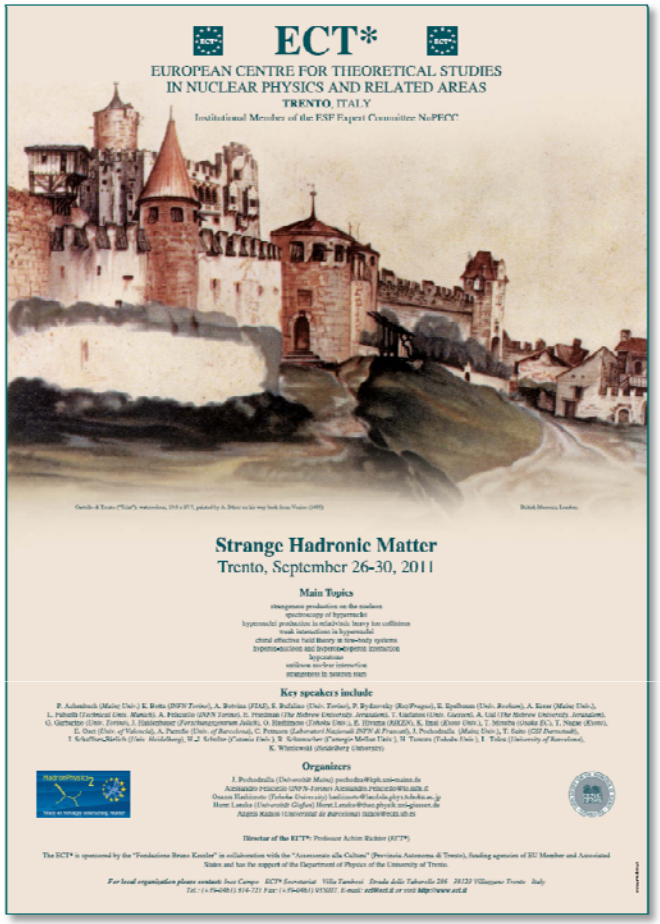
Super(B)nuclei



SuperB: an opportunity to study baryons with beauty and supernuclei

Alessandro Feliciello

I.N.F.N. - Sezione di Torino

Summary

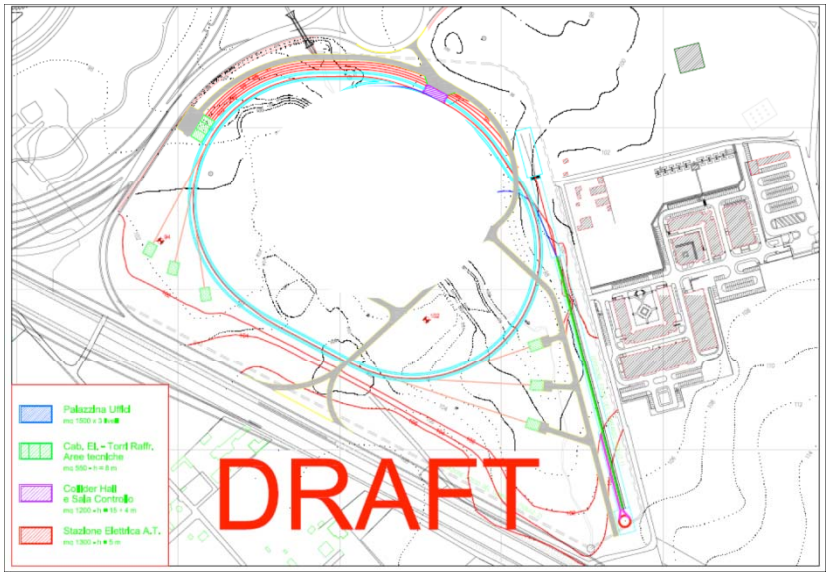
- The INFN Super*B* project
- The (nuclear) physics case
- A possible experimental program

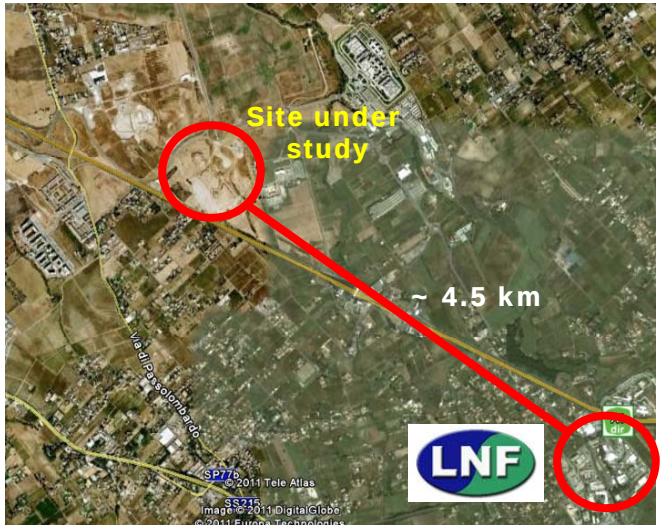
The SuperB project

INFN Istituto Nazionale di Fisica Nucleare

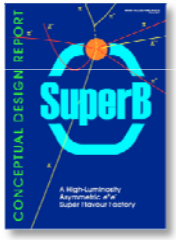
- SuperB is a flagship INFN project
- It was approved and funded in December 2010 by Italian Education and Research Minister

SuperB



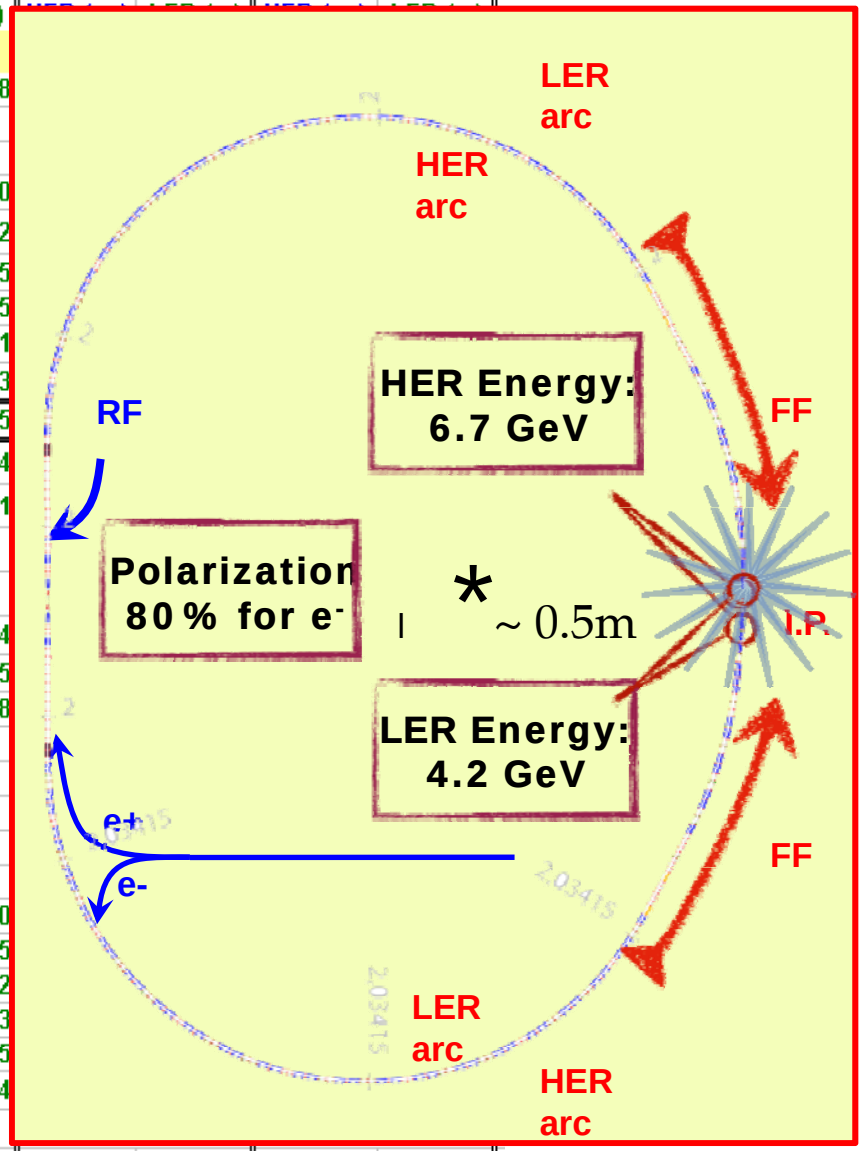


- Conceptual Design Report: arXiv:0709.0451v2 [hep-ex]
  http://web.infn.it/superb/images/stories/upload_file/superb-cdr.pdf
- Accelerator Progress Report: arXiv:1009.6178v2 [physics.acc-ph]



SuperB beam parameters

		Base Line		Low Emittance		High Current	Tau/Charm (prelim.)
Parameter	Units	HER (e+)	LER (e-)	HER (e+)	LER (e-)		
LUMINOSITY	$cm^{-2}\ s^{-1}$	1.00E+36		1.00E+36			
Energy	GeV	6.7	4.18	6.7	4.18		
Circumference	m	1258.4		1258.4			
X-Angle (full)	mrad	66		66			
Piwinski angle	rad	22.88	18.60	32.36	26.30		
β_x @ IP	cm	2.6	3.2	2.6	3.2		
β_y @ IP	cm	0.0253	0.0205	0.0179	0.0145		
Coupling (full current)	%	0.25	0.25	0.25	0.25		
ε_x (without IBS)	nm	1.97	1.82	1.00	0.91		
ε_x (with IBS)	nm	2.00	2.46	1.00	1.23		
ε_y	pm	5	6.15	2.5	3.075		
σ_x @ IP	μm	7.211	8.872	5.099	6.274		
σ_y @ IP	μm	0.036	0.036	0.021	0.021		
Σ_x	μm	11.433		8.085			
Σ_y	μm	0.050		0.030			
σ_L (0 current)	mm	4.69	4.29	4.73	4.34		
σ_L (full current)	mm	5	5	5	5		
Beam current	mA	1892	2447	1460	1888		
Buckets distance	#	2		2			
Ion gap	%	2		2			
RF frequency	Hz	4.76E+08		4.76E+08			
Harmonic number		1998		1998			
Number of bunches		978		978			
N. Particle/bunch		5.08E+10	6.56E+10	3.92E+10	5.06E+10		
Tune shift x		0.0021	0.0033	0.0017	0.0025		
Tune shift y		0.0970	0.0971	0.0891	0.0892		
Long. damping time	msec	13.4	20.3	13.4	20.3		
Energy Loss/turn	MeV	2.11	0.865	2.11	0.865		
σ_E (full current)	dE/E	6.43E-04	7.34E-04	6.43E-04	7.34E-04		
CM σ_E	dE/E	5.00E-04		5.00E-04			
Total lifetime	min	4.23	4.48	3.05	3.00		
Total RF Power	MW	17.08		12.72			



SuperB main physics goals

Study of fundamental symmetries of Nature,
as CP and CPT,
through a systematic observation of
B meson decay

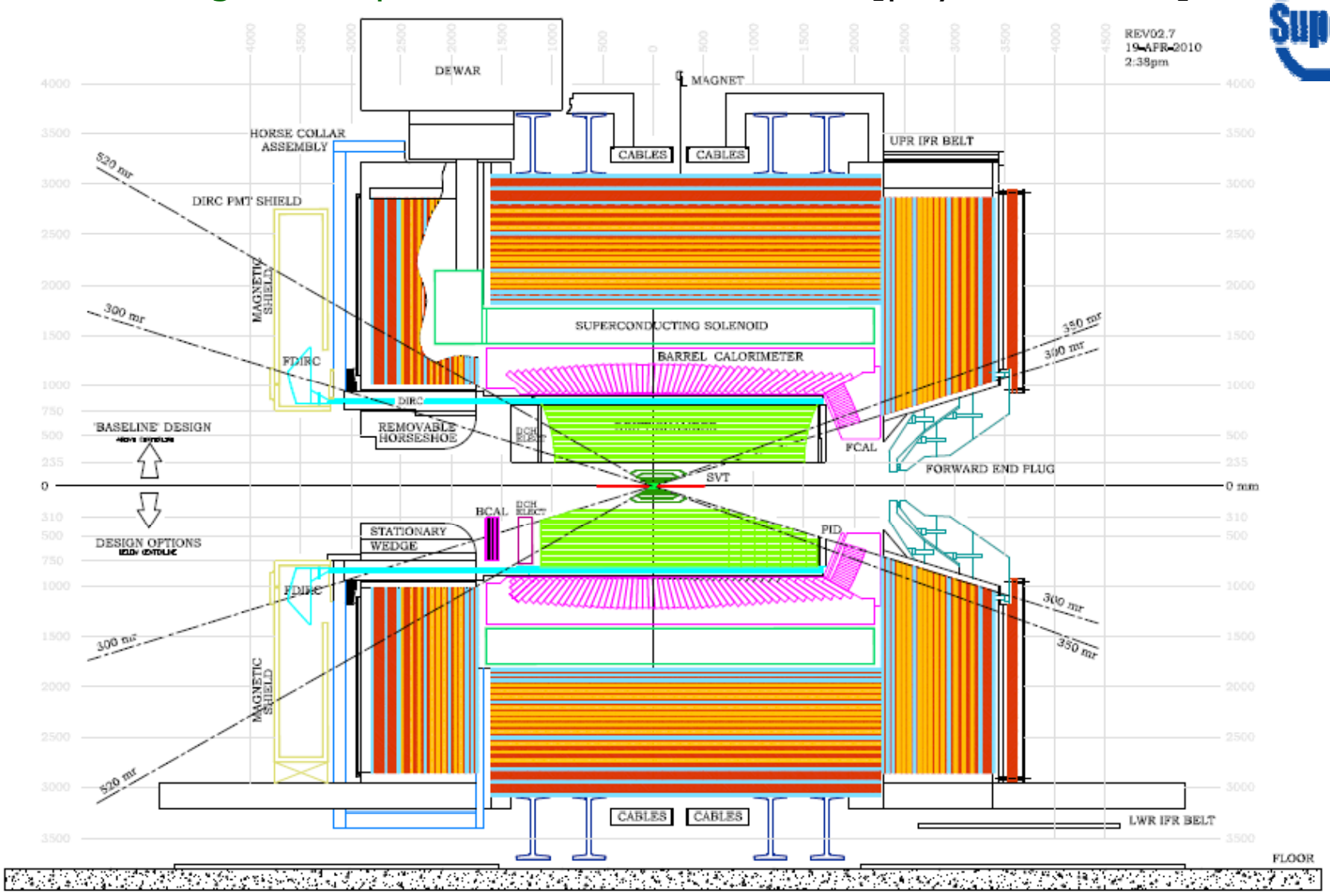
omissis

Search for deviations from
the Standard Model behavior
as signal of new physics

Physics Progress Report: arXiv:1008.1541v1 [hep-ex]

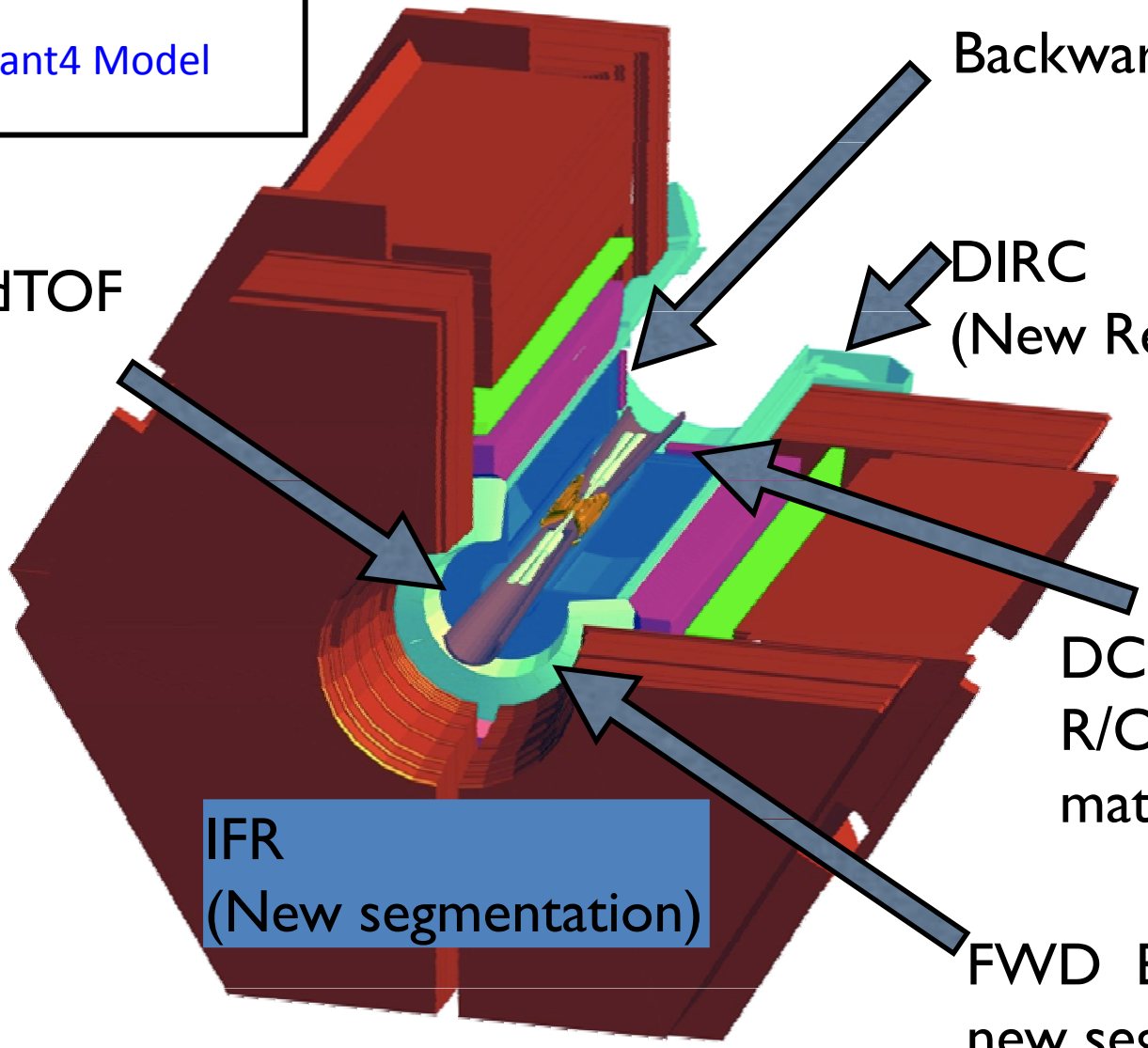
SuperB apparatus (with options)

Detector Progress Report: arXiv:1007.4241v1 [physics.ins-det]

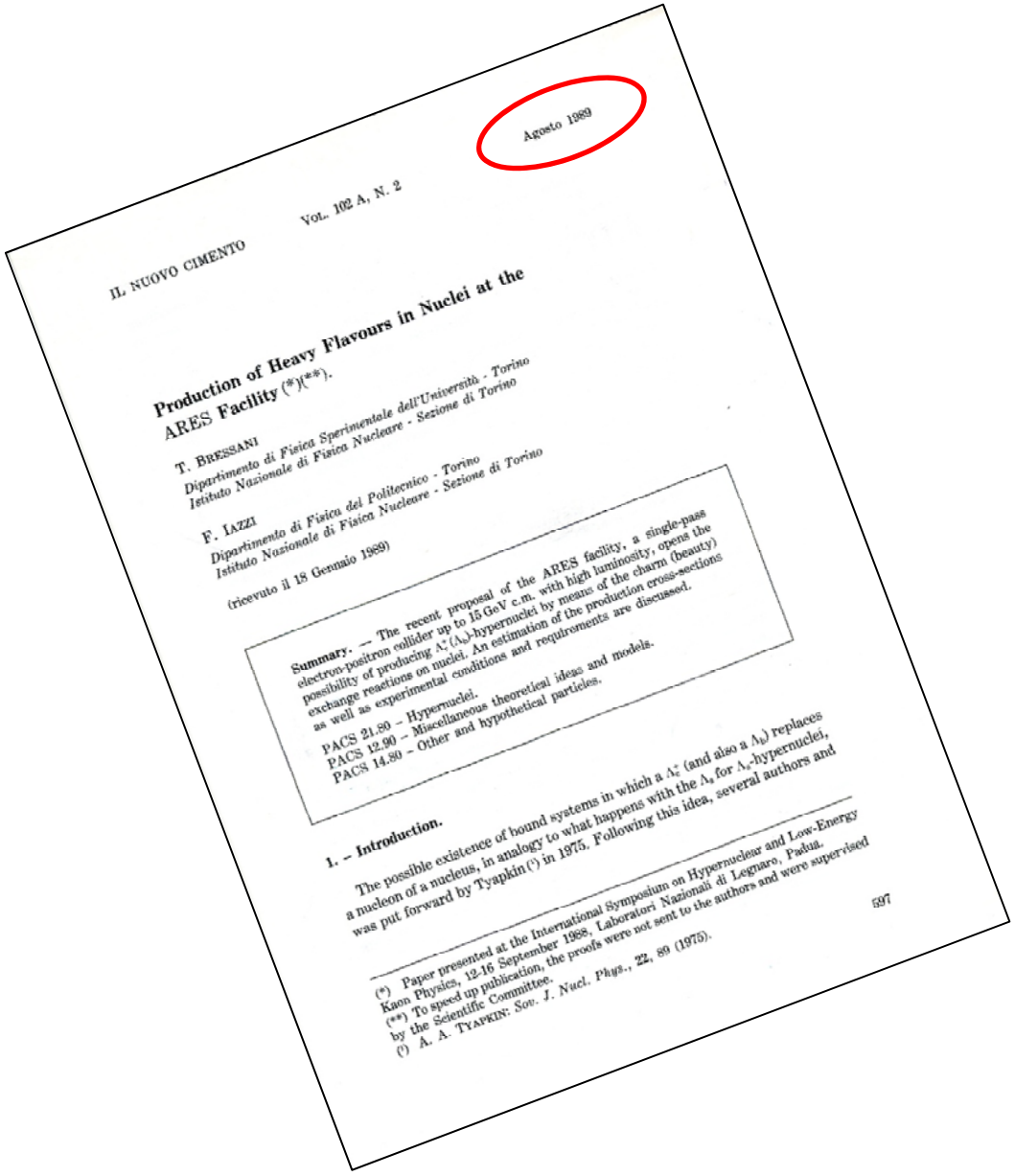


Detector modelling

Geant4 Model



Good ideas are like good wine…



IL NUOVO CIMENTO Vol. 102 A, N. 2 Agosto 1989

Production of Heavy Flavours in Nuclei at the ARES Facility (*)(**).

T. BRESSANI
Dipartimento di Fisica Sperimentale dell'Università - Torino
Istituto Nazionale di Fisica Nucleare - Sezione di Torino

F. IAZZI
Dipartimento di Fisica del Politecnico - Torino
Istituto Nazionale di Fisica Nucleare - Sezione di Torino

(ricevuto il 18 Gennaio 1989)

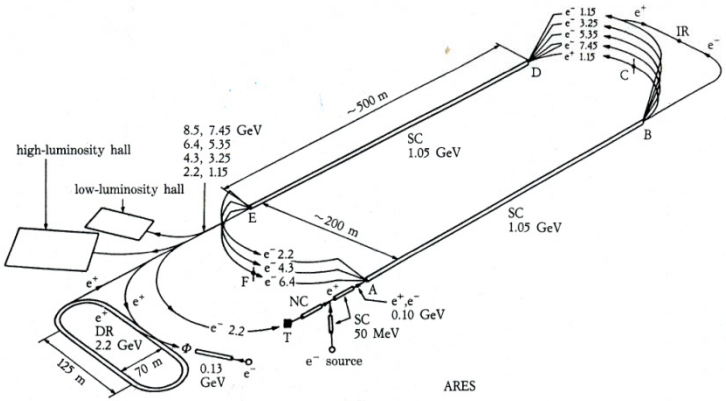
Summary. — The recent proposal of the ARES facility, a single-pass electron-positron collider up to 15 GeV c.m. with high luminosity, opens the possibility of producing Λ_c^+ (Λ_b)-hypernuclei by means of the charm (beauty) exchange reactions on nuclei. An estimation of the production cross-sections as well as experimental conditions and requirements are discussed.

PACS 21.80 – Hypernuclei.
PACS 12.90 – Miscellaneous theoretical ideas and models.
PACS 14.80 – Other and hypothetical particles.

1. – Introduction.

The possible existence of bound systems in which a Λ_c^+ (and also a Λ_b) replaces a nucleon of a nucleus, in analogy to what happens with the Λ_s for Λ_s-hypernuclei, was put forward by Tyapkin(*) in 1975. Following this idea, several authors and

(*) Paper presented at the International Symposium on Hypernuclear and Low-Energy Kaon Physics, 12-16 September 1988, Laboratori Nazionali di Legnaro, Padua.
(**) To speed up publication, the proofs were not sent to the authors and were supervised by the Scientific Committee.
(*) A. A. TYAPKIN: *Sov. J. Nucl. Phys.*, 22, 89 (1975).



Bottom baryons at SuperB?!?

Impossible!!! $E_{c.m.} \approx 10600$ MeV < $m(\Lambda_b^0 \overline{\Lambda}_b^0) = 2 \times 5620.2 \text{ MeV} = 11240.4 \text{ MeV}$

lightest bottom baryon

Strange baryons at DAΦNE?!?

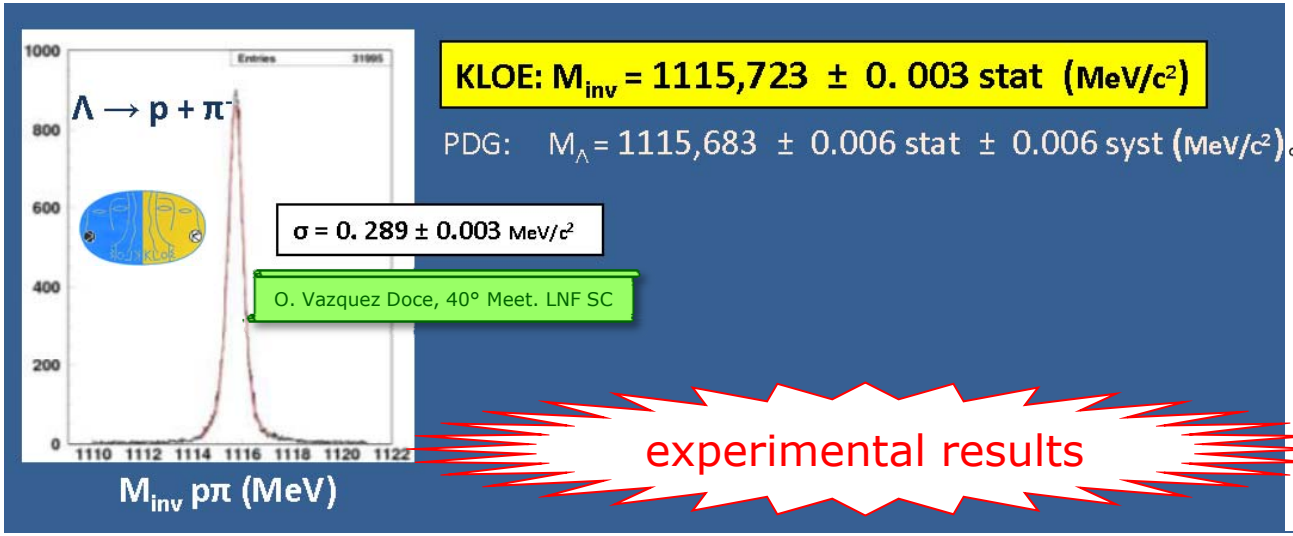
Impossible!!! $E_{c.m.} \approx 1020$ MeV < $m(\Lambda^0 \overline{\Lambda}^0) = 2 \times 1115.7 \text{ MeV} = 2231.4 \text{ MeV}$

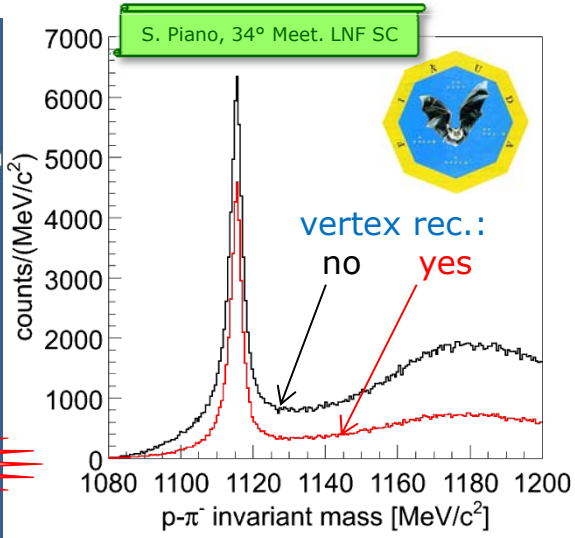
lightest strange baryon

$e^- + e^+ \rightarrow \phi$

$K^- + K^+$

$K^-_{stop} + \mathcal{N}_{bound} \rightarrow \Lambda^0 + \pi^{-0}$





Event rate rough estimate (I)

$e^- + e^+ \rightarrow \Upsilon(4S)$ σ ≈ 1.1 nb $\mathscr{L} \approx 1 \times 10^{36}$ cm^{-2}s^{-1} ≈ 1.1 kHz

$B^- + B^+$ $76.7\ MeV \lesssim T_{B^\pm} \lesssim 273.7\ MeV$ ≈ 550 Hz

$B^-_{stop} + \mathcal{N}_{bound} \rightarrow \Lambda^0_b + \pi^{-0}$

$B^-_{stop} + \mathcal{N}_{bound} \rightarrow \Sigma^\pm_b + \pi^{-0+}$

$B^-_{stop} + \mathcal{N}_{bound} \rightarrow \Sigma^{\pm *}_b + \pi^{-0+}$

$B^-_{flight} + \mathcal{N}_{bound} \rightarrow \Xi^{-0}_b + K^{+0}$?

~~$B^-_{flight} + \mathcal{N}_{bound} \rightarrow \Omega^-_b + K^+ + K^0$~~

Event rate rough estimate (II)

B^- surviving probability: ≈ 0.7%

$c\tau$ = 491 μm

≈ 4 Hz

target acceptance + stop efficiency: ≈ 10%

≈ 0.4 Hz

reconstruction efficiency: ≈ 10%

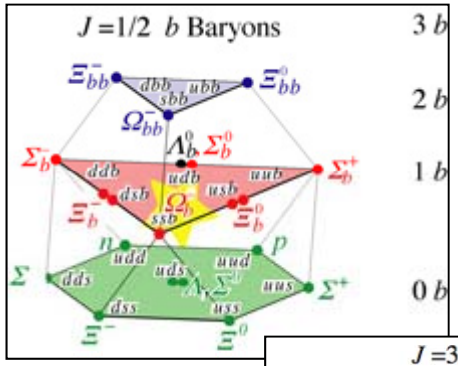
≈ 0.04 Hz

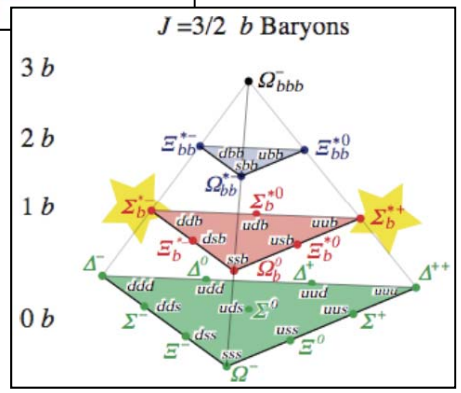
daily duty cycle: ≈ 70%

≈ 2.3 10^3 ev/d

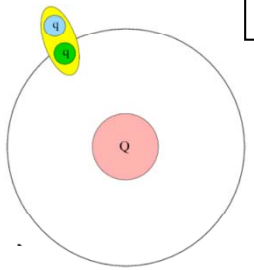
few weeks of data taking could allow to collect a data sample larger than the statistics available today on bottom baryons

Physics goals





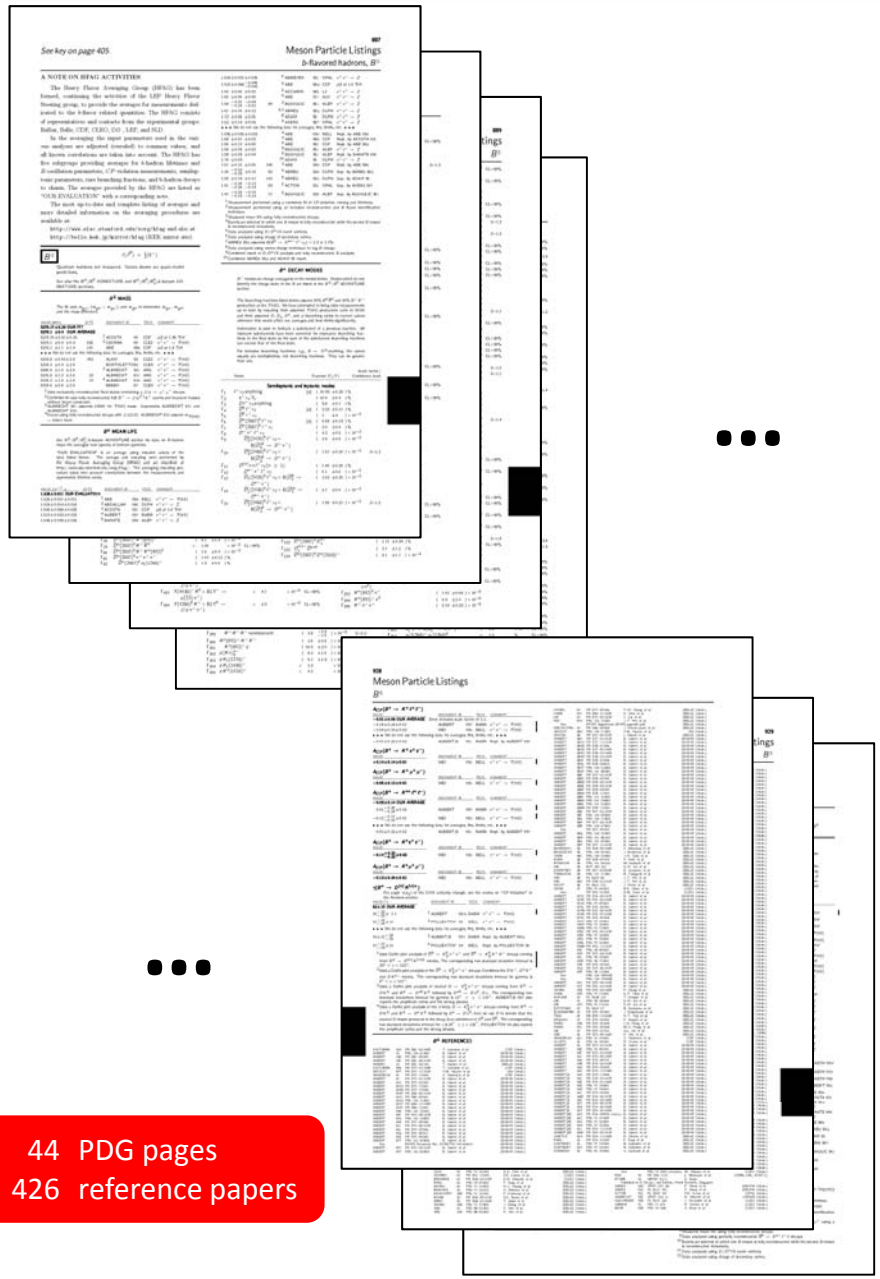
- To provide a high statistics data sample to determine the bottom baryon properties



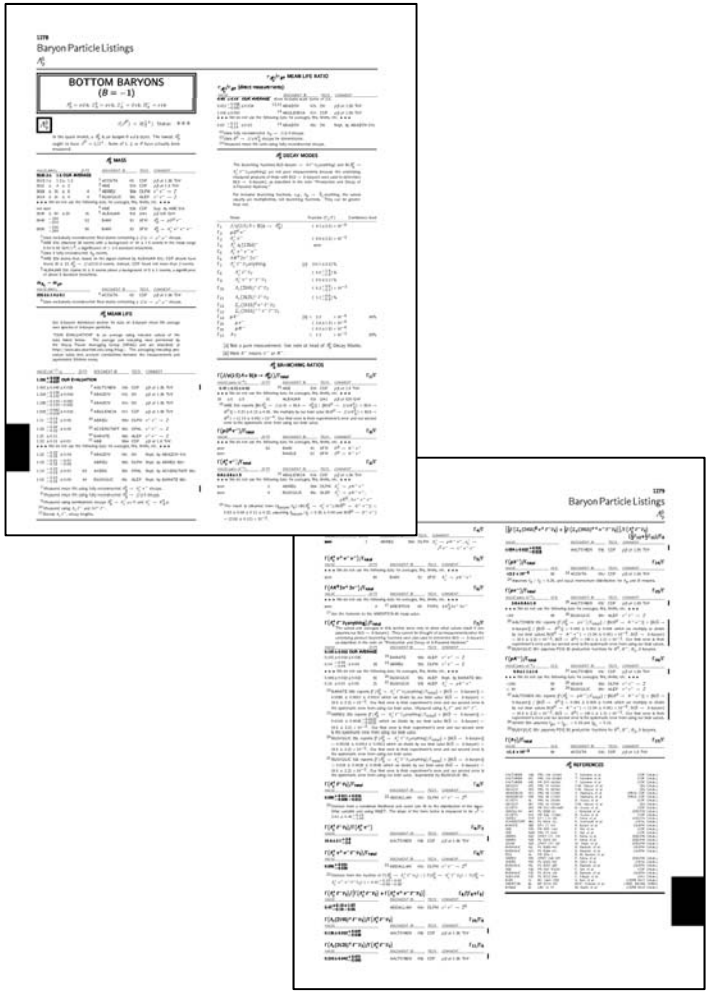
- To get information on non-perturbative QCD and potential models

- From hyper- to super-nuclear physics (?)

Bottom mesons vs. bottom baryons



44 PDG pages
426 reference papers

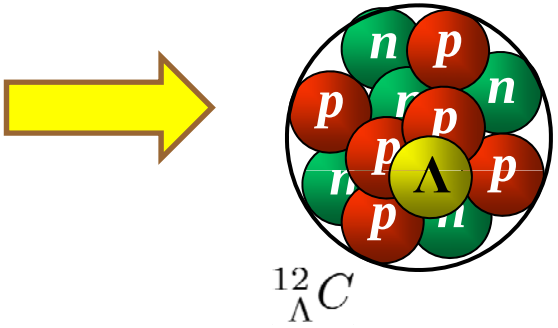


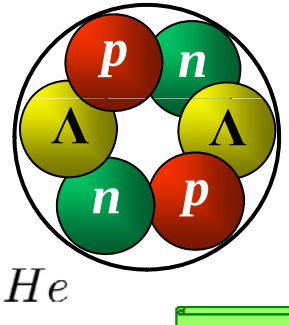
2 PDG pages
31 reference papers

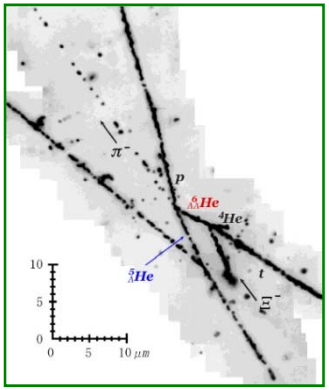
From hyper- to super-nuclear physics

$\Lambda(uds)$

m = 1115.7 MeV
τ = 263.1 ps



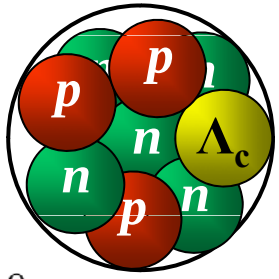


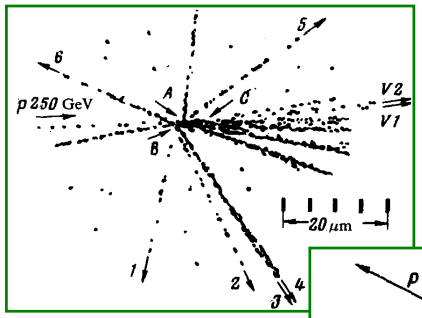


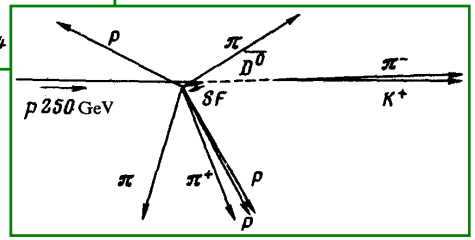
Phys. Rev. Lett. 87 (2001) 212502

$\Lambda_c^+(udc)$

m = 2286.5 MeV
τ = 200.0 fs



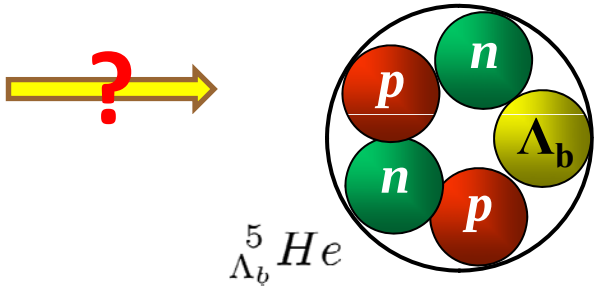




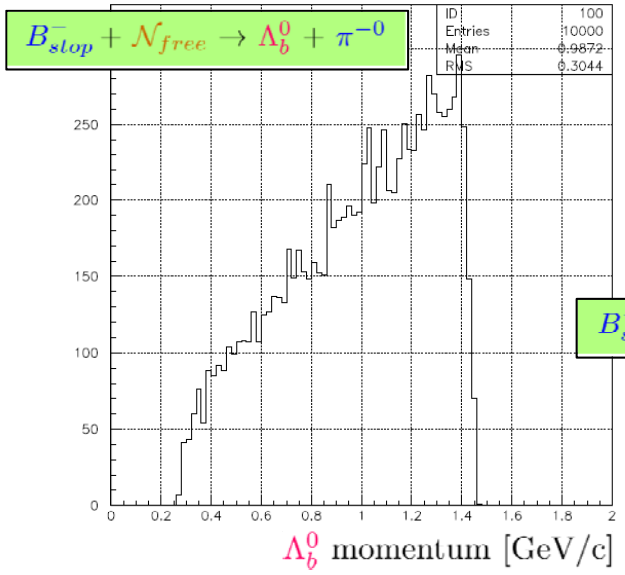
JETP Lett., 33 (1981) 52

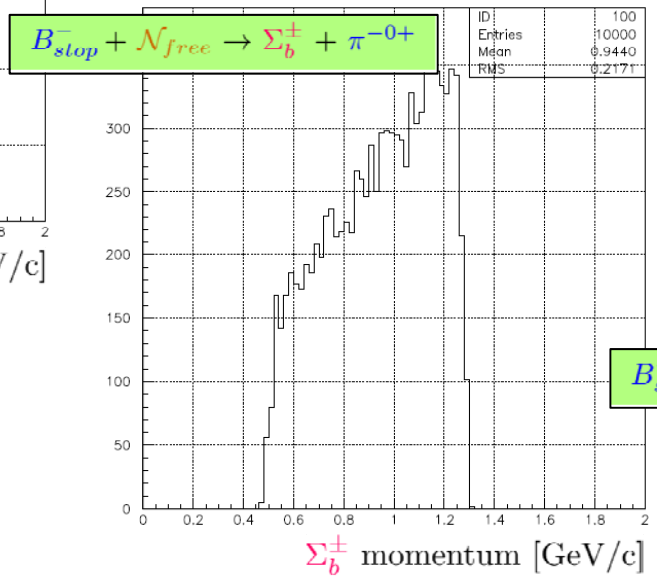
$\Lambda_b^0(udb)$

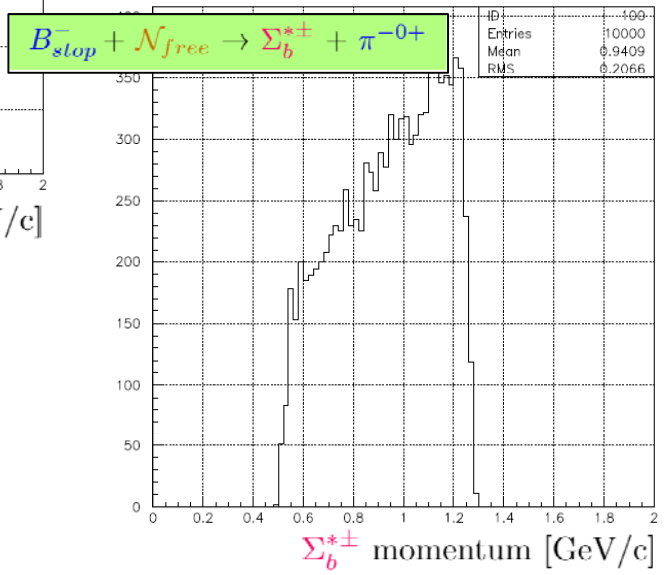
m = 5620.2 MeV
τ = 1391 .0 fs



Kinematics issue





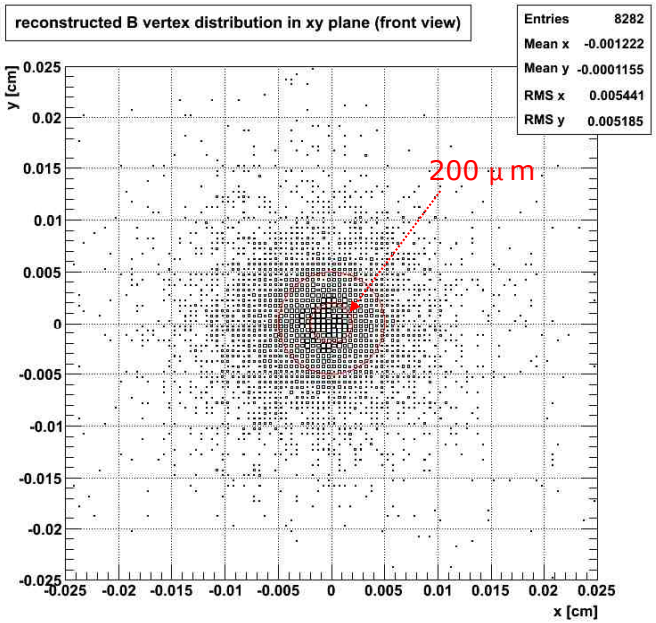


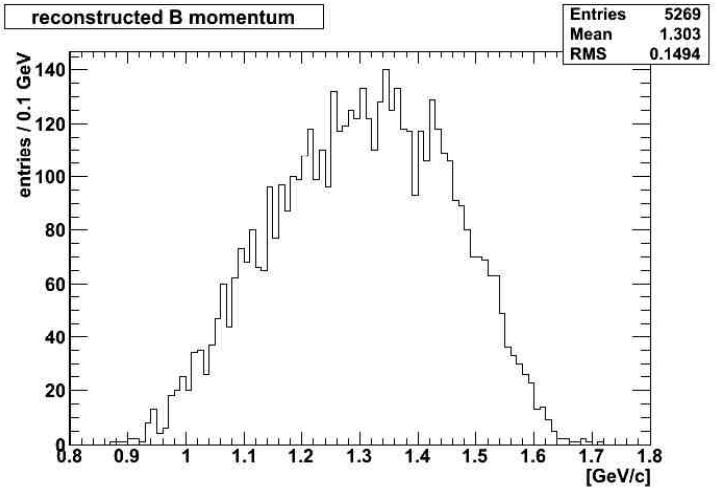
Physics goals

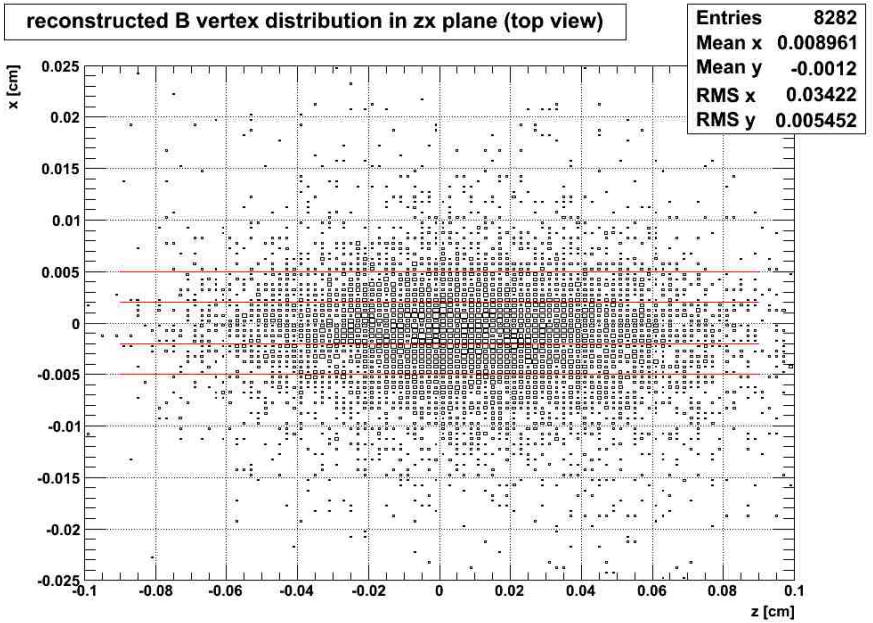
- To study of the interaction potential between B_i and nucleus (i = s, c, b, …)

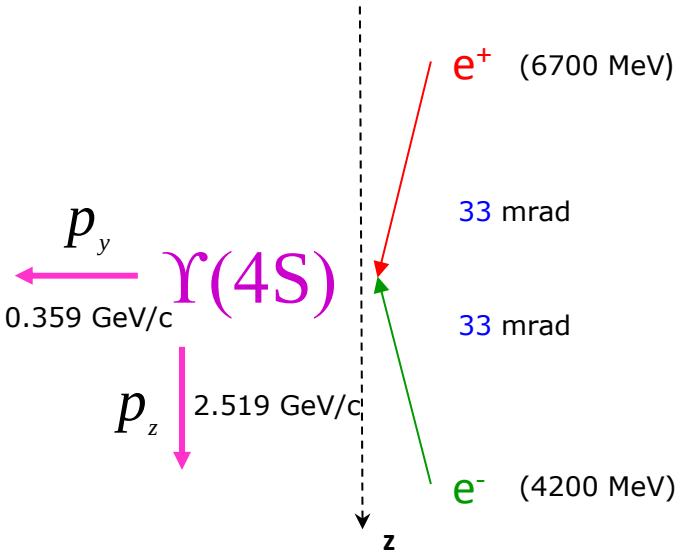
- To get basic information about flavour baryons and nucleon interaction at low energies (absolutely inaccessible by other experimental methods)

SuperB fast simulation output

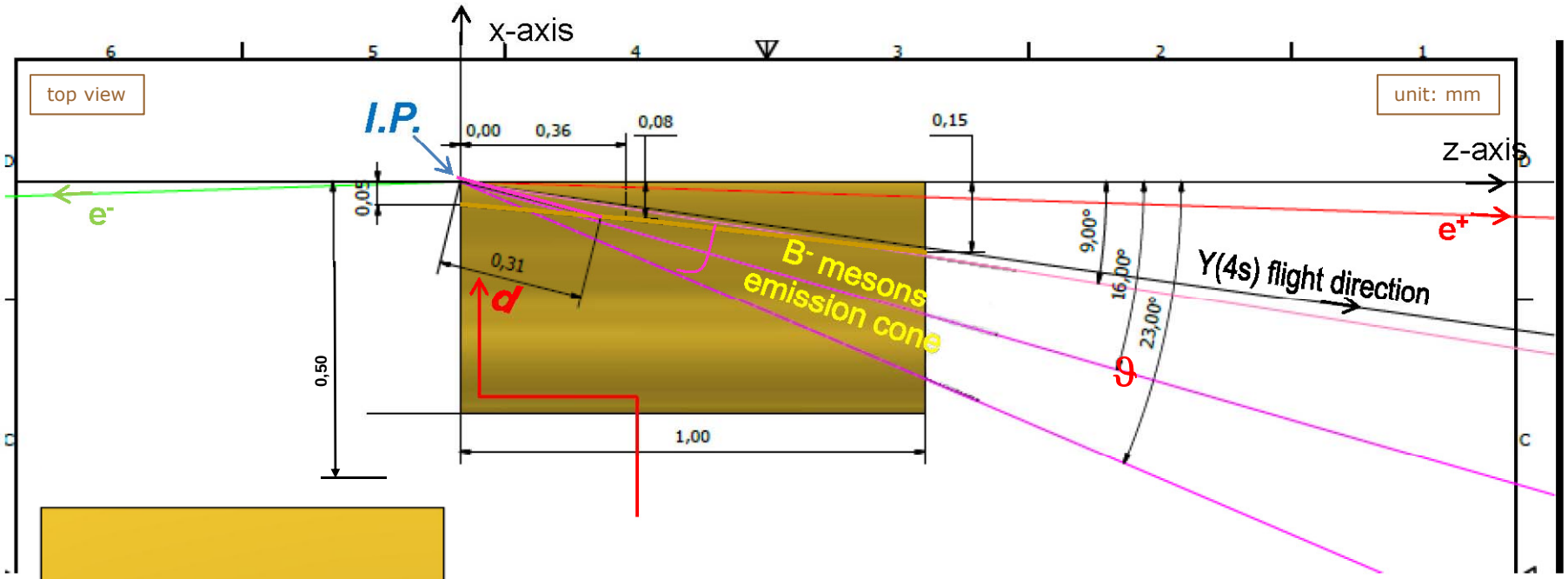


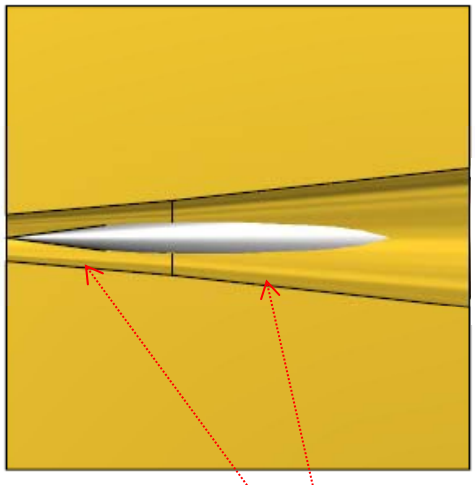






Schematic target design



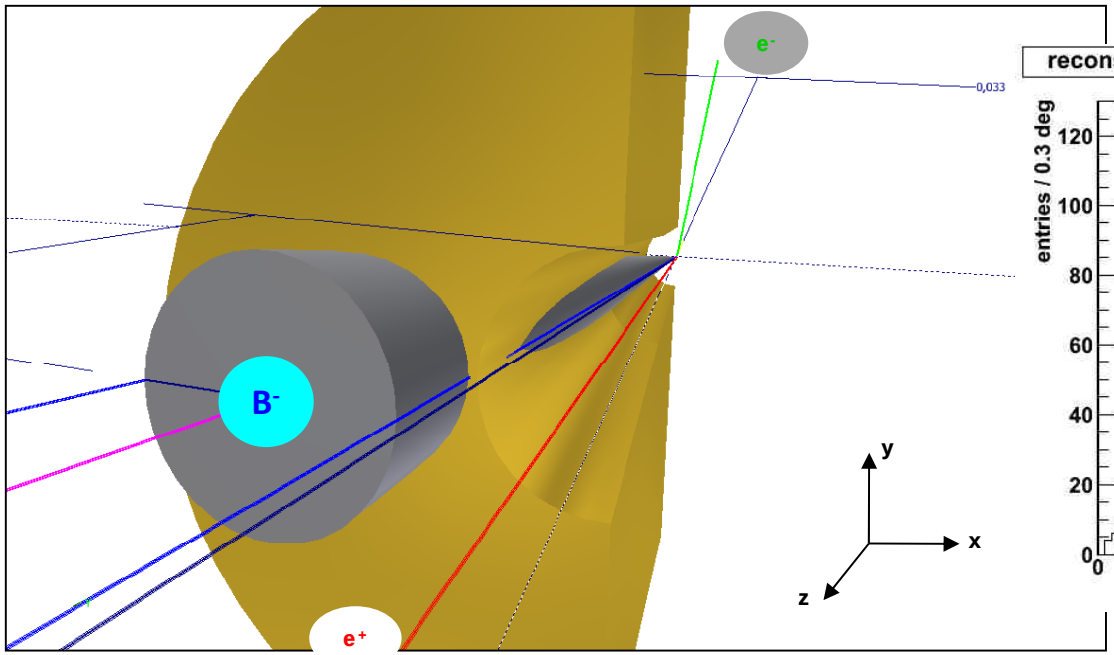


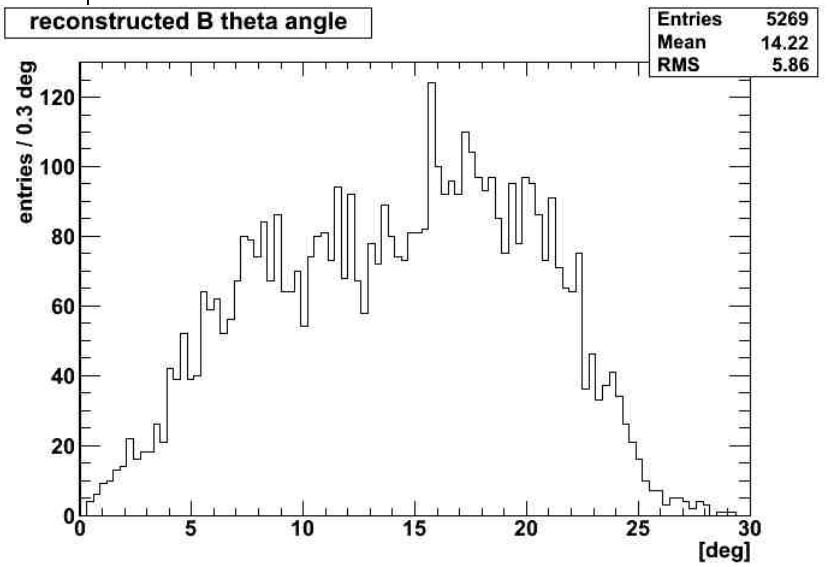
side view

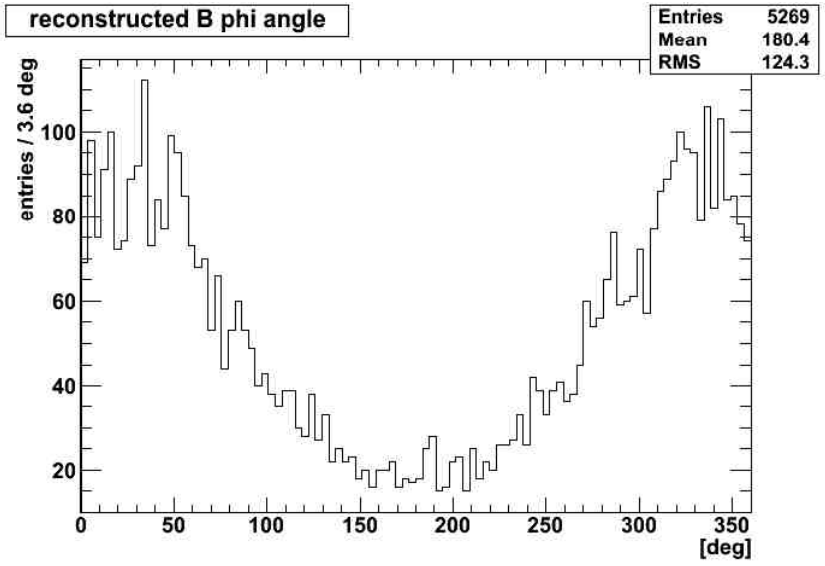
- requirement: to maximize the fraction of B^- mesons entering the target (keeping in mind that $c\tau$ = 501 μm) ➠ to minimize d = r/sinϑ
- constraint: to avoid any interference between target and circulating beams ➠ to not introduce any (additional) background source
- material: to maximize event counting rate
  Au vs. Pt: comparable, good mechanical, thermal and electrical properties
  Pt: higher density and higher melting point

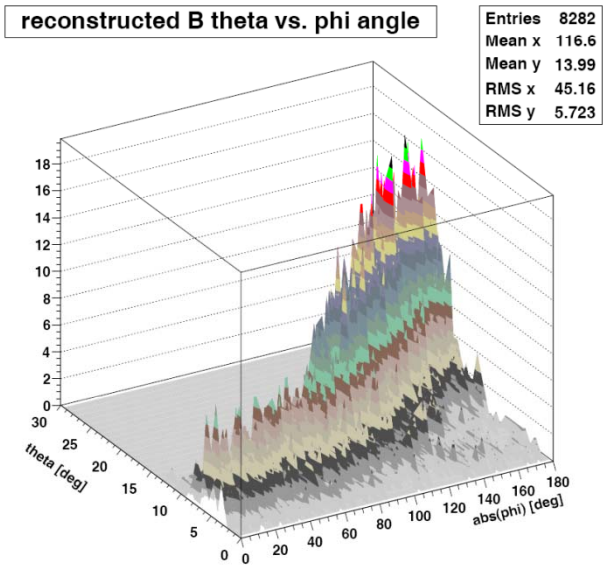
"twin" radius (frustum of) cone to cope with the beam divergence

Schematic target design









Outlook

- Despite the experimental hardness SuperB could offer a unique opportunity for:
  - an extensive study of the bottom baryon properties
  - a new and, hopefully, fruitful approach to the super-nuclear physics field
- Next steps:
  - to validate the initial calculations by means of SuperB full simulation program and to give more solid basis to the proposal
  - to carefully evaluate machine and physics backgrounds
  - to get feedback from the Community about the interest in the subject