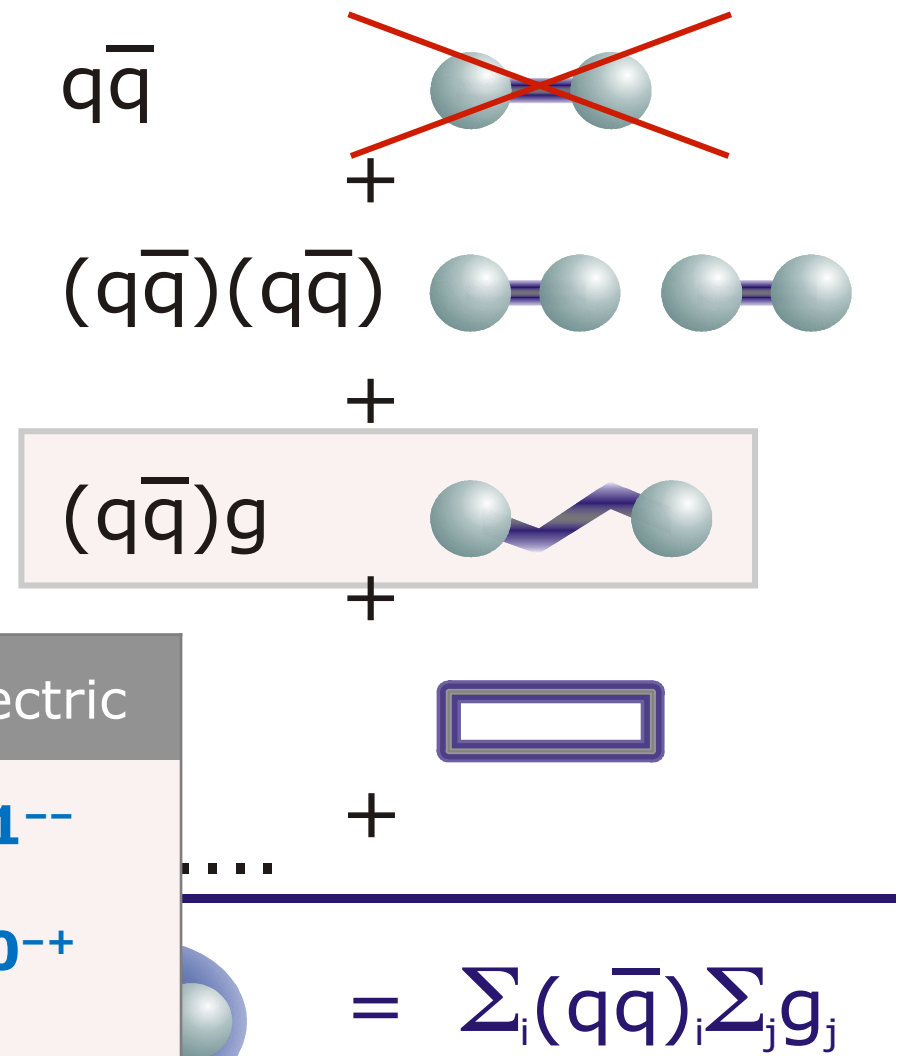
- remove the leading term due to selection of quantum numbers

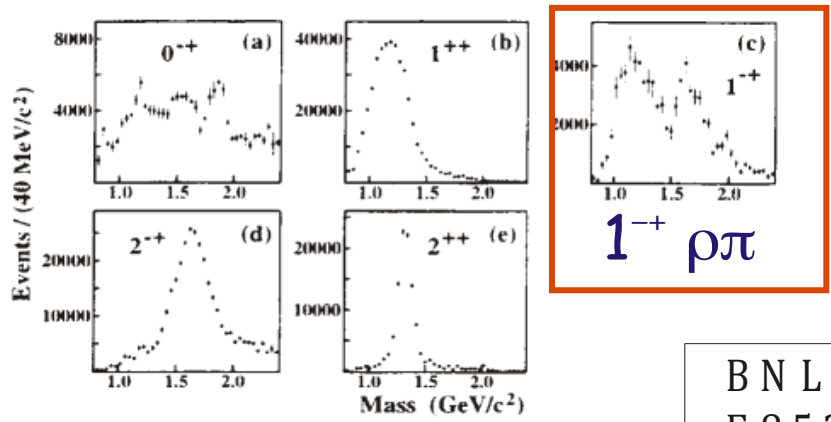
- e.g. for hybrids



impossible for $q\bar{q}$
 J^{PC} exotic

Gluon	Magnetic	Electric
$1S_0, 0^{-+}$	1^{++}	1^{--}
$3S_1, 1^{--}$	0^{+-}	0^{-+}
	1^{+-}	1^{-+}
	2^{+-}	2^{-+}

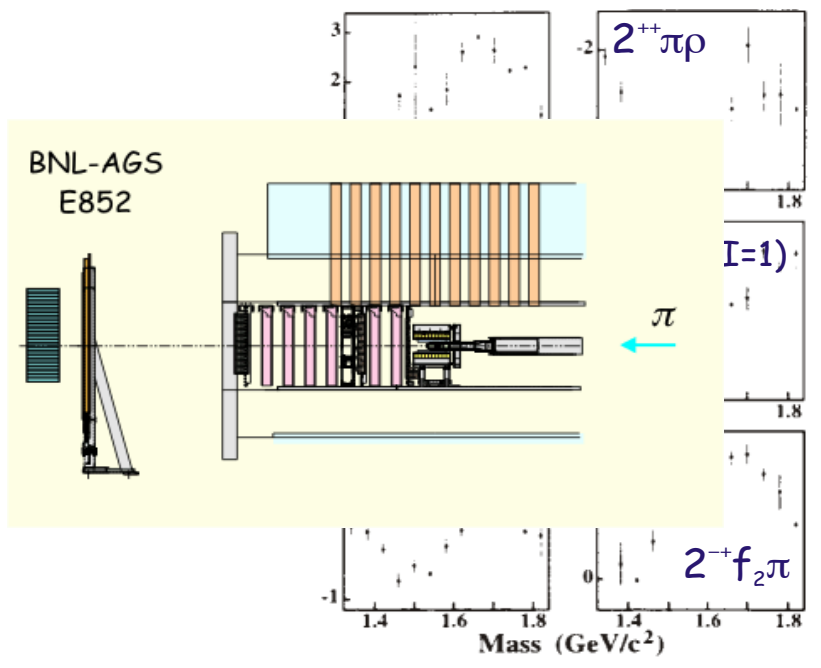




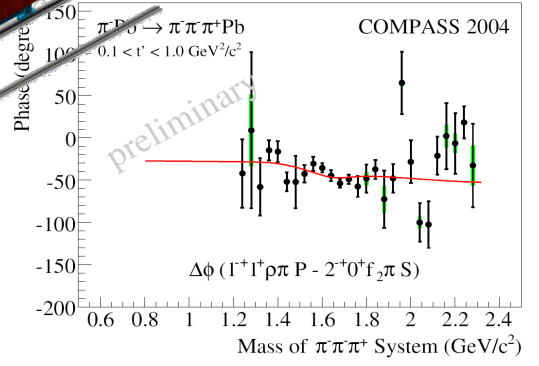
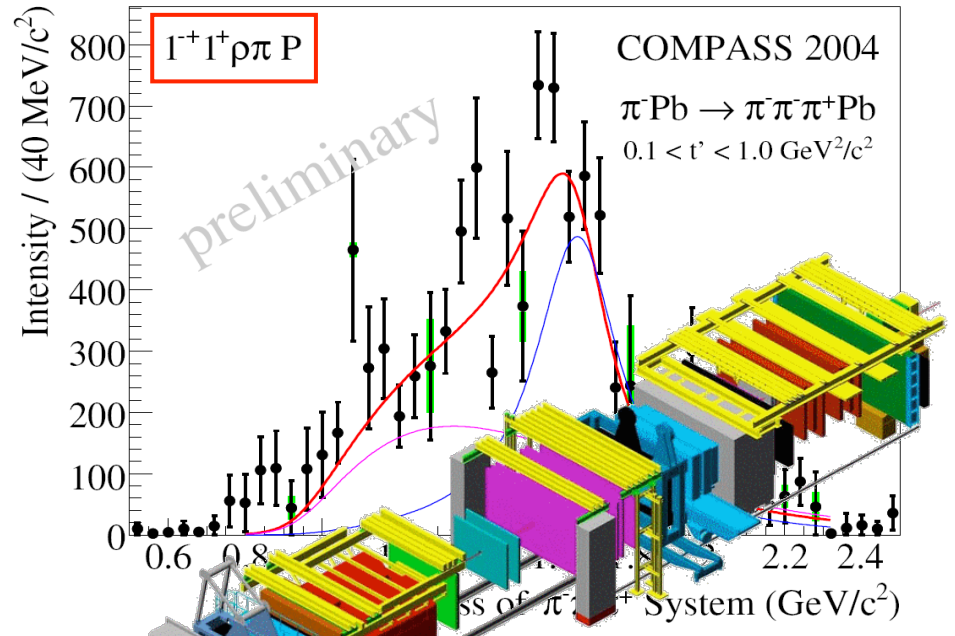
$1^{-+} \rho\pi$

BNL
E852

$\phi(X-1^{-+})$



$\pi^- p \rightarrow \pi^- \rho^0 p \rightarrow \pi^- \pi^- \pi^+ p$



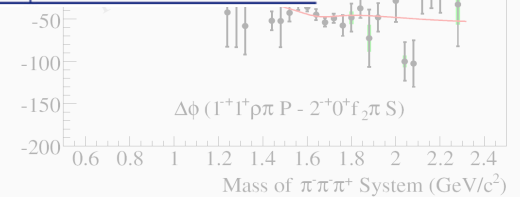
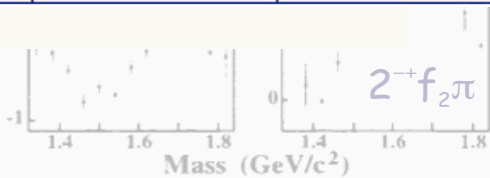
$\pi_1(1600)$...E852 $\rho\pi$ in 1997 and COMPASS today



thanks to G. Adams, RPI

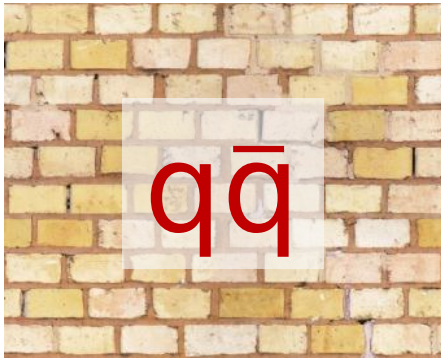
	Experiment	Mass	Width	Decay	Citation
$\pi_1(1400)$	E852	1359 (+16-14) (+10-24)	314 (+31-29) (+9-66)	$\eta\pi$	PR D60, 092001
	Crystal Barrel	1400 (+20-20) (+20-20)	310 (+50-50) (+50-30)	$\eta\pi$	PL B423,175
	Crystal Barrel	1360 (+25-25)	220 (+90-90)	$\eta\pi$	PL B446,349
	Obelix	1384 (+28-28)	378 (+58-58)	$\rho\pi$	EPJ C35, 21
$\pi_1(1600)$	E852	1593 (+8-8) (+29-47)	168 (+20-20) (+150-12)	$\rho\pi$	PR D65, 072001
	E852	1597 (+10-10) (+45-10)	340 (+40-40) (+50-50)	$\eta'\pi$	PRL 86, 3977
	Crystal Barrel	1590 (+50-50)	280 (+75-75)	$b_1\pi$	PL B563,140
	E852	1709 (+24-24) (+41-41)	403 (+80-80) (+115-115)	$f_1\pi$	PL B595,109
	E852	1664±8±10	185±25±28	$(b_1\pi)^-$	submitted to PRL
	E852	$\cong 1700$		$(b_1\pi)^0$	preliminary
$\pi_1(2000)$	E852	2001±30±92	333±52±49	$f_1\pi$	PL B595,109
	E852	2014±20±16	230±32±73	$(b_1\pi)^-$	submitted to PRL
$h_2(1950)$	E852	1954±8 (stat.)	138±3 (stat.)	$(b_1\pi)^0$	preliminary

BNL-AGS
E852



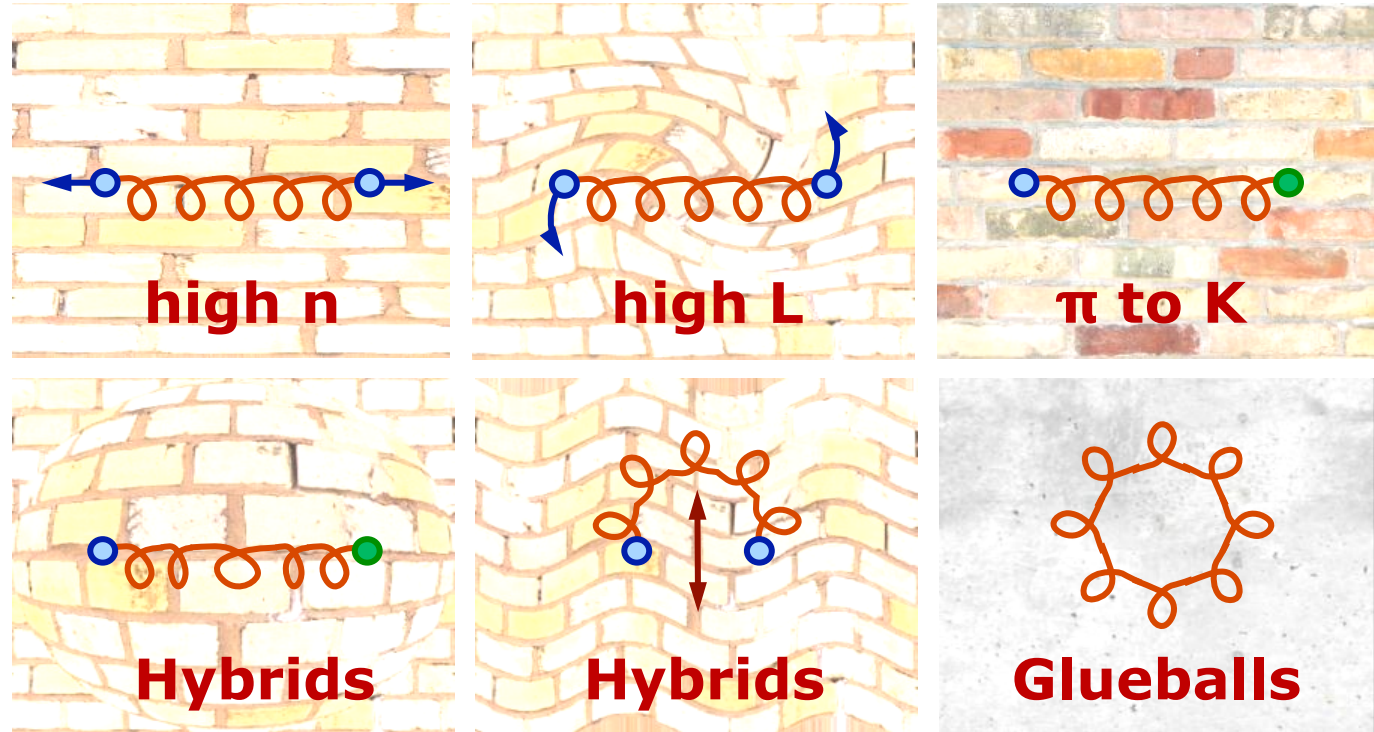
COMPASS 2004
 $\rightarrow \pi^- \pi^- \pi^+ P b$
 $< 1.0 \text{ GeV}^2/c^2$

COMPASS 2004



one may drag, bend, heat or resonate walls
one may exchange stones
one may remove the stones and has only grout

but back to the hadrons



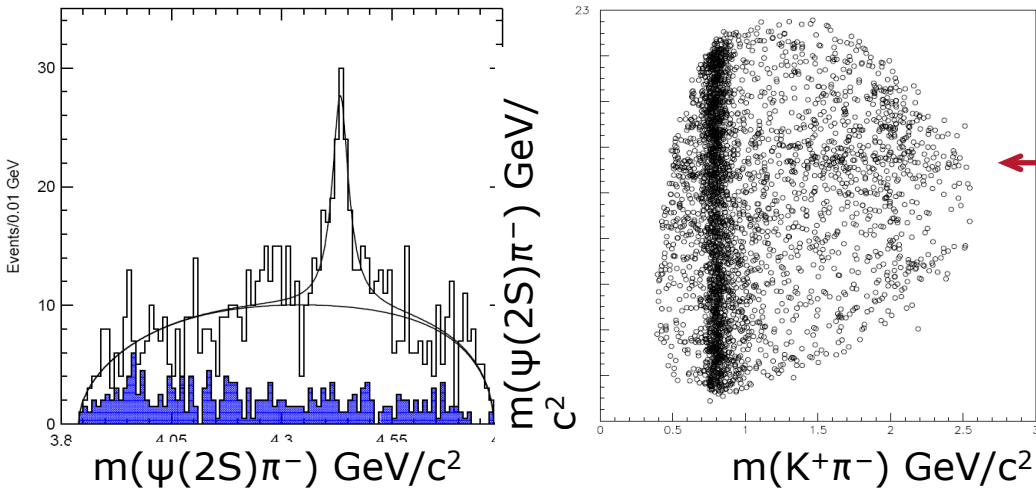
one may drag, bend, heat or resonate hadrons
one may exchange constituents
one may remove the constituents and has only grout

$Z(4430)^- \rightarrow \psi(2S) \pi^-$

in B-decays

Belle

PRL 100,142001



First time charge exchange

$B^0 \rightarrow K^+ Z^-$

Significance

$> 6.5\sigma$

Belle

PRD 80,031104

Dalitz plot analysis by Belle

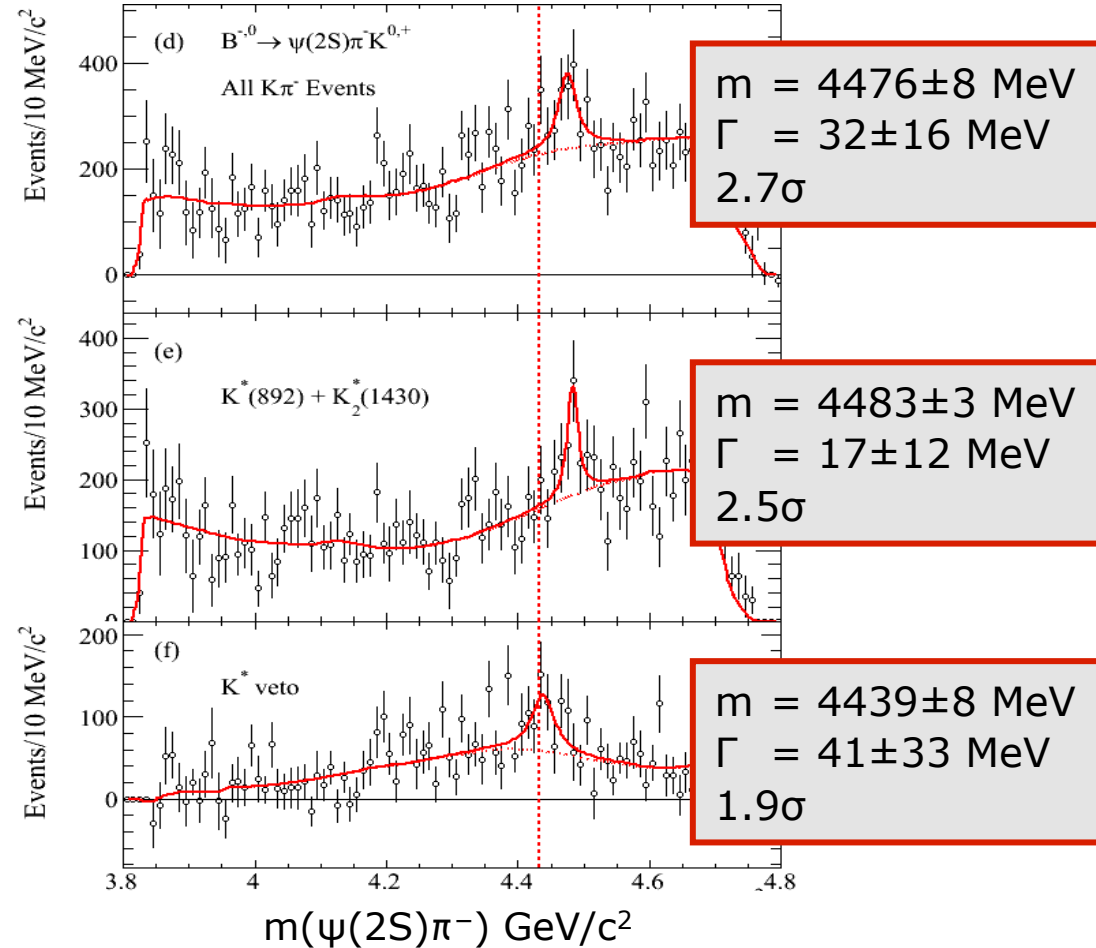
$> 6.4\sigma$

BaBar

PRD 79,112001

Search for

$Z(4430)^- \rightarrow \psi(1S,2S) \pi^-$



$\psi(2S) \pi^-: 2-3\sigma$

$\psi(1S) \pi^-: \text{No signal}$

Observation of a charged charmoniumlike structure in $e^+e^- \rightarrow \pi^+\pi^-J/\psi$ at $\sqrt{s}=4.26$ GeV

- Observed by BESIII (arXiv:1303.5949)
- Many theoretical papers
→ main trend: DD*
- E. Braaten (arXiv:1305.6905)
→ connection between hybrids and molecules/tetraquarks

Experimental Questions

- Masses
- Dispersive Effects
- Decays

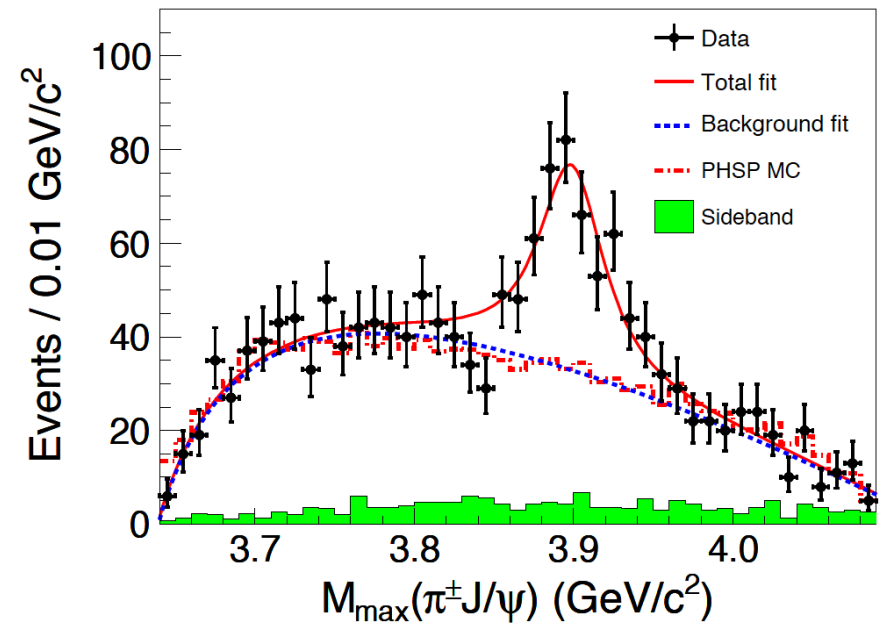
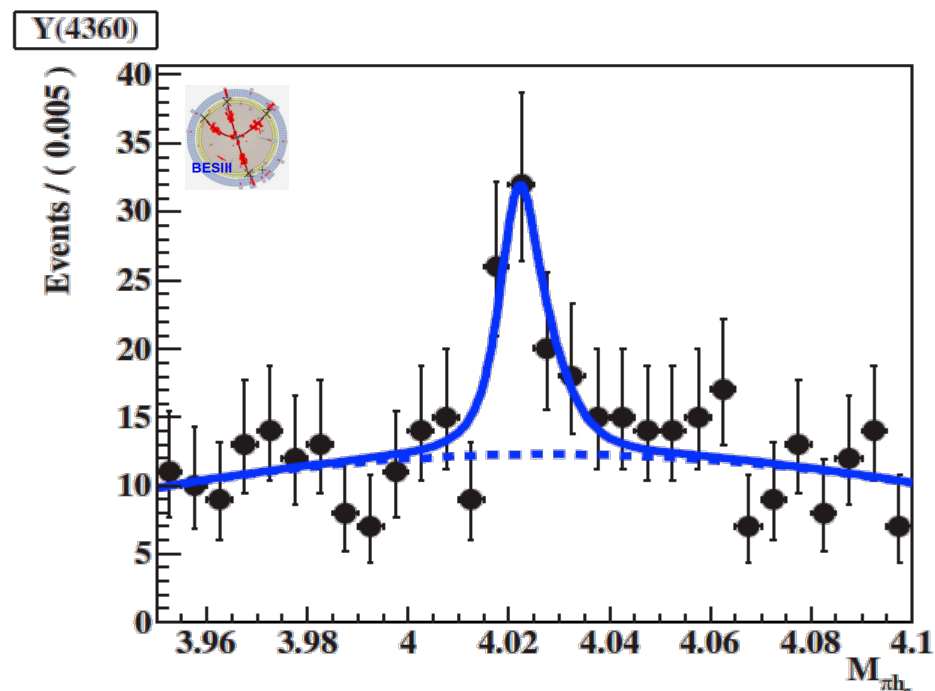
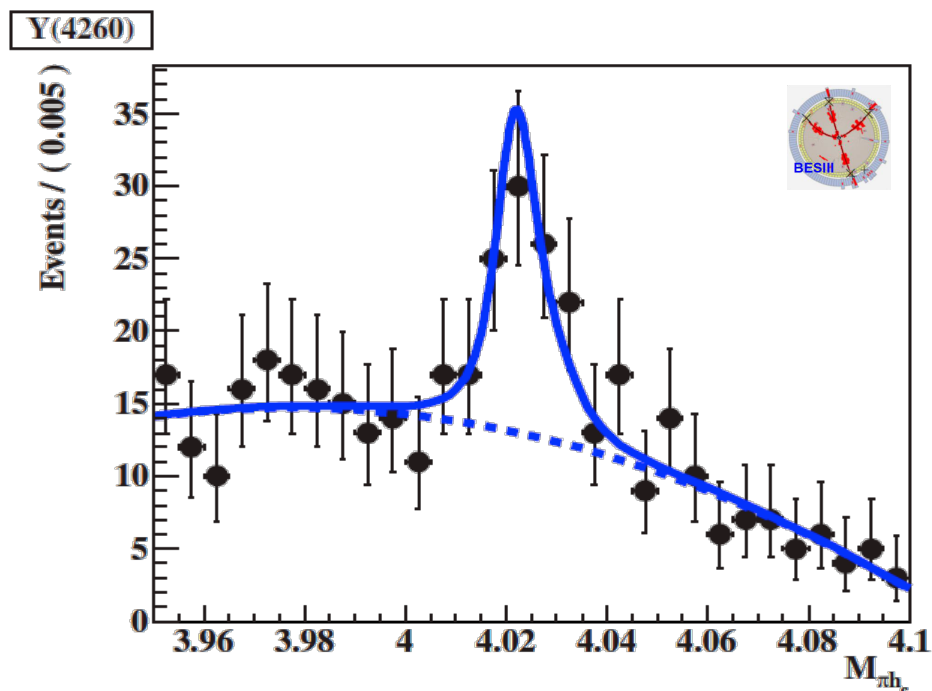


FIG. 4: Fit to the $M_{\max}(\pi^\pm J/\psi)$ distribution as described in the text. Dots with error bars are data; the red solid curve shows the total fit, and the blue dotted curve the background from the fit; the red dot-dashed histogram shows the result of a phase space MC simulation; and the green shaded histogram shows the normalized J/ψ sideband events.



Simultaneous fit to 4.26/4.36 GeV data 6.4σ

From $h_c\pi^\pm$

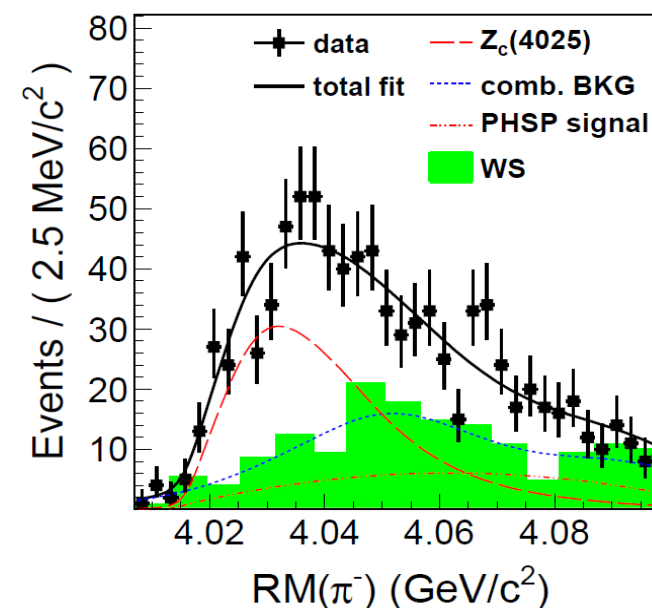
$$M(Z_c(4020)) = 4021.8 \pm 1.0 \pm 2.5 \text{ MeV}$$

$$\Gamma(Z_c(4020)) = 5.7 \pm 3.4 \pm 1.1 \text{ MeV}$$

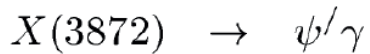
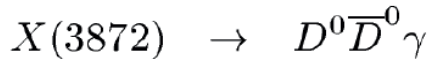
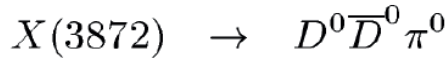
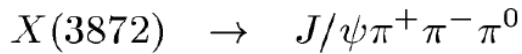
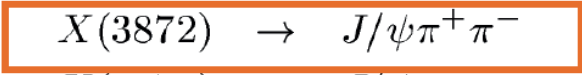
From $(D^*\bar{D}^*)^\pm$

$$M(Z_c(4025)) = 4026.3 \pm 2.6 \pm 3.7 \text{ MeV}$$

$$\Gamma(Z_c(4025)) = 24.8 \pm 5.7 \pm 7.7 \text{ MeV}$$



- observed in more than one decay channel

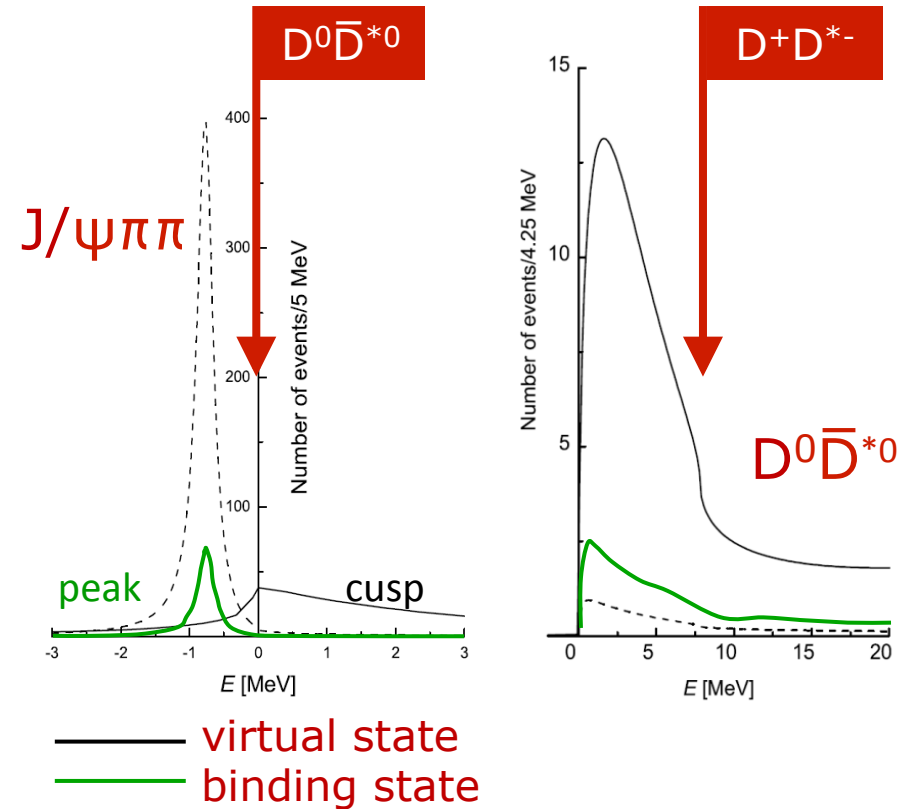


- narrow width $\Gamma < 2.3$ MeV (90% CL)
- Mass 3871.46 ± 0.19 MeV very close to threshold

$$M_X - (m_{D^*} + m_{\bar{D}^0}) = -0.32 \pm 0.35 \text{ MeV}$$

S-wave molecular state?

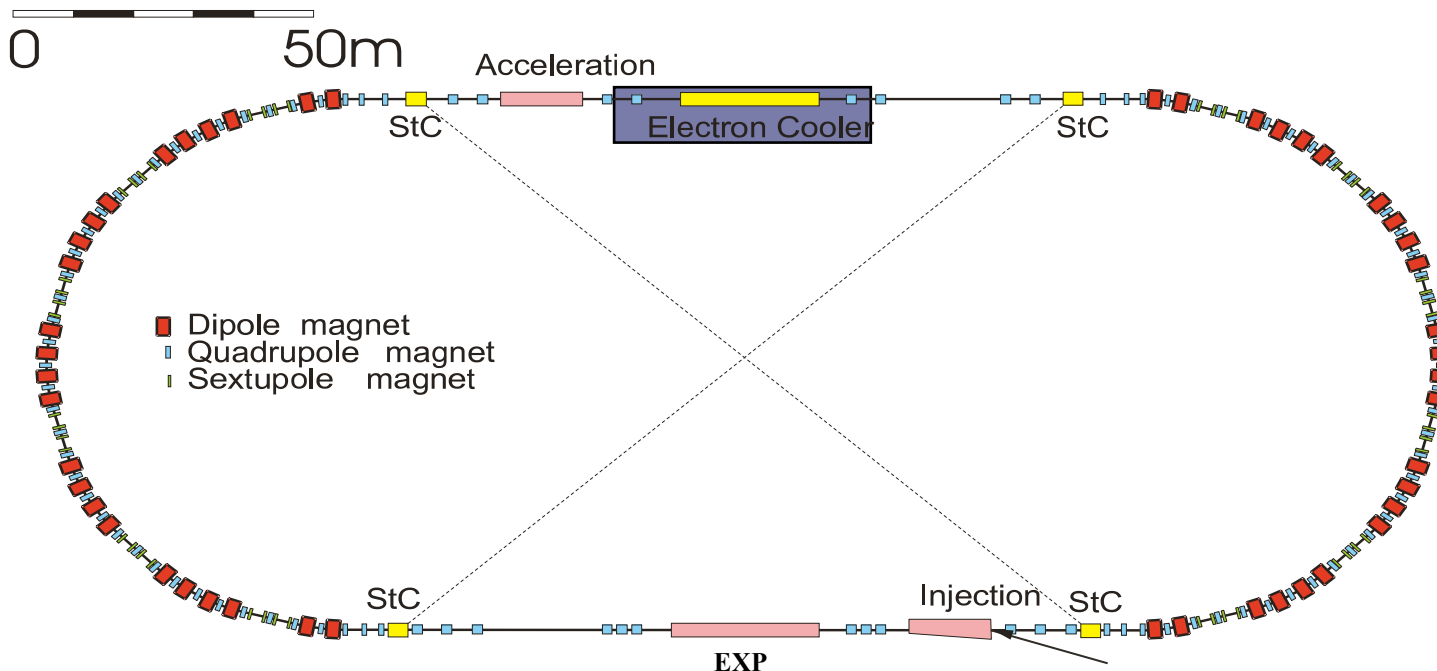
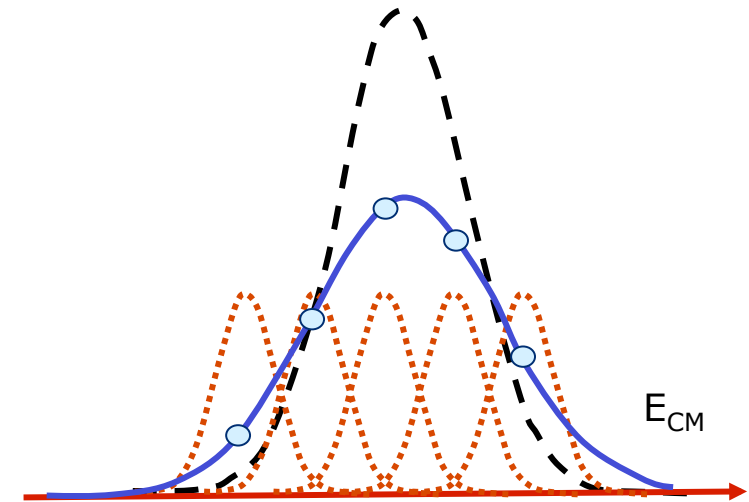
needs a line shape measurement



Scan with simultaneous extraction of $J/\psi \pi \pi$, $D^0 \bar{D}^{*0}$, $D^+ D^{*-}$, $\psi(2S) \gamma$, $J/\psi \gamma$, $J/\psi \rho$ and $J/\psi \omega$ essential !

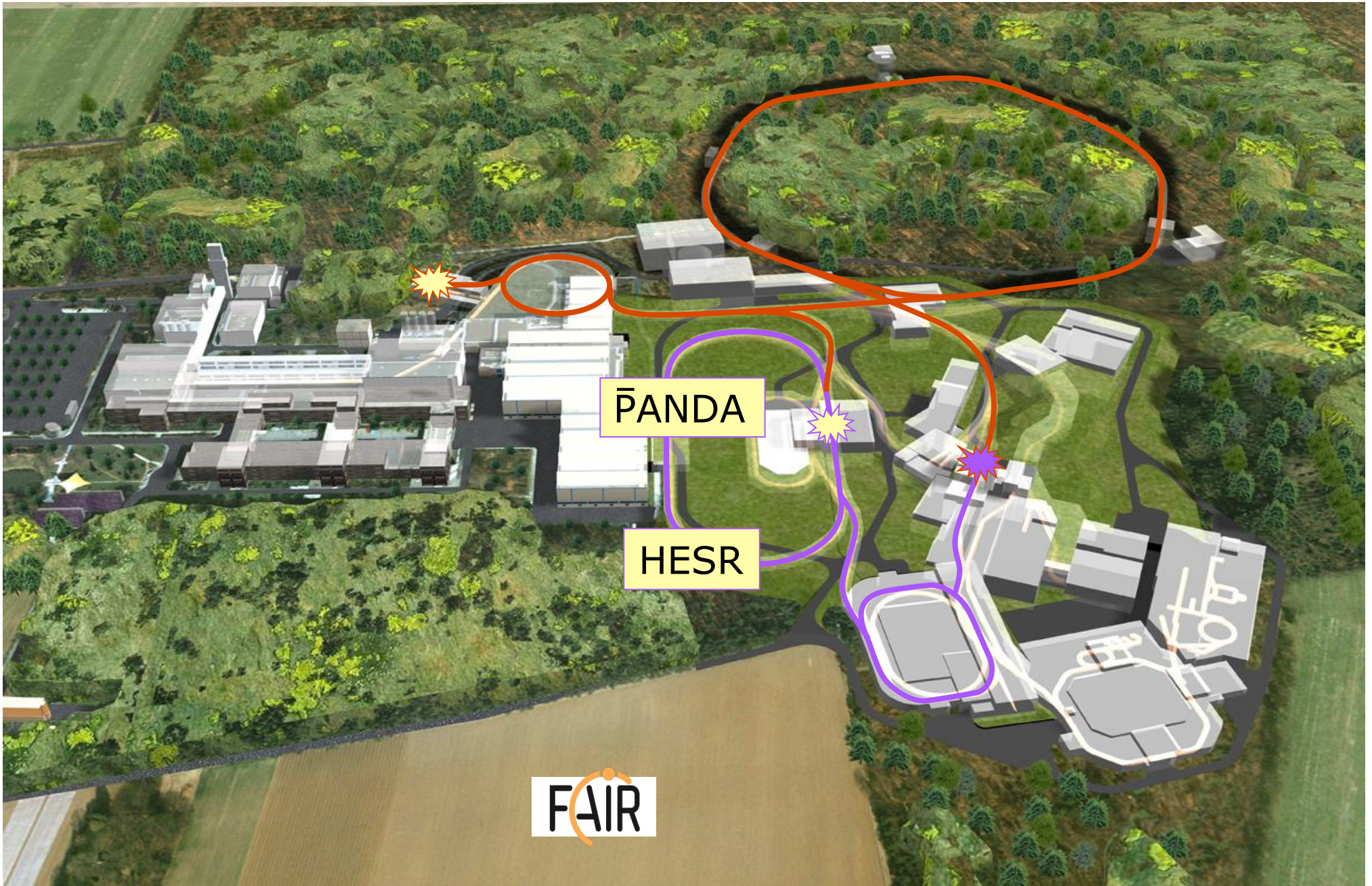
Parameters of HESR

- Injection of p at 3.7 GeV
- Slow synchrotron (1.5-14.5 GeV/c)
- Storage ring for internal target operation
- Luminosity up to $L \sim 2 \times 10^{32} \text{ cm}^{-2} \text{ s}^{-1}$
- Beam cooling (stochastic & electron)

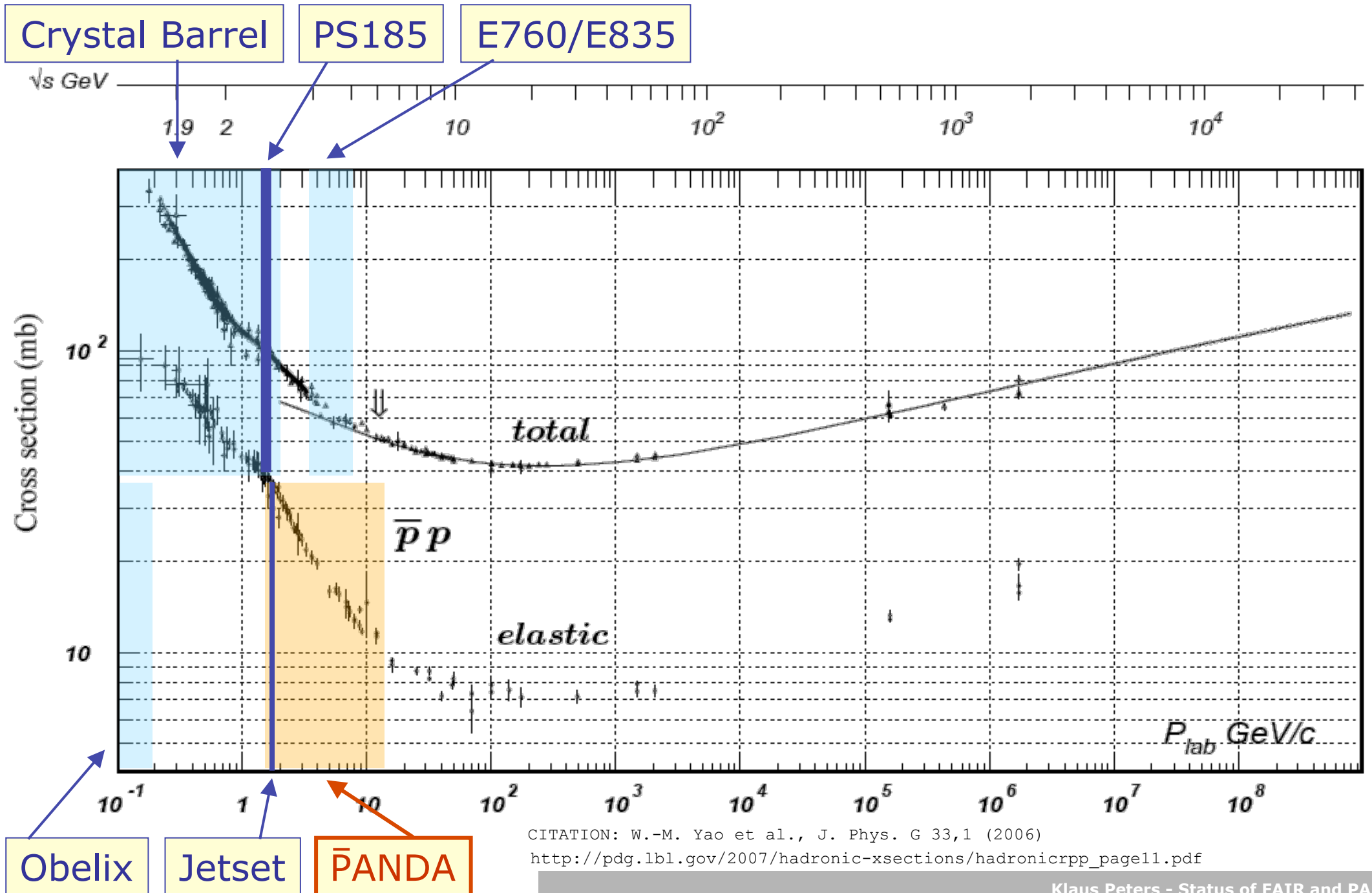


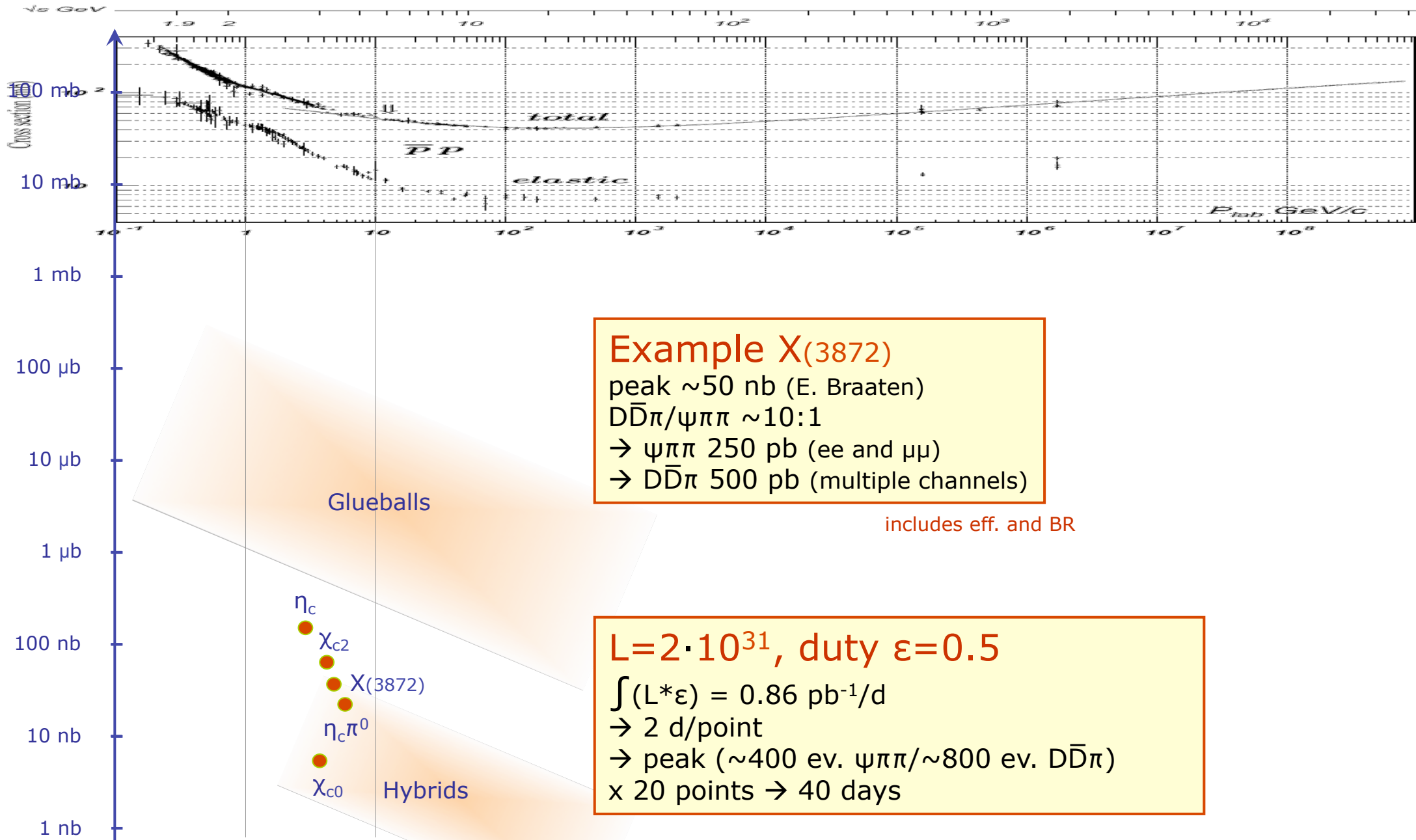
Resonance scan

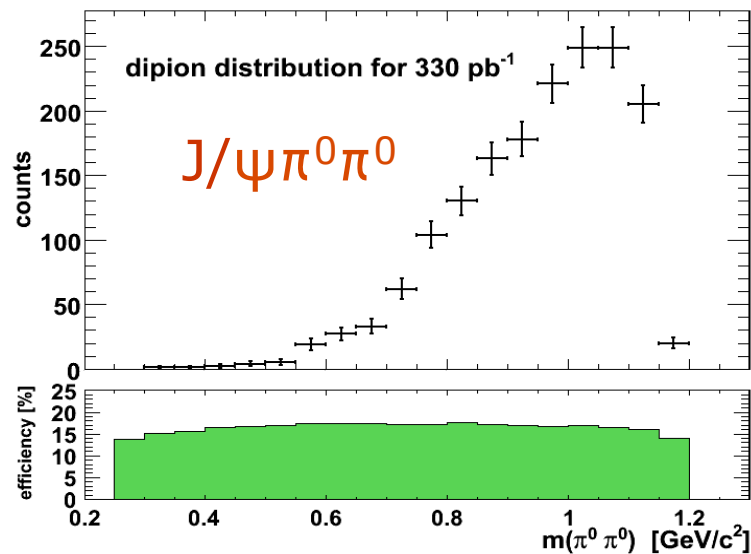
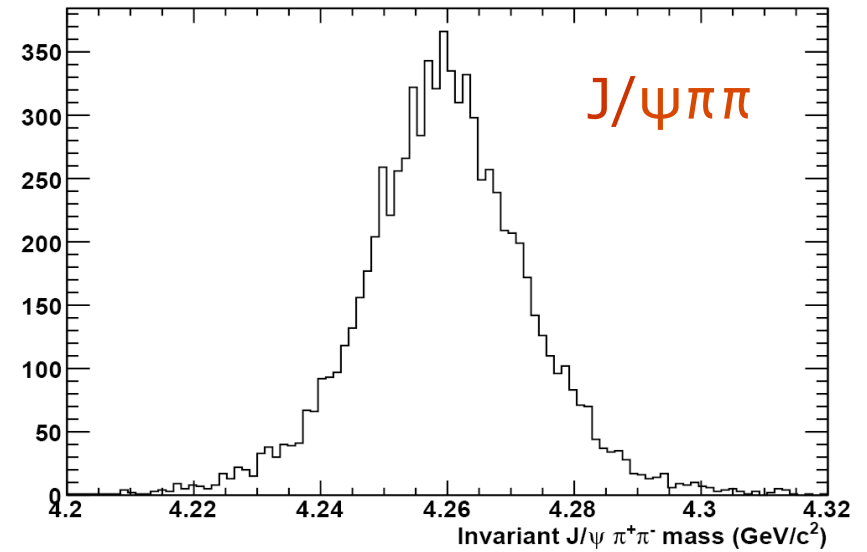
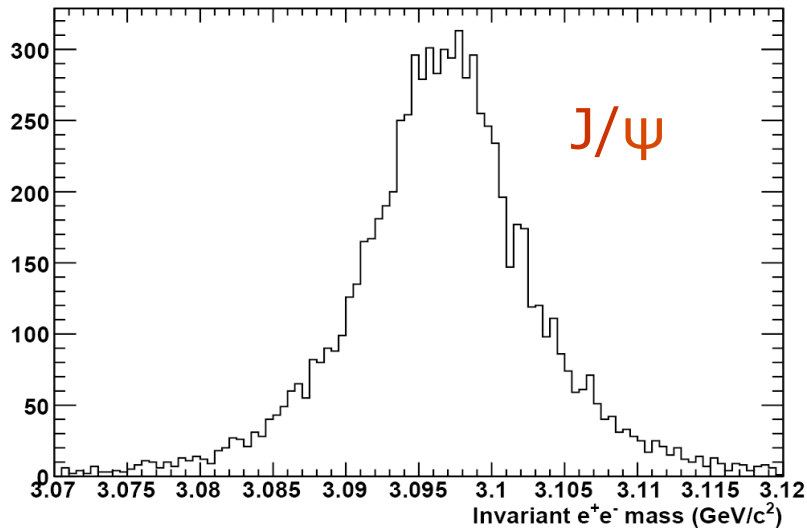
- Energy resolution $\sim 50 \text{ keV}$
- Tune E_{CM} to probe resonance
- Get precise mass and width



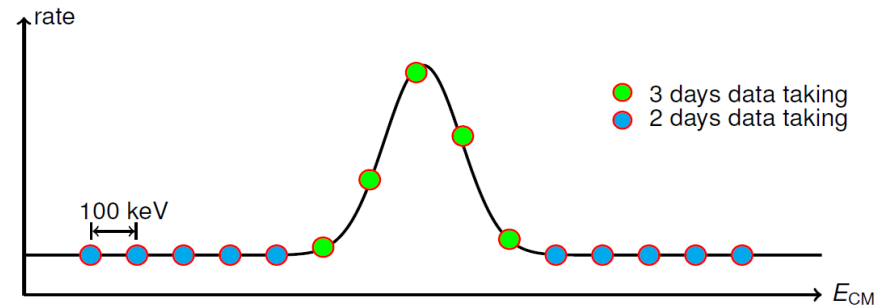
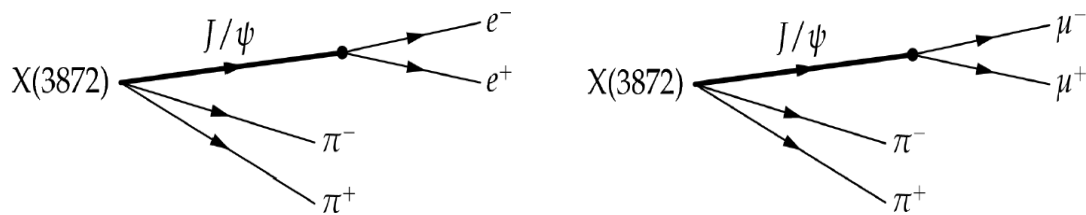
$\bar{p}p$ cross sections





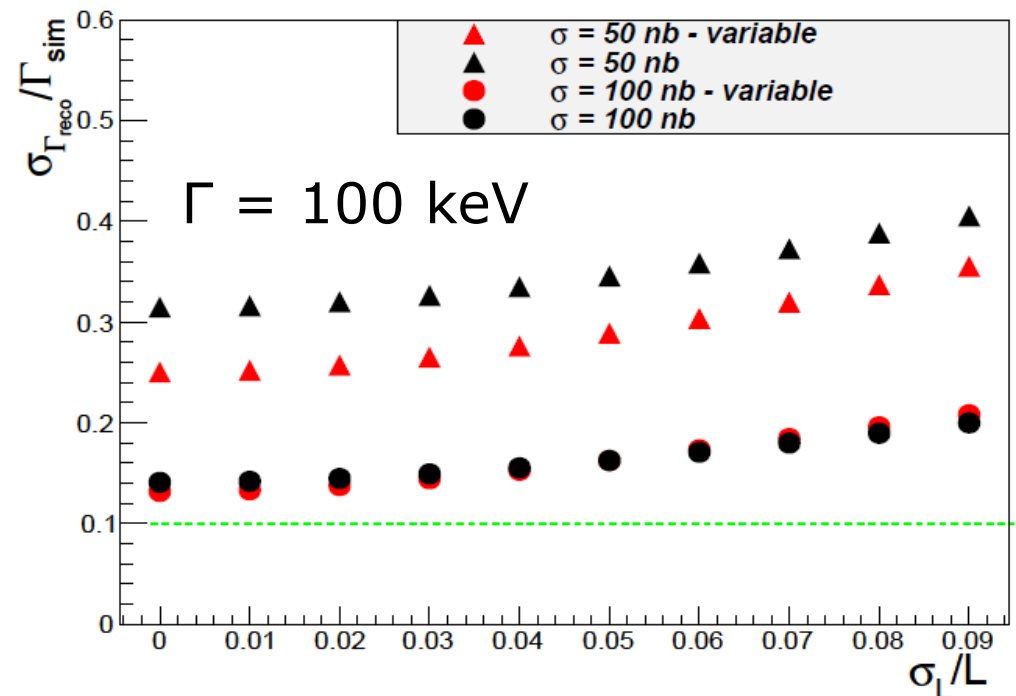
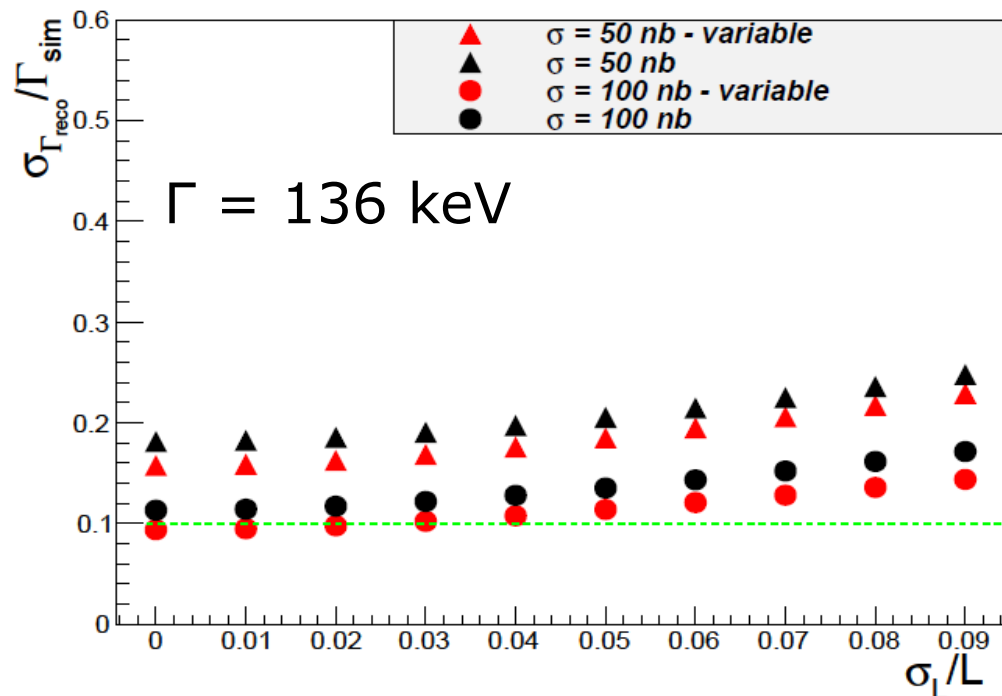


\sqrt{s} [GeV]	Eff [%]	RMS [MeV]
3.526	27.52	3.7
3.686	30.90	5.7
3.872	32.07	8.3
4.260	32.58	13.4
4.600	30.60	18.5
5.000	29.70	24.3



Extraction of the Width
after beam profile deconvolution

16 Scan-Points
 $\Delta E = 100$ keV
2-3 days per Scan-Point

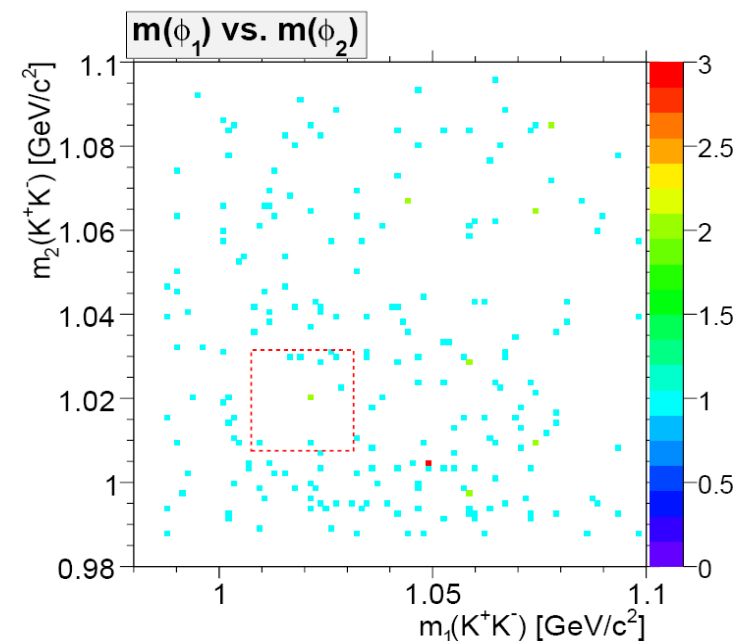
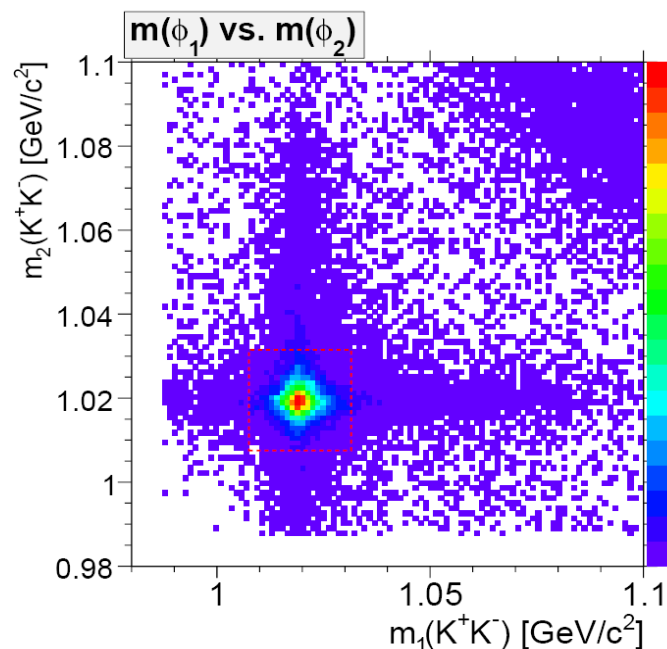


Input

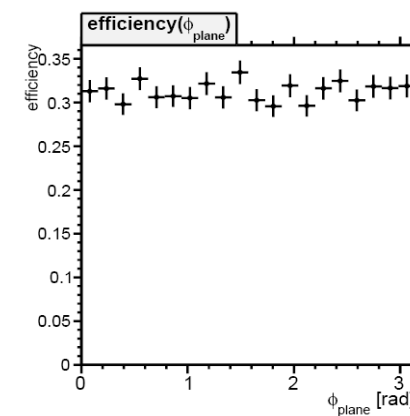
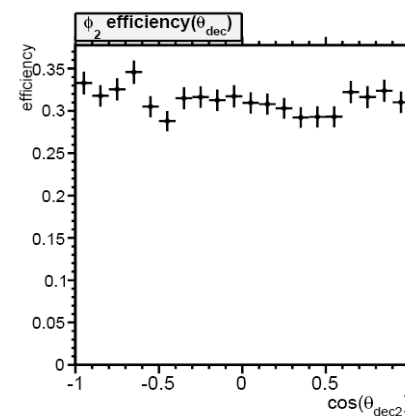
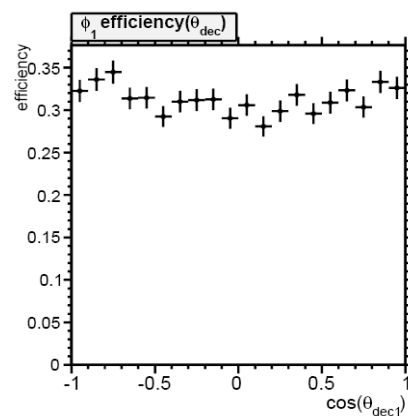
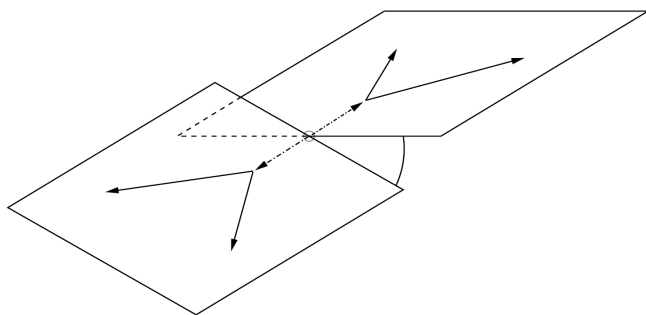
$$M = 2.235 \text{ GeV}/c^2$$

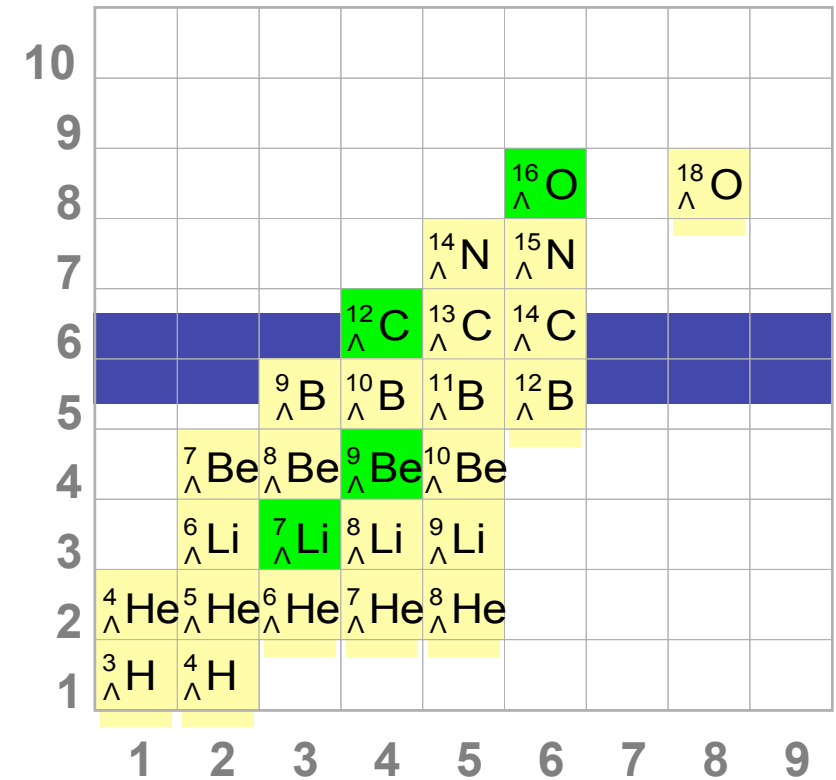
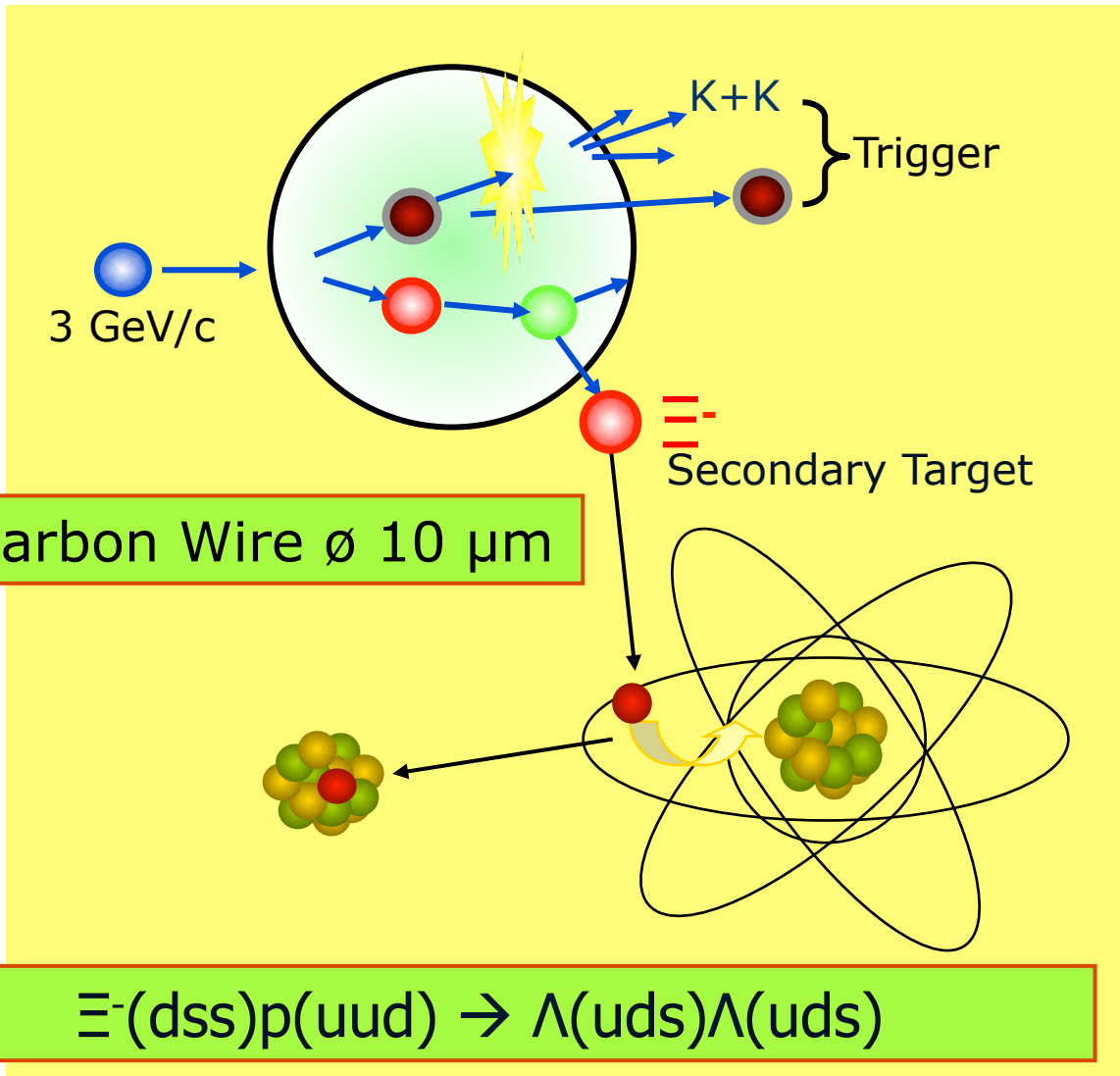
$$\Gamma = 15 \text{ MeV}/c^2$$

σ_S [nb]	Beam time T_b (\approx)
1	13.7 y
5	200 d
10	50 d
100	12 h
500	0.5 h
1000	7.2 min



Channel	rel. X-sec	$\epsilon(\text{VL})[\%]$	$\epsilon(\text{L})[\%]$	$\epsilon(\text{T})[\%]$	$\epsilon(\text{VT})[\%]$
Signal	1	30.1	28.5	23.7	18.8
DPM generic	10^6	$< 4.3 \cdot 10^{-4}$	$< 4.3 \cdot 10^{-4}$	$< 4.3 \cdot 10^{-4}$	$< 4.3 \cdot 10^{-4}$
r_{SN}	—	$> 1 : 14$	$> 1 : 14$	$> 1 : 17$	$> 1 : 22$

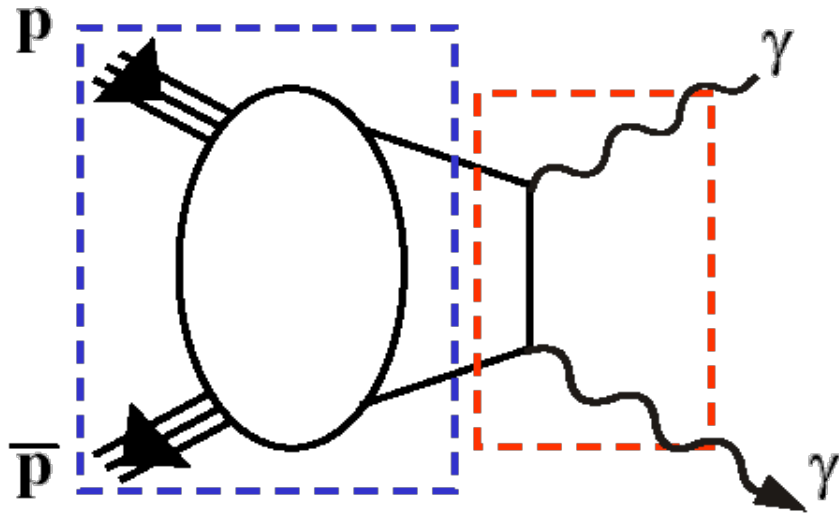




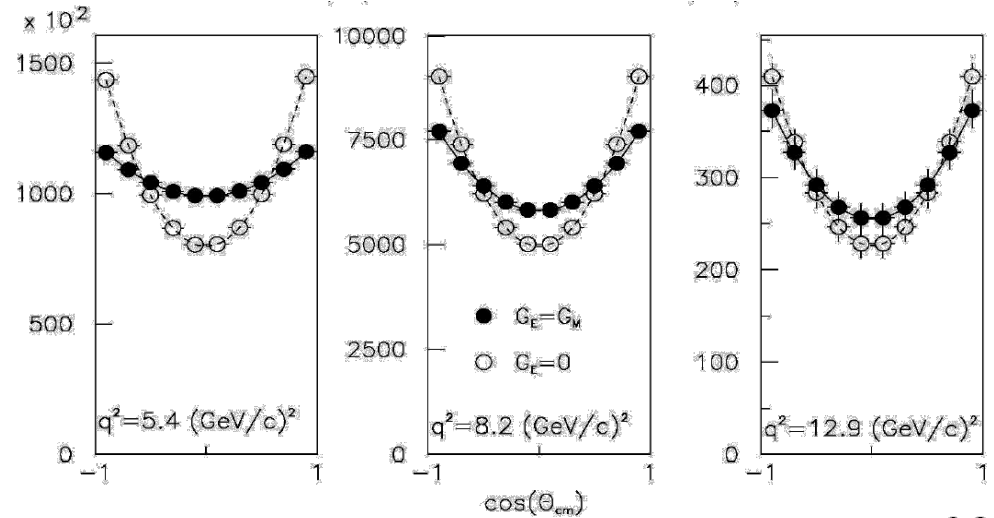
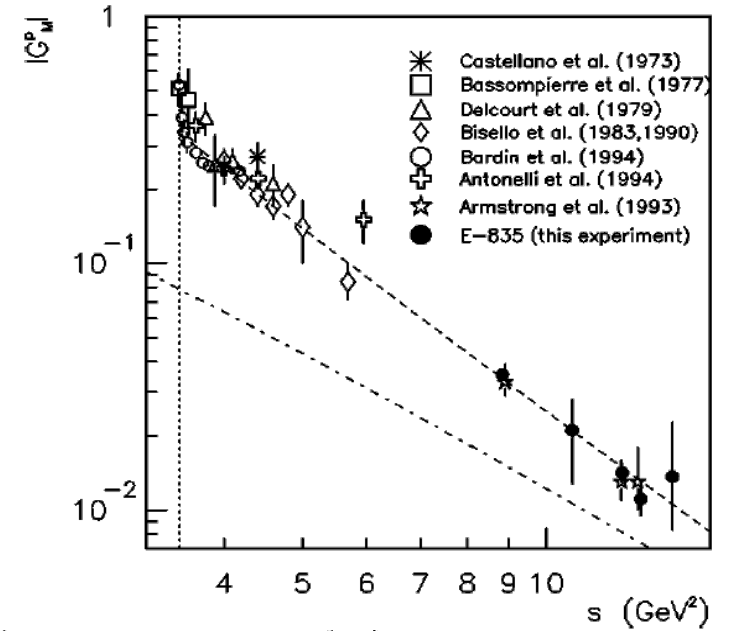
- Limiting factor
 - charged particle load on central detector $(0.6-1.0) \cdot 10^7$
- $L = (3-5) \cdot 10^{30} \text{ cm}^{-2}\text{s}^{-1}$
 - \bar{p} re-storage $< 6 \cdot 10^6$

Minimum 8 months full running

Crossed-Channel Compton Scattering



Cross section $\sigma \approx 2.5 \text{ pb} @ s \approx 10 \text{ GeV}^2$
 $L = 2 \cdot 10^{32} \text{ cm}^{-2} \text{ s}^{-1} \rightarrow 10^3 \text{ Events/Month}$



B. Ramstein

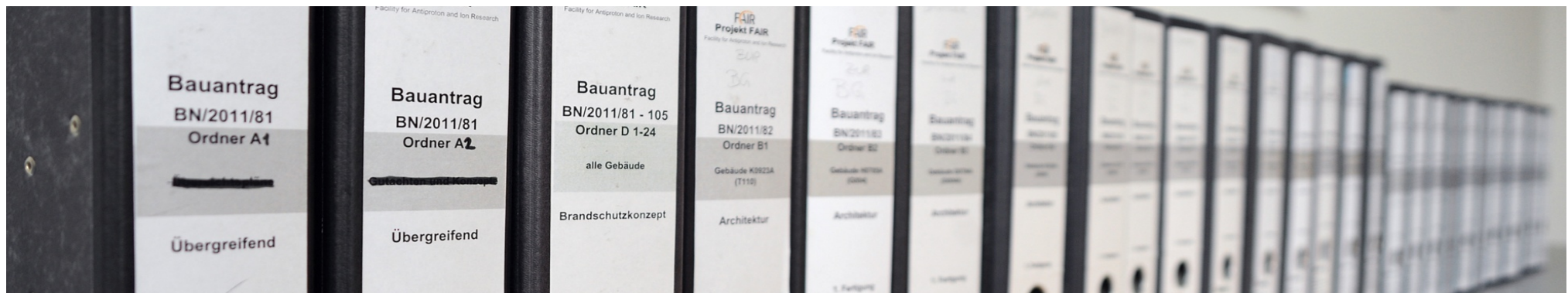
Electromagnetic Formfactor of the Proton (time-like)

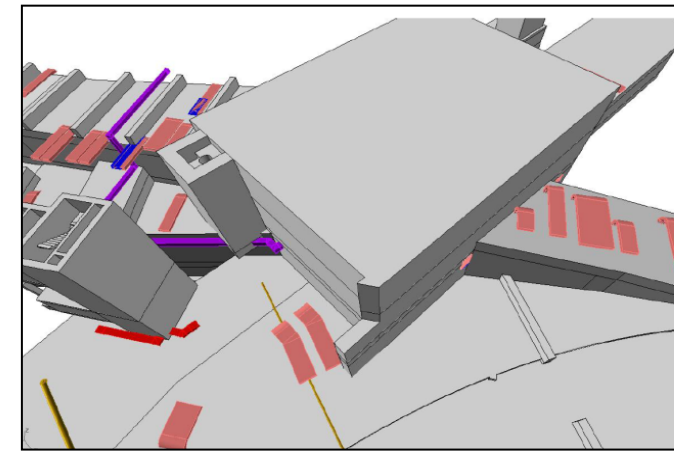
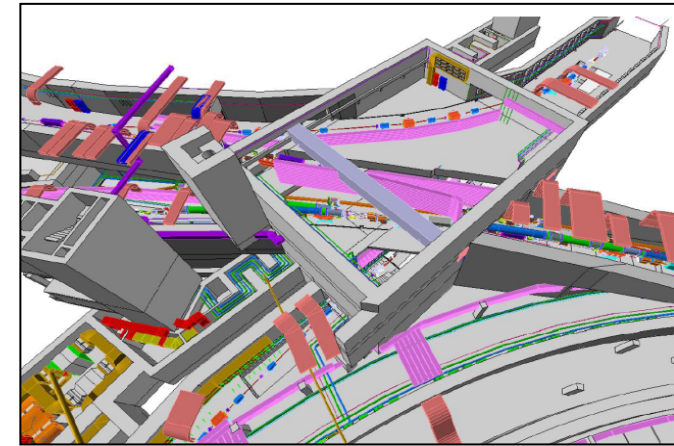
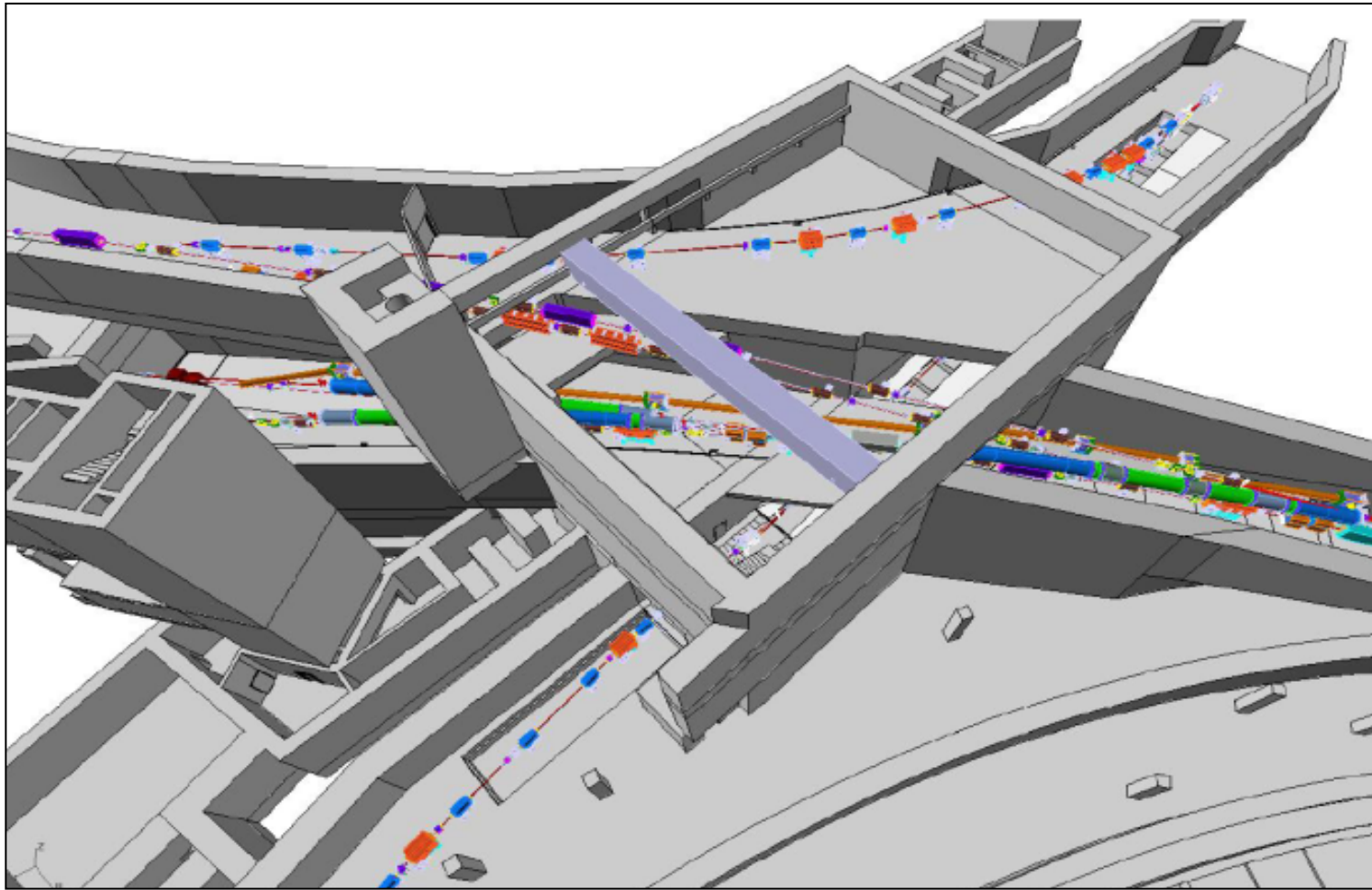


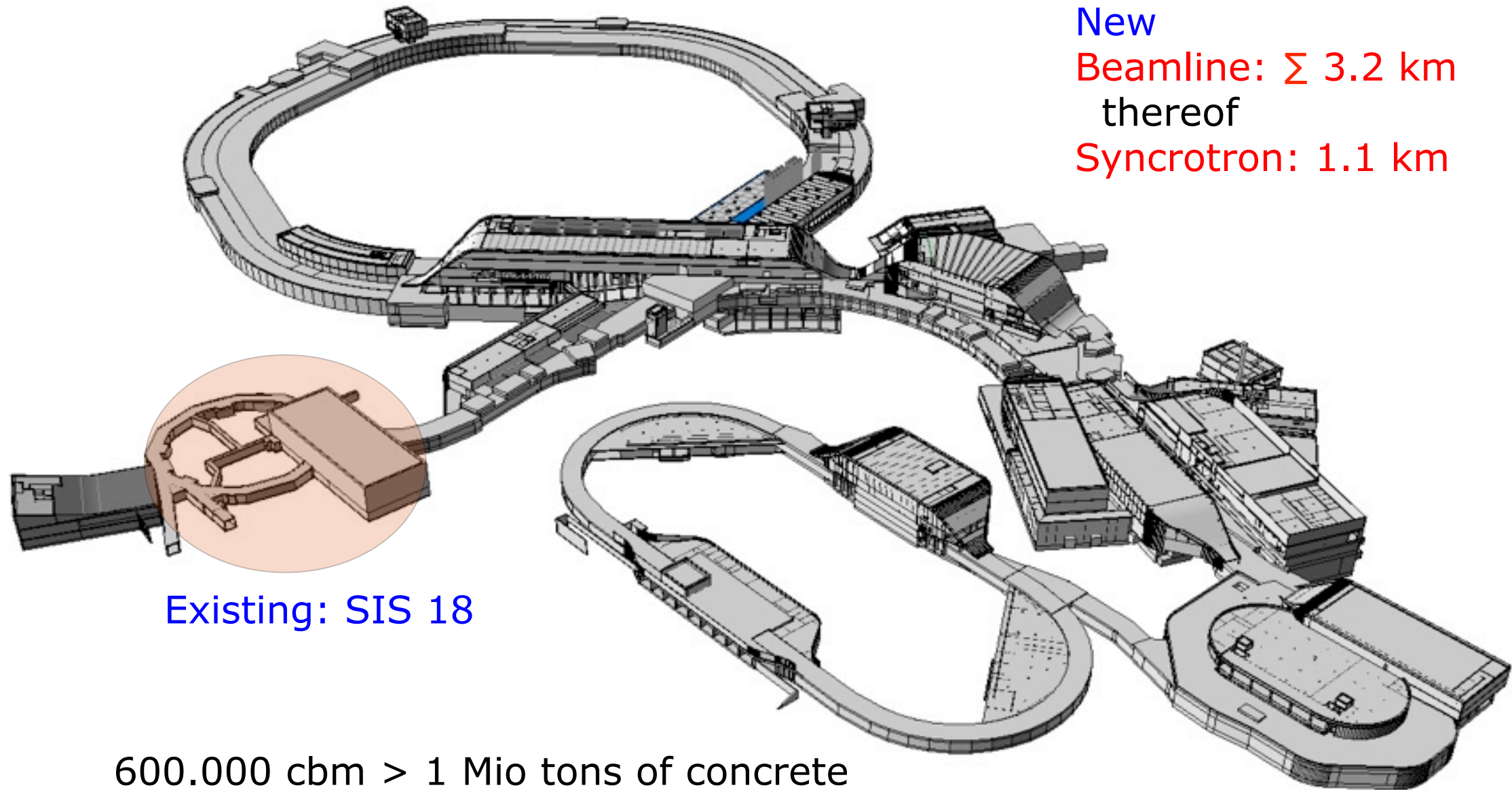
13.01.2013



		IV / 1	II / 13	III / 13
building permit	29.10.12	◆		
permit for water rights (piling works)	14.11.12	◆		
permit for water rights (groundwater lowering)			06.05.13 (draft) ◆	
3. partial permit of radiation protection (G007)			21.02.13 ◆	
4. partial permit of radiation protection (G004/17.1)				◆ expected in Q III/13





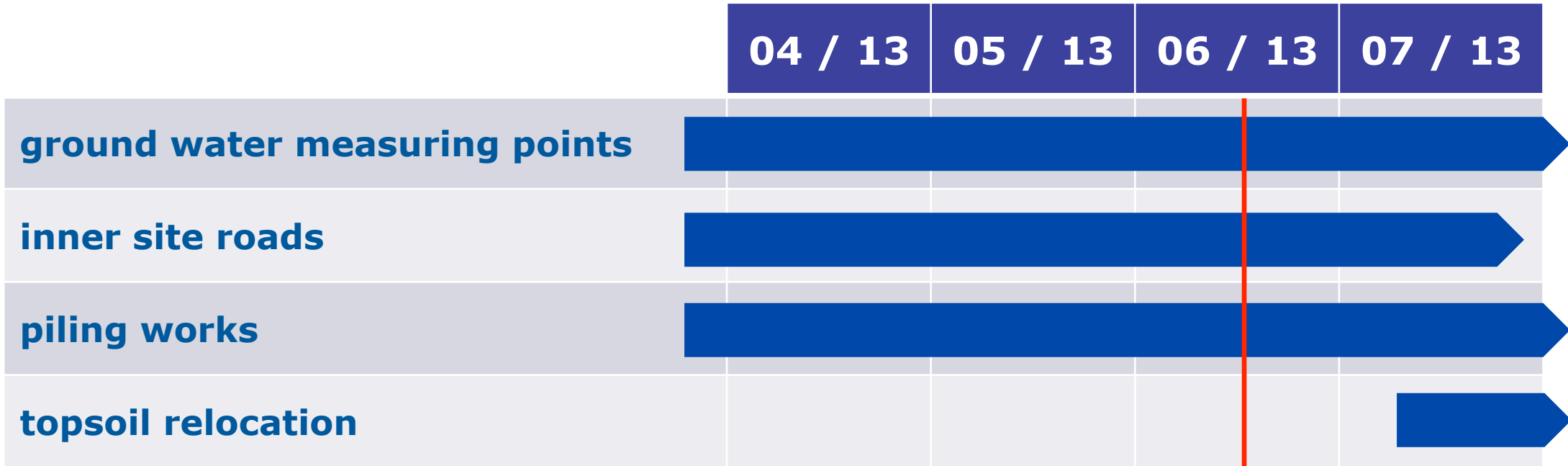


New
Beamline: Σ 3.2 km
thereof
Synchrotron: 1.1 km

Existing: SIS 18

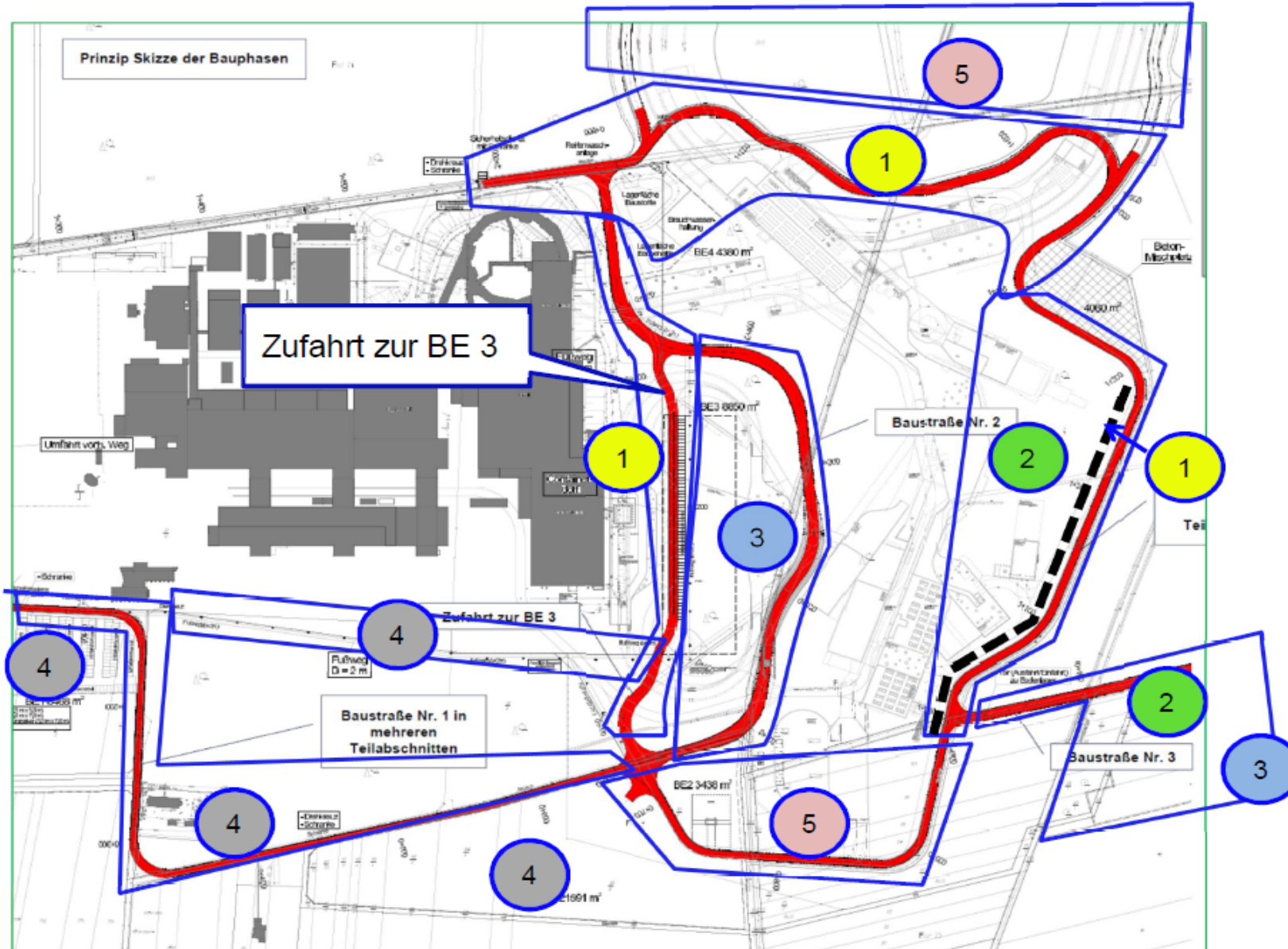
600.000 cbm > 1 Mio tons of concrete
35.000 tons of steel





Skizze zu den Ausführungsfristen

Anlage 214-A1



Neue Einzelfristen

1:	15.03.2013	✓
2:	12.04.2013	✓
3:	30.04.2013	✓
4:	31.05.2013	✓
5:	31.07.2013	

- piling to date on schedule
- more than 100 holes drilled >4/day
- holes partially concrete-lined
- goal: finished Q IV/2014



A close-up photograph of a bartender's hands pouring beer from a tap into a glass. The scene is lit with warm, golden light, creating a bokeh effect in the background. The text "THANK YOU" is overlaid in a bold, red, sans-serif font across the center of the image.

THANK YOU