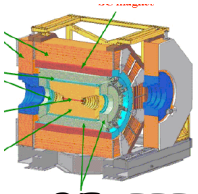
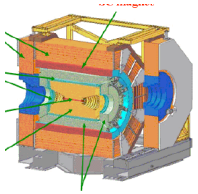


Status di BESIII

R. Baldini Ferroli, M.Bertani, A. Calcaterra, A. Zallo

6 luglio 2011, Consiglio di Laboratorio LNF

Indice



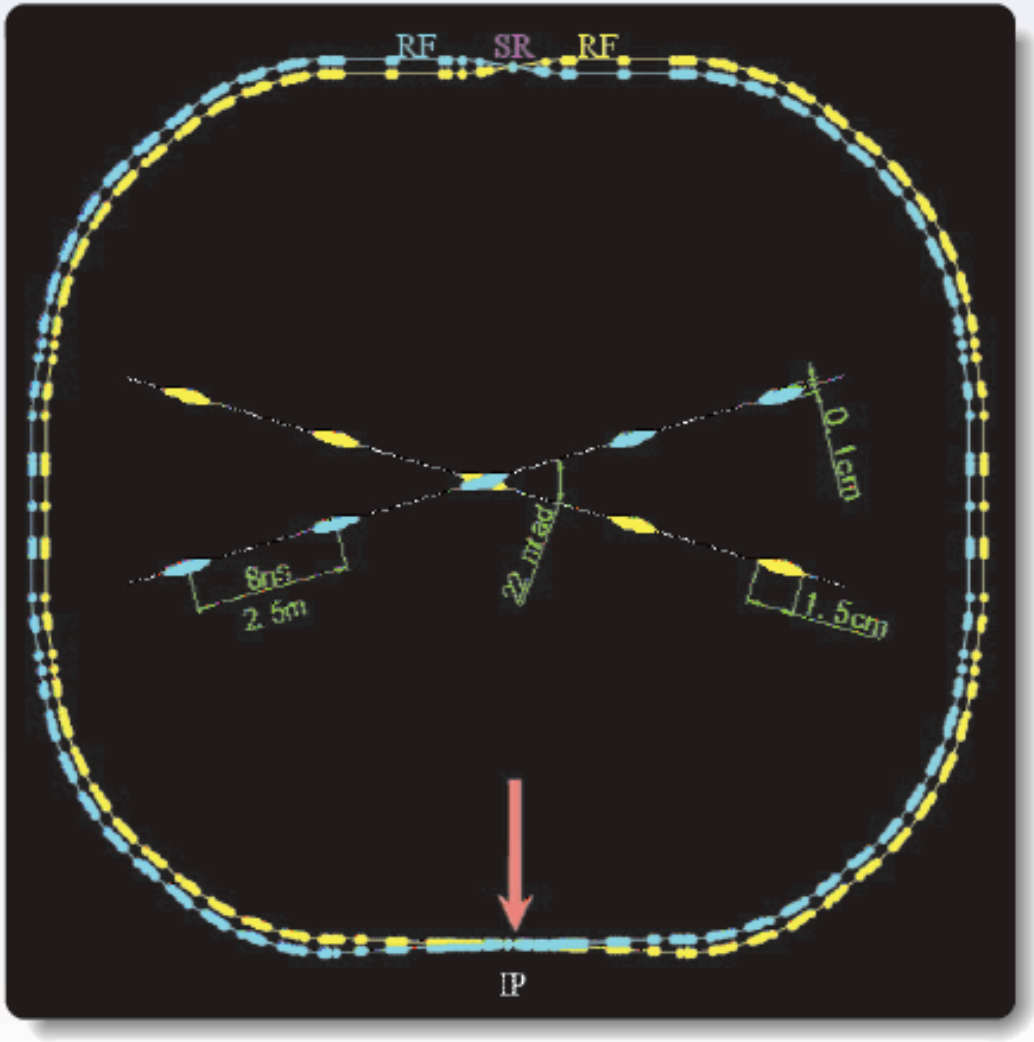
status di BESIII e BEPCII

Le proposte della collaborazione italiana:

fisica ISR & ZDD e misura della fase di decadimento della J/ψ

Le richieste per il 2012

Beijing Electron Positron Collider II



Design Features

- Beam energy: **1.0 - 2.3** GeV
- Crossing angle: **22** mrad (DAΦNE 50 mrad)
- **Luminosity: 10^{33} $cm^{-2}s^{-1}$**
- **Optimum energy: 1.89 GeV**
- Energy spread: **5.16×10^{-4}**
- Number of bunches: **93**
- Bunch length: **1.5** cm
- Total current: **0.91** A

BESIII Collaboration: 46 institutions

US (6)
Univ. of Hawaii
Univ. of Washington
Carnegie Mellon Univ.
Univ. of Minnesota
Univ. of Rochester
Univ. of Indiana

EUROPE (8)
Germany: Univ. of Bochum, Univ. of Giessen, GSI
Russia: JINR, Dubna; BINP, Novosibirsk
Italy: INFN Frascati National Lab (LNF), Univ. of Torino and INFN
Netherland: KVI/Univ. of Groningen

Korea (1)
Seoul Nat. Univ.

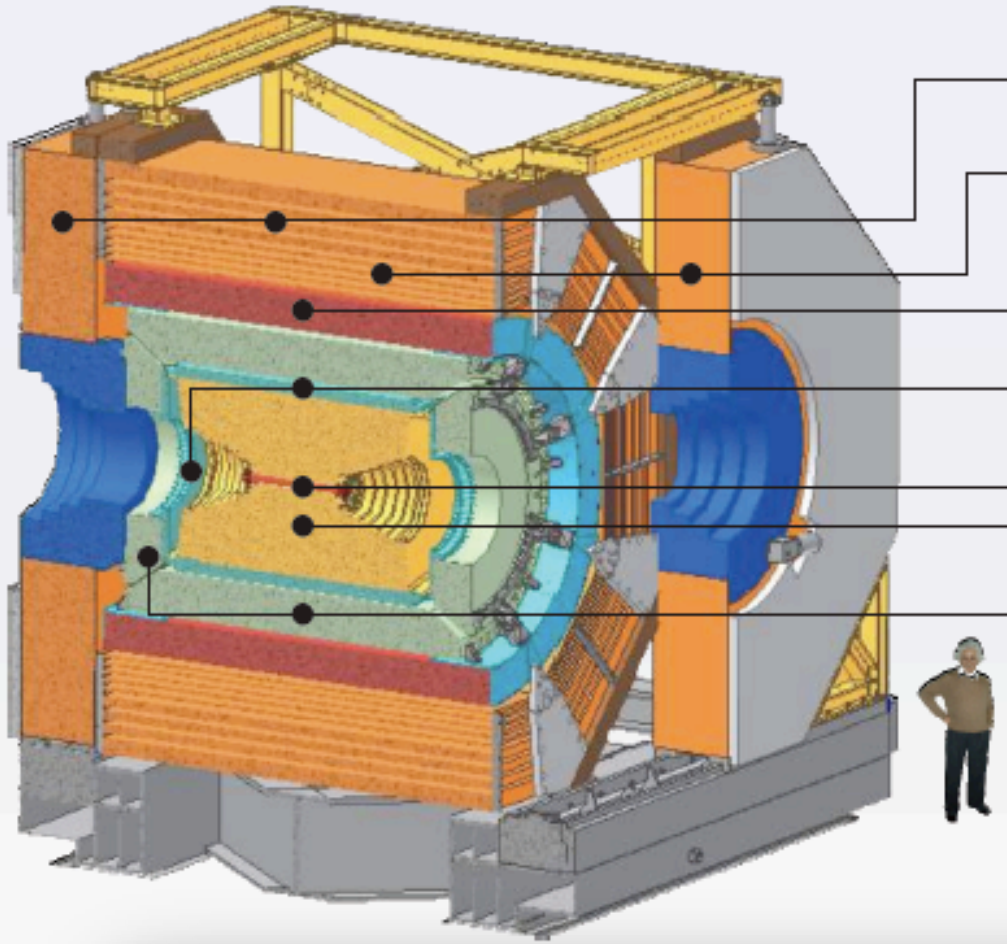
Japan (1)
Tokyo Univ.

Pakistan (1)
Univ. of Punjab

China(29)
IHEP, CCAST, Shandong Univ.,
Univ. of Sci. and Tech. of China
Zhejiang Univ., Huangshan Coll.
Huazhong Normal Univ., Wuhan Univ.
Zhengzhou Univ., Henan Normal Univ.
Peking Univ., Tsinghua Univ. ,
Zhongshan Univ.,Nankai Univ.
Shanxi Univ., Sichuan Univ
Hunan Univ., Liaoning Univ.
Nanjing Univ., Nanjing Normal Univ.
Guangxi Normal Univ., Guangxi Univ.
Suzhou Univ., Hongzhou Normal Univ.
Henan Sci. and Tech. Univ.
Hong Univ., Hong Kong Chinese Univ.

~ 300 collaborators

Il rivelatore BESIII

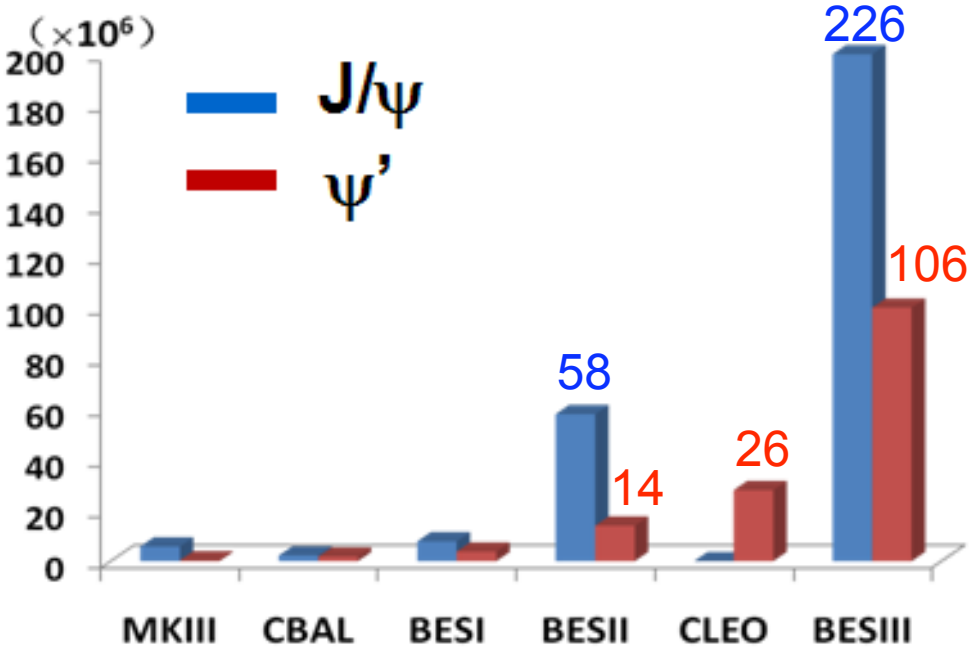


- Magnete yoke
- RPC (9/8 strati Barrel/Endcaps)
- Magnete SC, 1 Tesla
- TOF (scintillatore), 90 ps
- Tubo del fascio in Be
- MDC, 120μm , <0.5%
- Calorimetero CsI(Tl), 2.5% a 1 GeV

Prestazioni à la *BABAR*

BESIII tutto nuovo: ermetico per particelle cariche e neutre con eccellenti risoluzioni, PID e grande copertura angolare

BESIII @ BEPCII status

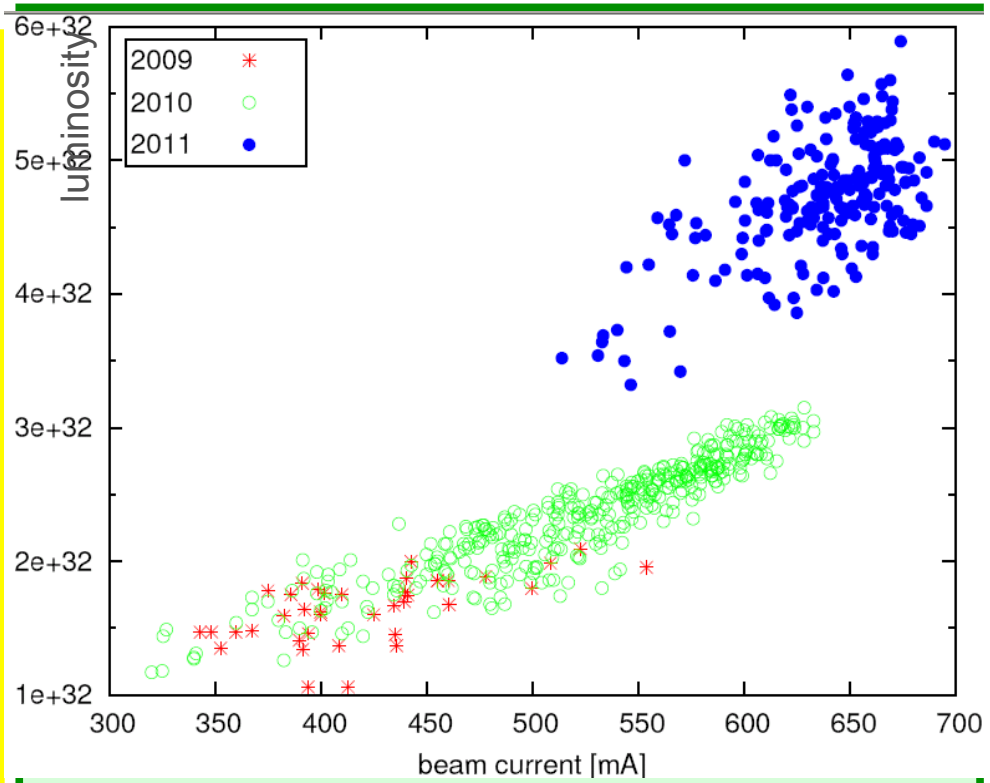


So far **world largest** data samples:

- ~226 Million J/Ψ
- ~106 Million Ψ'
- ~2.9 fb^{-1} Ψ(3770)
- 0.5 fb^{-1} at 4010 MeV

  to search for XYZ states and D_s physics, etc

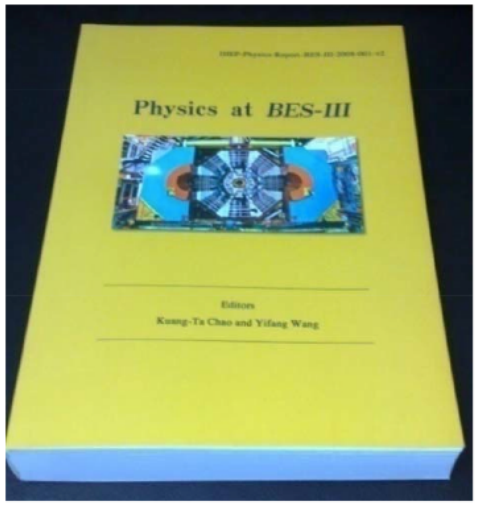
M. Bertani



- First collisions: March 2008
- First collisions in BESIII: July 2008
- Physics in BESIII: March 2009
- Record luminosity (April 2011): 6.3x10^{32}cm^{-2}s^{-1}

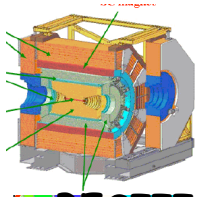
Physics in the tau-charm region

- **Light hadron physics**
  - Spectroscopy: normal and exotic hadrons **QCD**
  - How quarks form hadron ? **non-pQCD**
  - Baryon e.m. form factors
- **Charm physics**
  - Full spectra CKM matrix elements → **SM and beyond**
  - $D\bar{D}$ mixing and CPV →**SM and beyond**
- **Charmonium physics**
  - Spectroscopy and transition →**pQCD & non-pQCD**
  - New states above open charm thresholds →**exotic hadrons?**
  - pQCD: ρπ puzzle → a probe to **non-pQCD or?**
- **Tau physics and QCD**
  - Precision measurement of the tau mass and R measurement
- **Search for rare and forbidden decays**



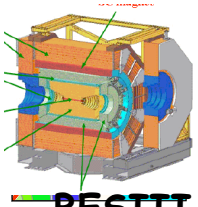
arXiv: 0809.1869

Precision tests of SM and search for new physics



BESIII publications

- **Light Quark states**
  - $a_0(980)$ - $f_o(980)$ **mixing** - *PRD83, 032003 (2011)*
  - **X(1860)** in J/ψ→γ ppbar - *CPC34, 4 (2010)*
  - **X(1835,…)** in J/ψ→γ(η`$\pi^+\pi^-$) – *PRL106, 072002 (2011)*
  - η`→ η$\pi^+\pi^-$ **mixing matrix elements** - *PRD83, 012003 (2011)*
- **Charmonium spectroscopy**
  - **Properties of h_c** - *PRL104,132002 (2010)*
- **Charmonium decays**
  - ψ`→γ$\pi^0$, γ η, γ η` - *PRL105, 261801 (2010)*
  - χ_{cJ}→4 π^0 – *PRD83, 012006 (2011)*
  - χ_{cJ}→$\pi^0\pi^0$, ηη – *PRD81, 052005 (2010)*
  - χ_{cJ}→γV (ρ, ω, ϕ) – *arXiv:1103.5564 Submitted to PRD*
  - χ_{cJ}→ppbar K^+K^- – *arXiv:11032661 Submitted to PRD*
  - *J/ψ →*nnbar,ppbar - *Preliminary*
- **Open Charm and more to come…**



The Italian Collaboration at BESIII

- Members of LNF-PG-TO Italian groups:

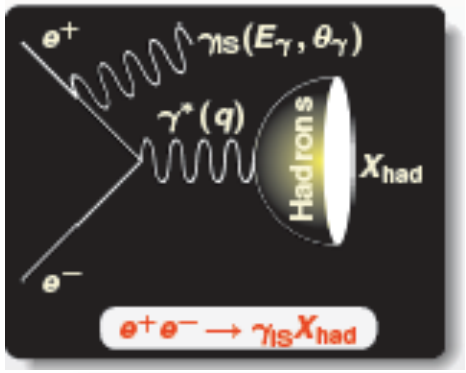
  M.Bertani, R. Baldini Ferroli, A. Calcaterra, A.Zallo ,

  S. Pacetti,

  D. Alberto, M. Destefanis, M. Greco, M. Maggiora, S. Spataro

- Main physics interests:
  - $e^+e^- \rightarrow B\bar{B}$ (B=n,p,Λ) energy scan and ISR technique
  - High statistics cross section measurements
  - Threshold effects and time-like form factors extraction
  - R_{had}, exclusive cross sections (6π, $\phi f_0(980)$,…), τ and charm…
- Detector: construction and installation (summer 2011) of a mini-calorimeter (ZDD) in the forward region to detect ISR photons
- Next: construction and installation (summer 2012) of the second ZDD station in the backward region.

Initial State Radiation: physics motivations



◎Existing results, mainly from BABAR (ISR) show interesting and unexpected behaviors expecially at threshold for $e^+e^- \to p\bar{p}$, $e^+e^- \to \Lambda\bar{\Lambda}$

◎Only one measurement by FENICE (energy scan) for $e^+e^- \to n\bar{n}$, now SND confirms FENICE

Physical limits in reaching threshold of many of these channels via energy scan (stable hadrons produced at rest cannot be detected)

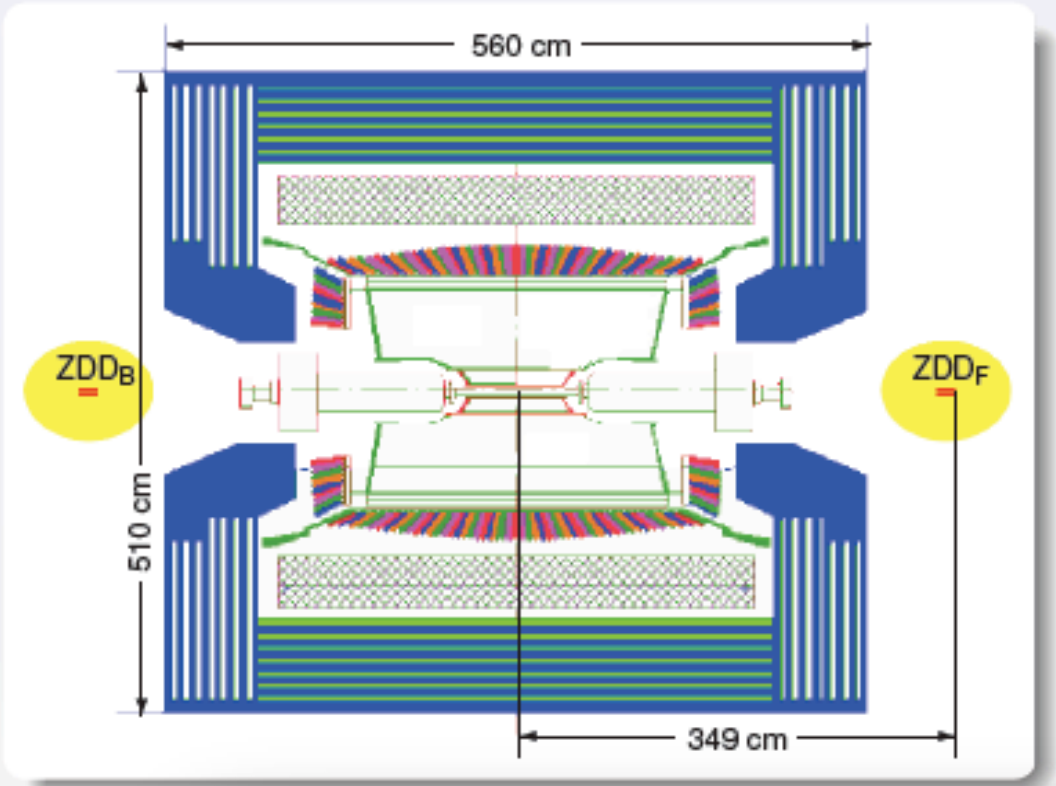
The ISR technique provides a unique tool to access threshold regions working at higher resonances:

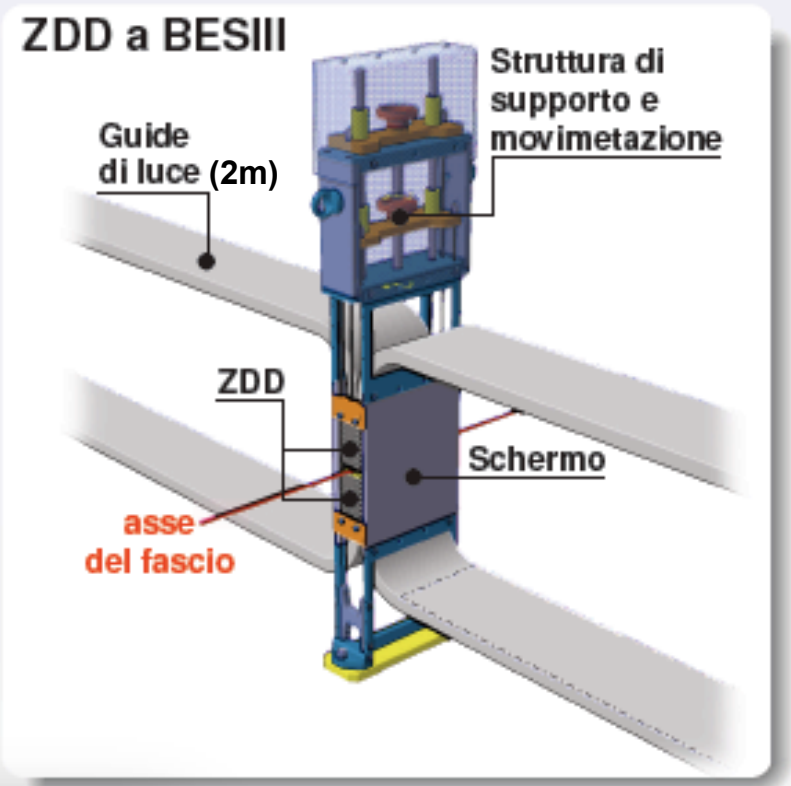
- all energies (q^2) at the same time → better control on systematics
- detect ISR photon → full X_{had} angular coverage

A Zero Degree radiative photon tagger will be installed at 3.5m from IP

- to detect ISR photons peaked at small angle
- to suppress background from π^0 and γ_{FS}

BESIII e Zero Degree Detector



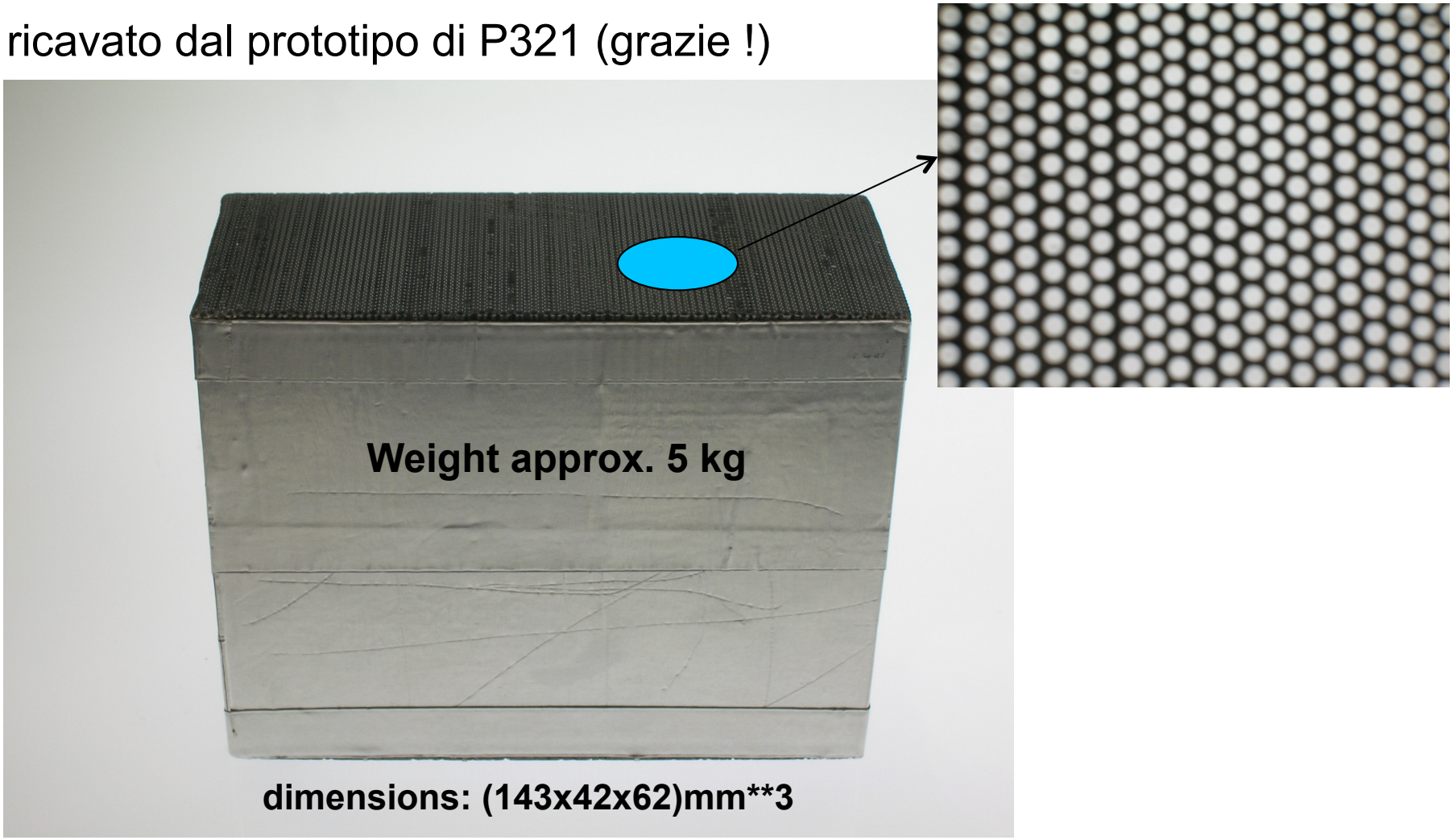


Tappe principali

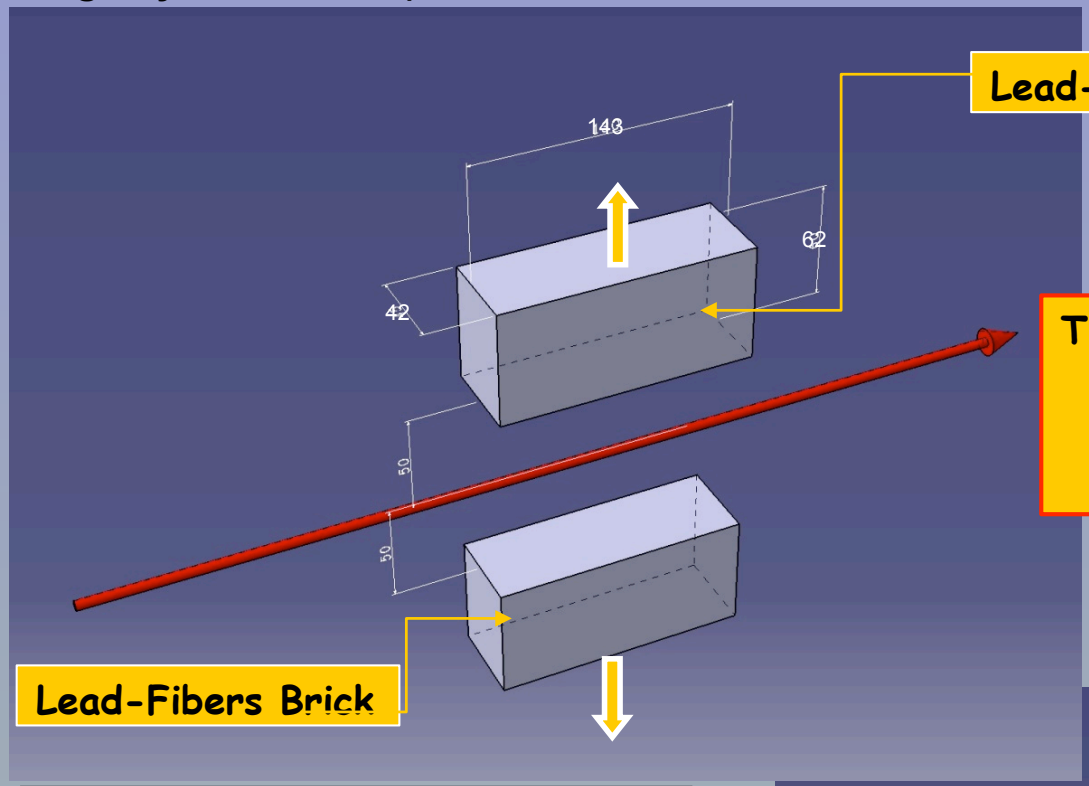
- **Maggo 2011:** Modulo up dello ZDD testato con successo alla BTF di Frascati
- **Giugno 2011:** Completamento e test con cosmici del modulo down
- **Giugno 2011**: Completamento della struttura di supporto
- **Luglio2011:** Completamento e test dell'elettronica di acquisizione e lettura
- **Agosto-settembre 2011**: Spedizione a IHEP e installazione a BEPCII
- **Ottobre 2011:** Inizio presa dati e messa in opera dello ZDD su fascio

ZDD: Pb/Sci.Fi Array, scintillating material 60% of total (in volume)

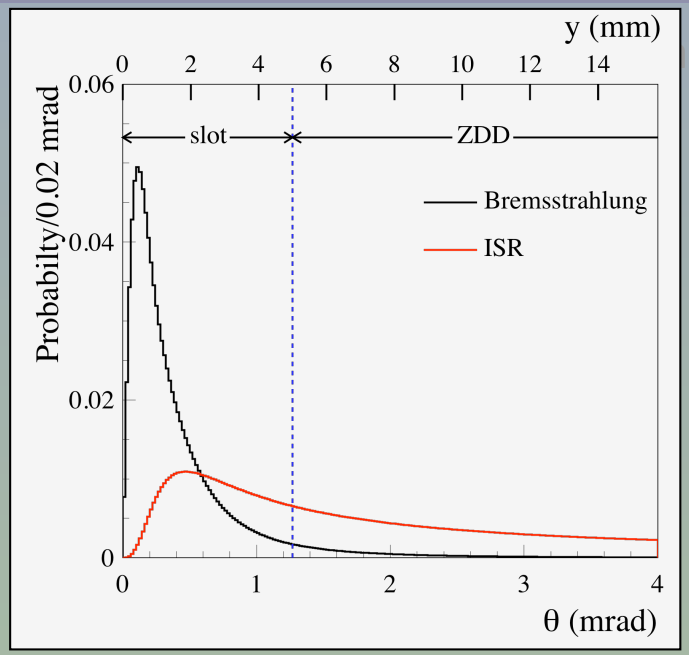
ricavato dal prototipo di P321 (grazie !)

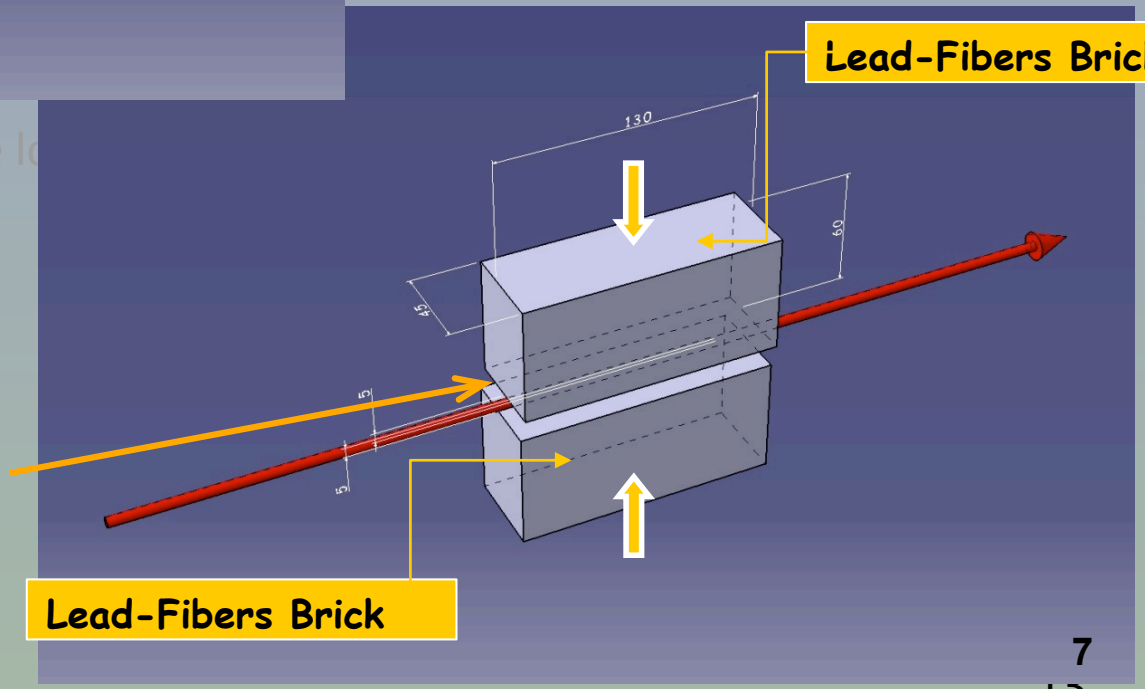


(design by D.Orecchini)

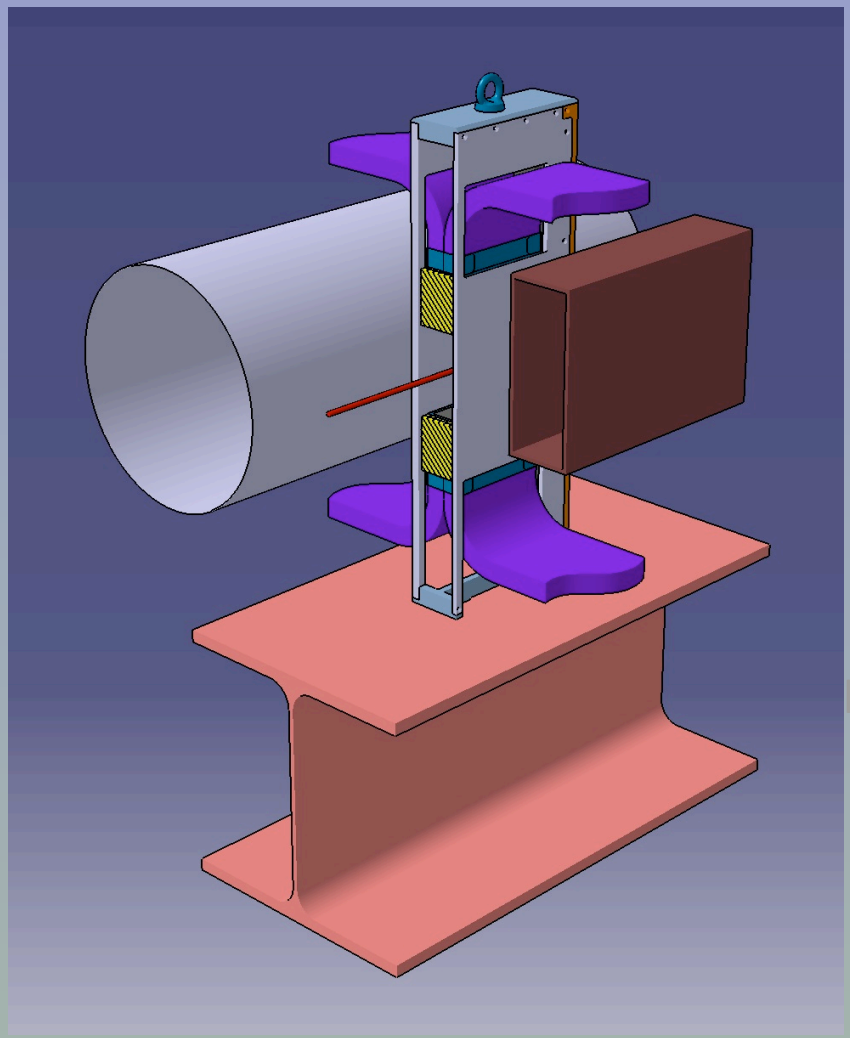


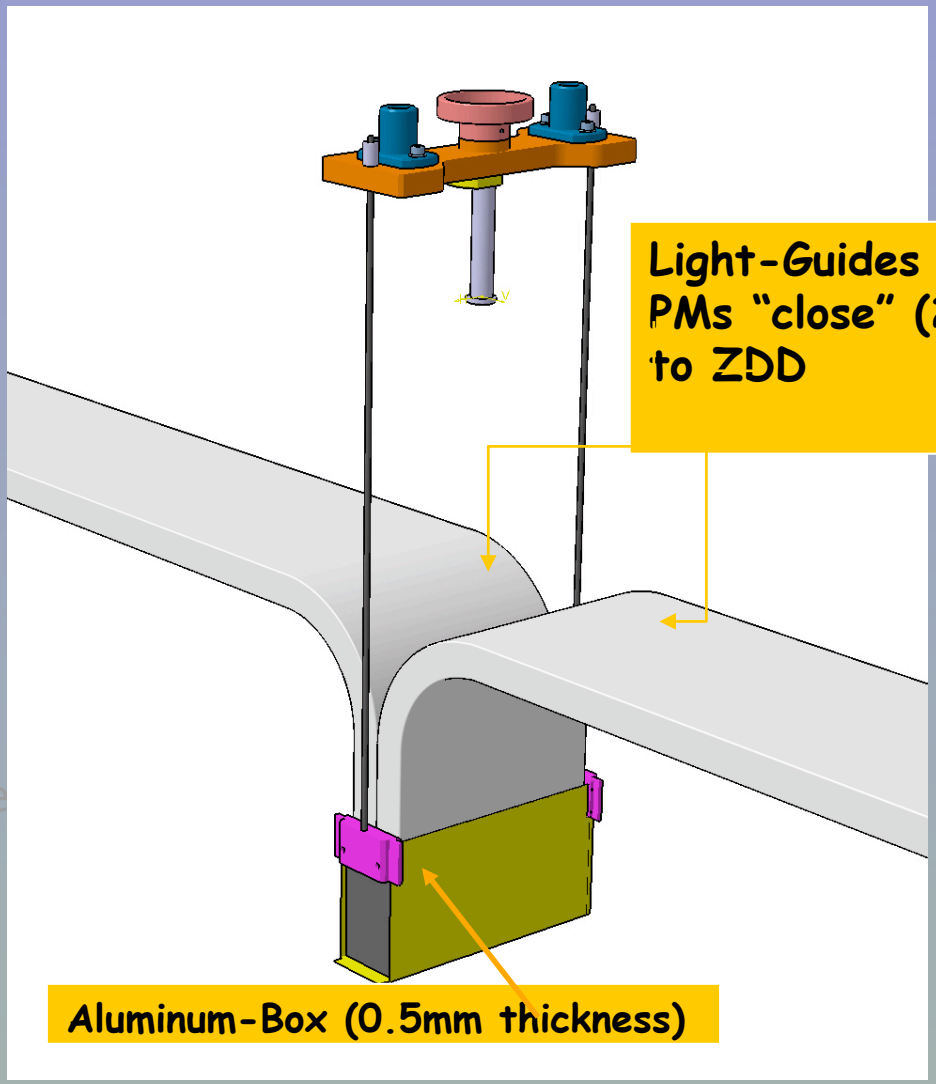
The opposite faces of the two bricks lift:
a) – Up, to 45mm from the beam;
b) – Down, to 5mm from the beam.





(design by D.Orecchini)

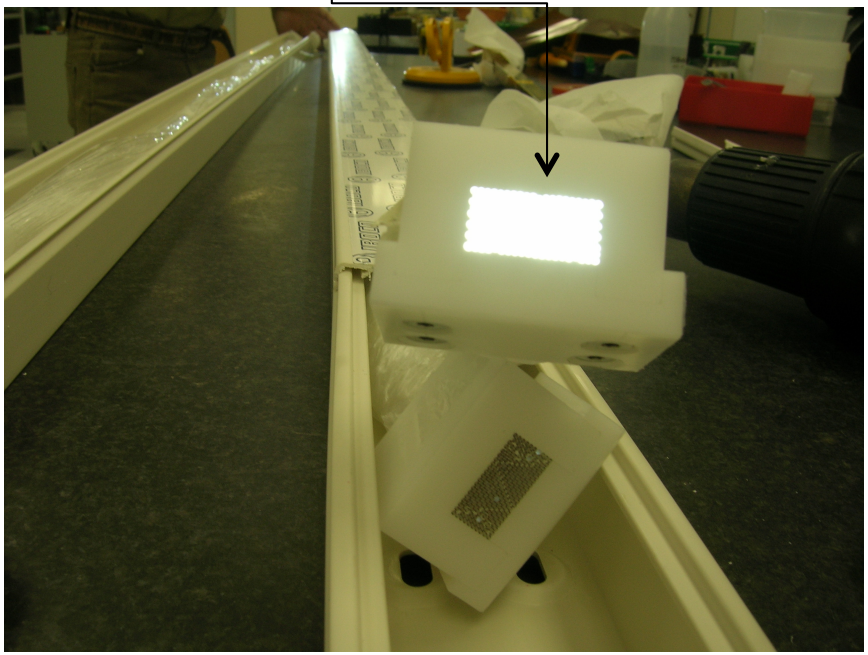


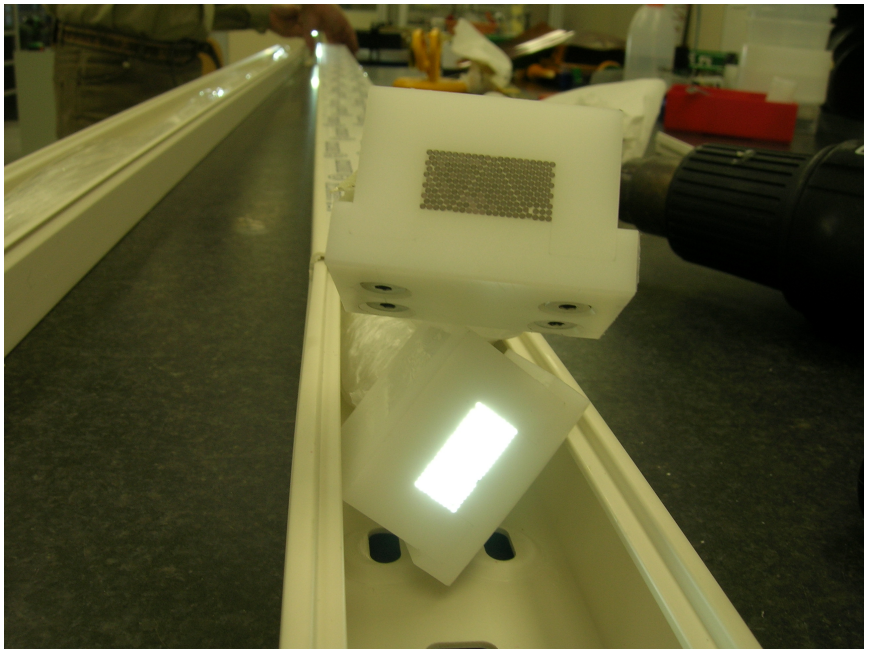


Bundles production (clear fibers): ZDD side

(SSE, resp. M.Anelli)

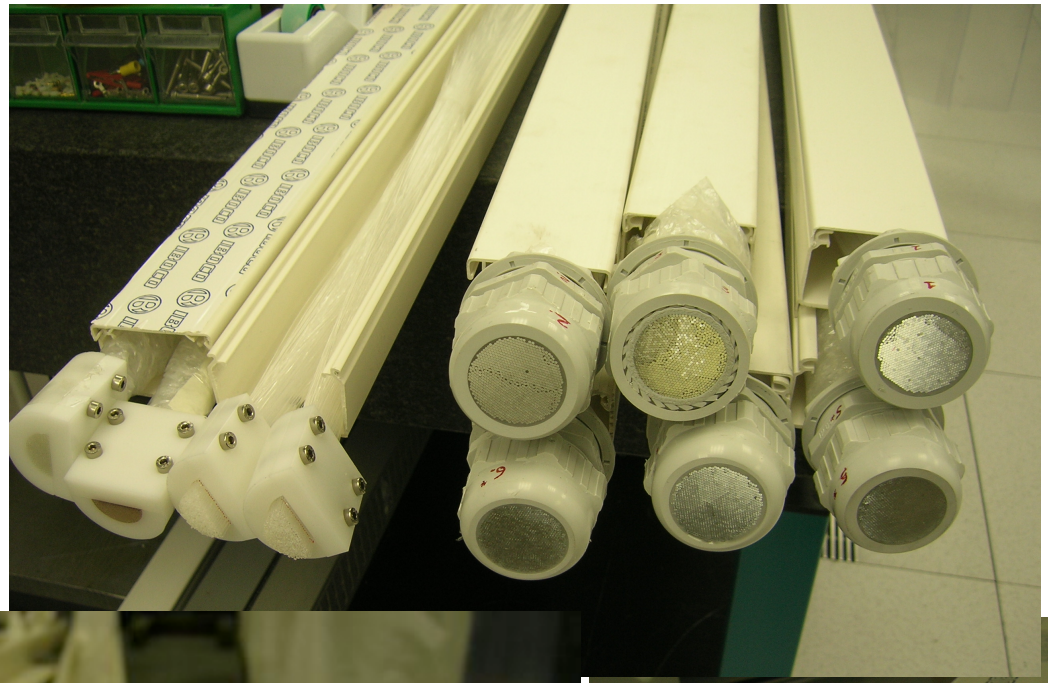
for each module:
6x(2x4x200)cm^3 + 4x(1x2x200)cm^3
8PM

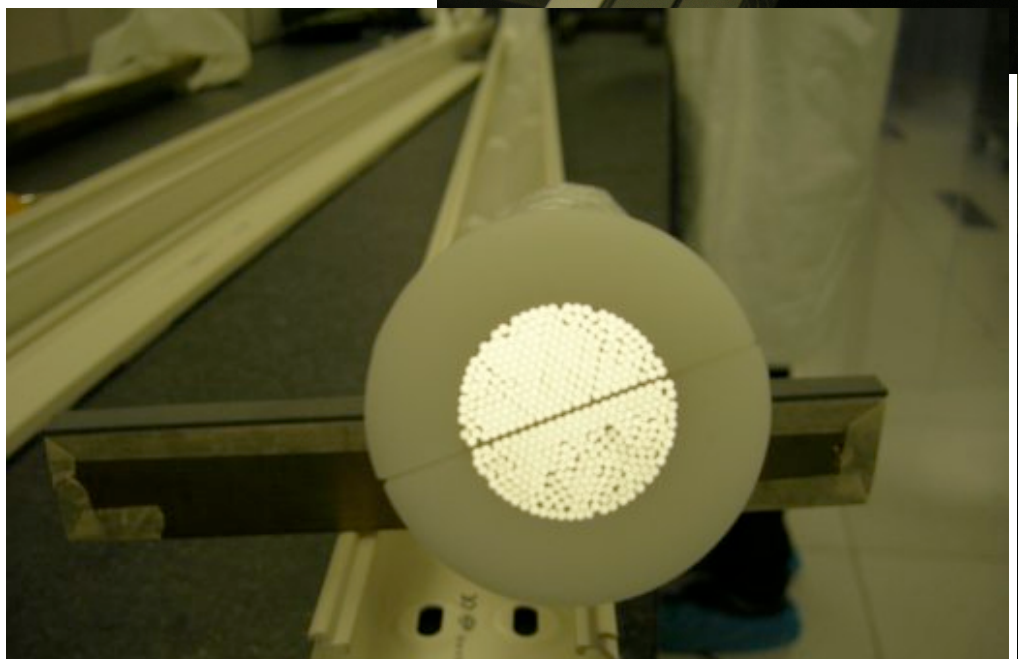


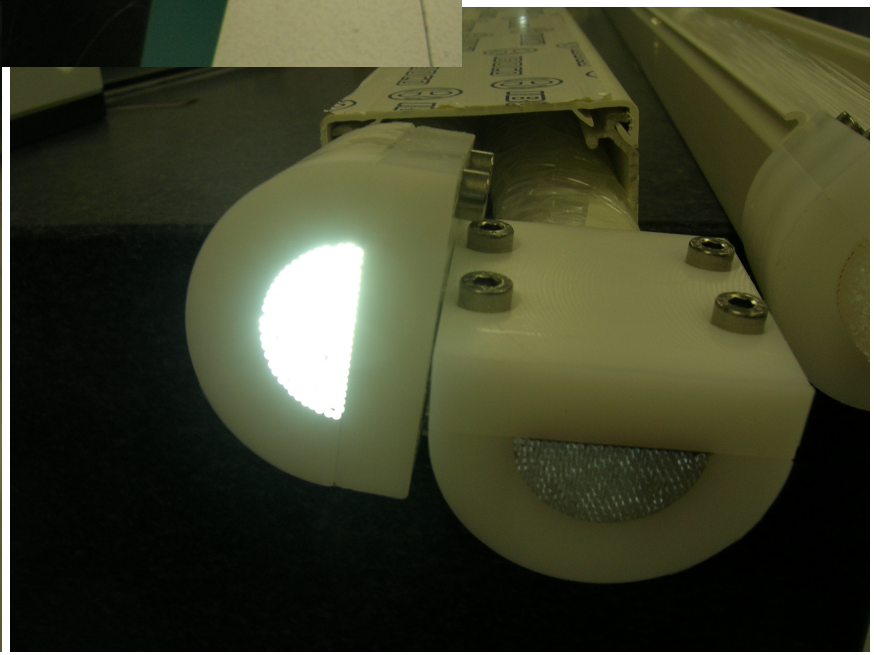


Bundles production (clear fibers): PM side

(SSE, resp. M.Anelli)

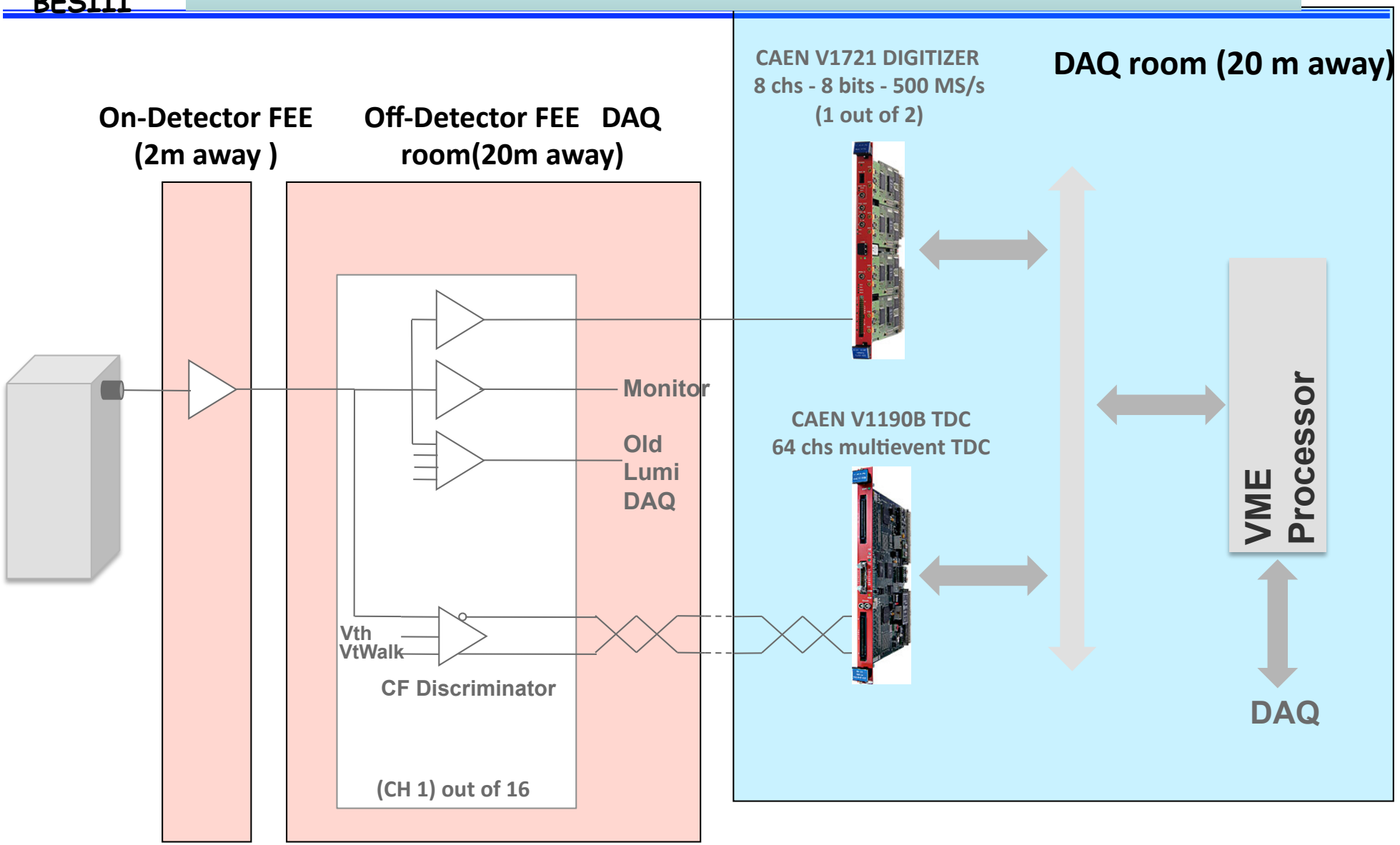






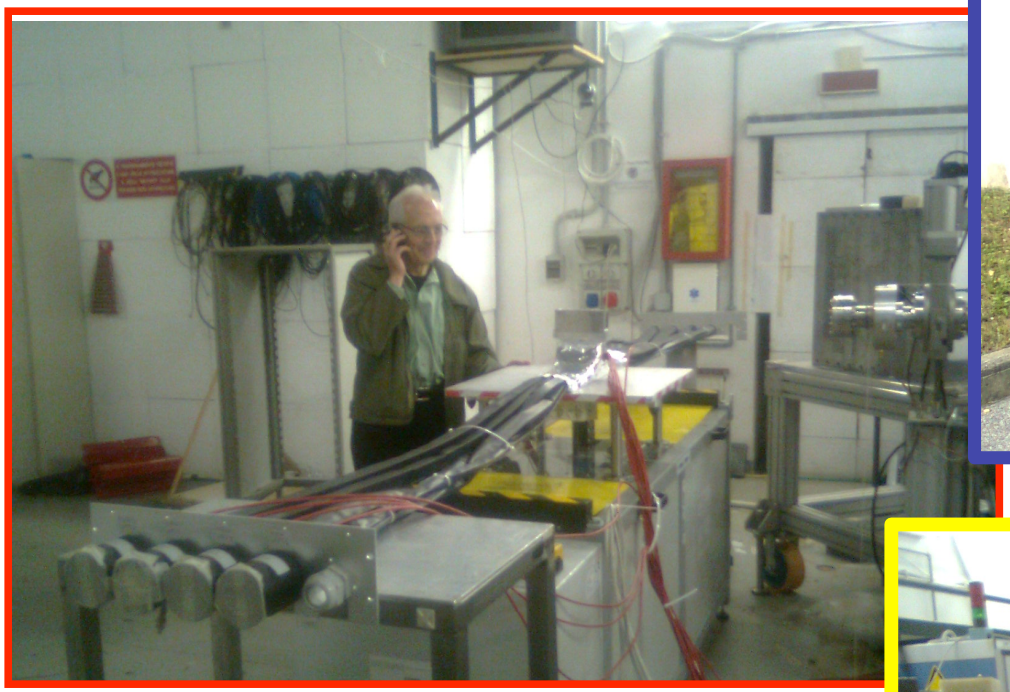
Front End Electronics

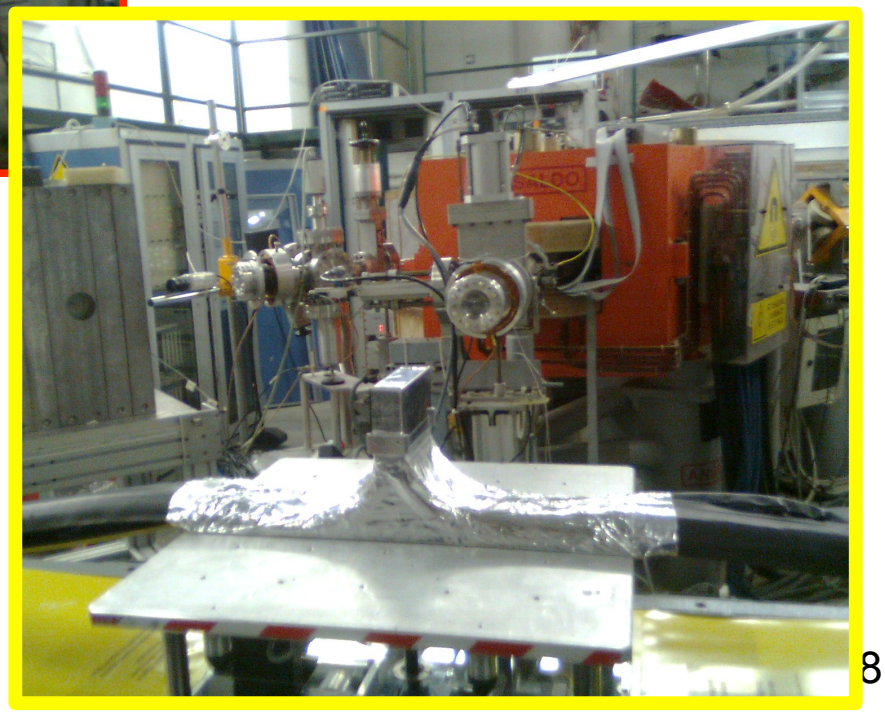
(by G.Felici, LNF-SEA)



BTF test beam

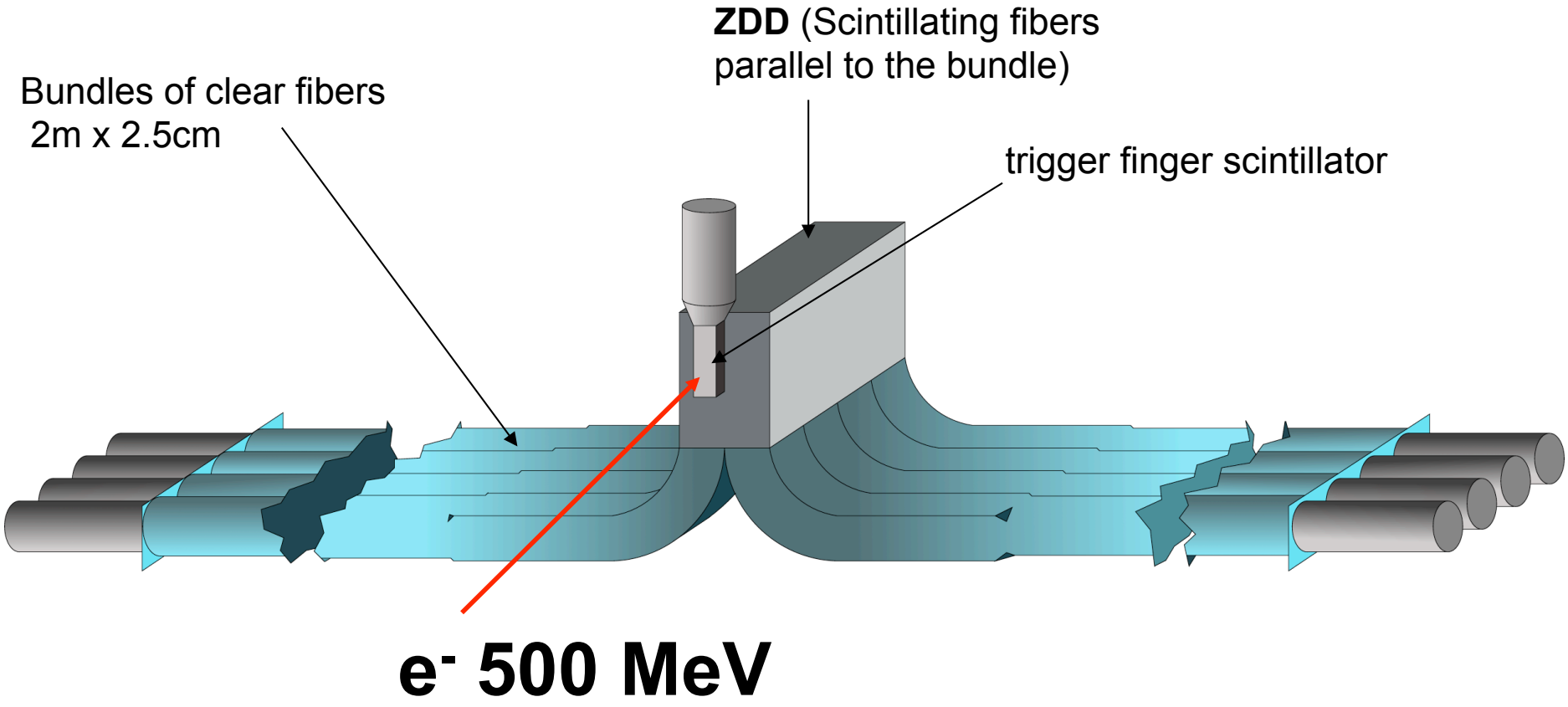
(may 16-22 2011)



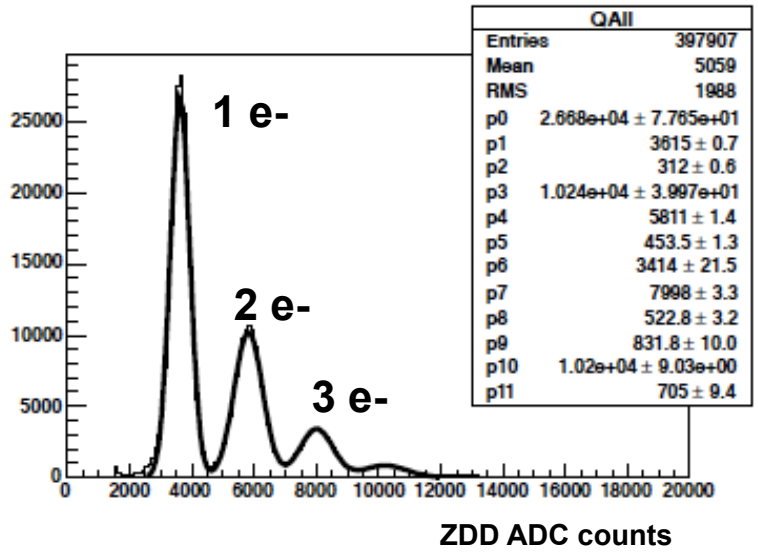


One (out of two) ZDD module tested at BTF
with 450, ~300, ~200 MeV e^- bunches (N_{e^-}=1,2,3)
Final Pb-scifi ZDD module, bundles guides,
PM's, TDC, at the moment not FADC but ADC
caen V V792N
Small scintillator (60x11x4) mm^3 used to trigger
and select electrons impact point

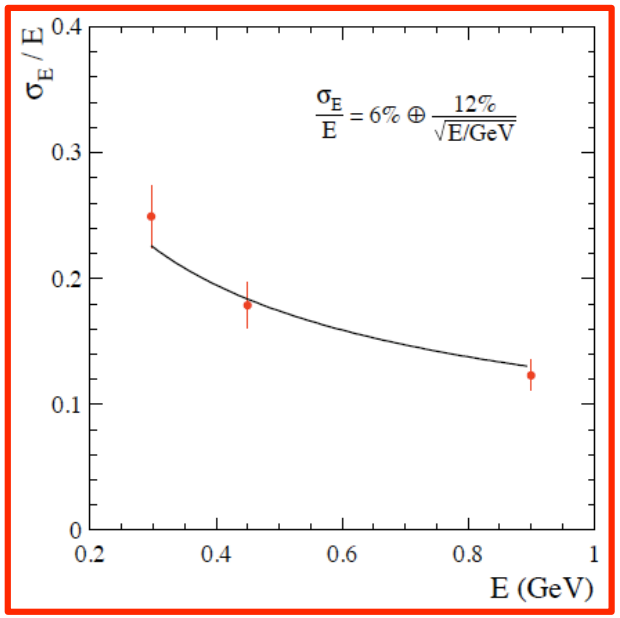
BTF Test beam setup



Test beam @ LNF: preliminary results

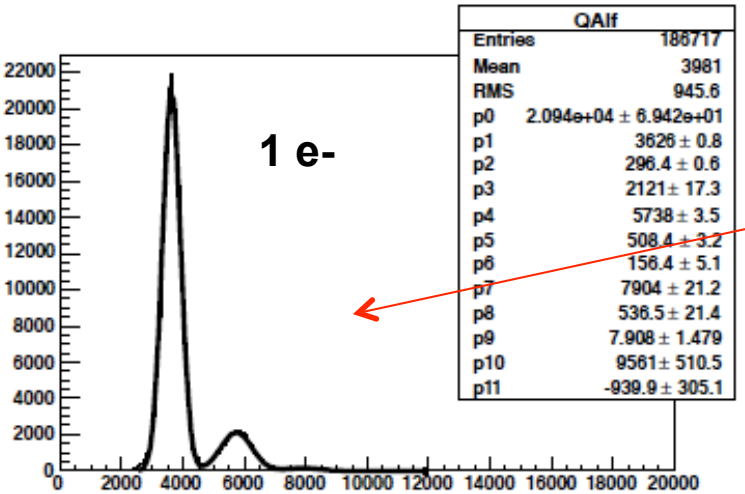


ZDD ADC counts

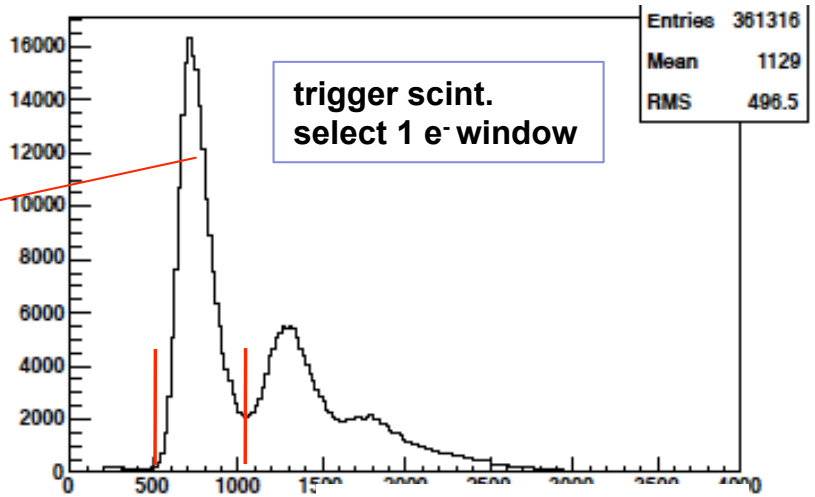


Preliminary (PM not equalized) energy resolution as expected from MC studies and KLOE results

work in progress for energy calibration and PM equalization cosmic rays test on going:



triggered ZDD ADC counts



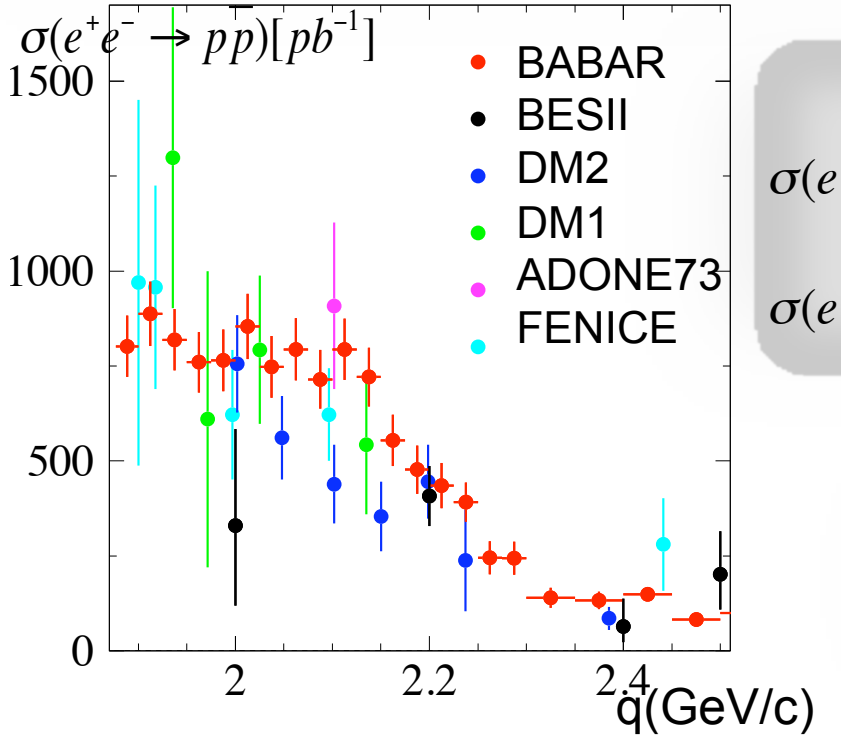
finger scint. ADC counts

$e^+e^- \to p\bar{p}$

EPJA39, 316

$$\sigma(e^+e^- \to p\bar{p}) = \frac{4\pi\,\alpha^2\beta_p C}{3q^2}\left[|G_M|^2 + \frac{2M_p^2}{q^2}|G_E|^2\right]$$

Coulomb factor: $C \underset{\beta_p \to 0}{\sim} \left(\frac{\pi\alpha}{\beta_p}\right)$



At threshold:

$$\sigma(e^+e^- \to p\bar{p})(4M_p^2) = \frac{\pi\,\alpha^3}{2M_p^2}\beta_p|G^p(4M_p^2)|^2$$

$$\sigma(e^+e^- \to p\bar{p})(4M_p^2) = 850\,|G^p(4M_p^2)|^2\ pb = 850\,pb \pm 50$$

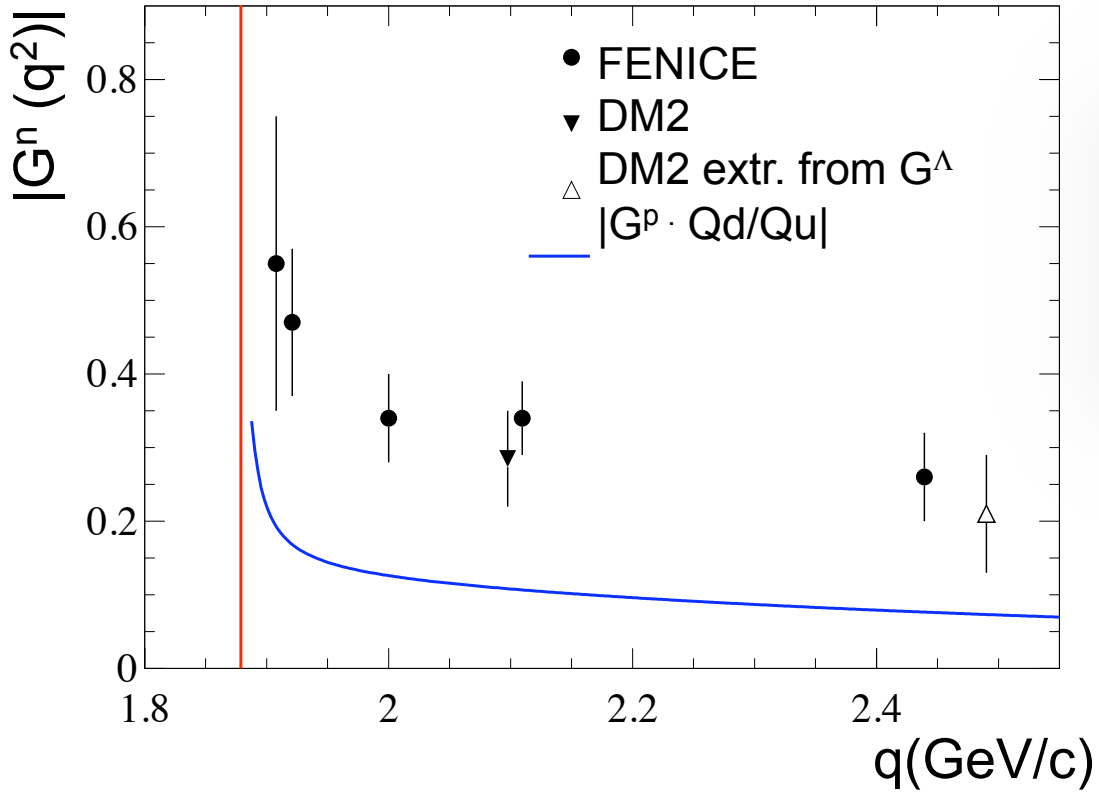
$\Downarrow$

$|G_p(4M^2_p)|=1$ as pointlike fermion pairs !

Using ISR technique with only few fb-1 of integrated luminosity BESIII can achieve the BABAR statistics

$e^+e^- \to n\bar{n}$

Nucl.Phys. B517,3 (1998)

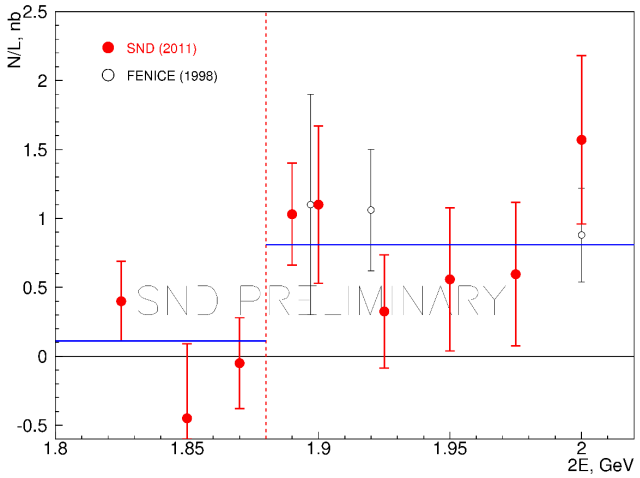


- **Measured only once by FENICE at ADONE**
- **500nb-1 (15' at BESIII)**
- **~100 candidates $n\bar{n}$**
- **$\sigma(n\bar{n}) > \sigma(p\bar{p})$?**
- **Not zero at threshold?**

$e^+e^- \rightarrow n\bar{n}$

First preliminary result from SND (HADRON 11)

$$e^+e^- \rightarrow n\bar{n}$$

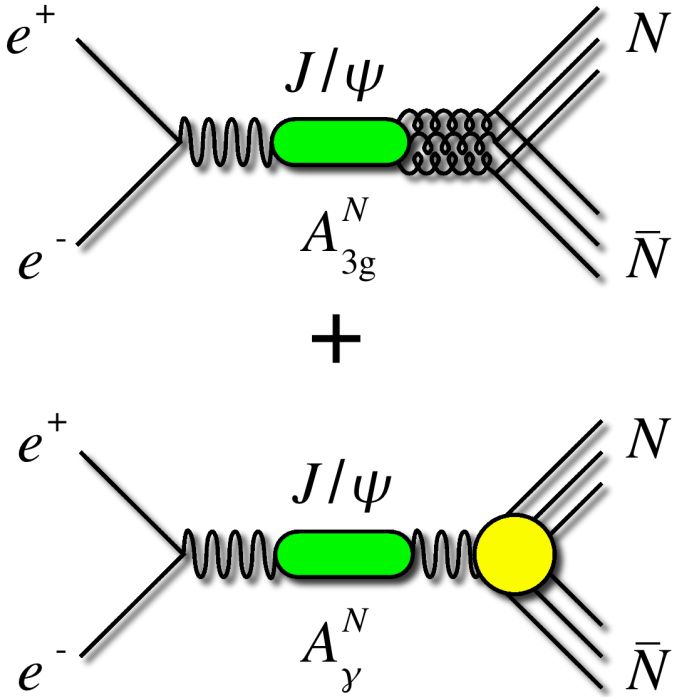


- Scan 2011
- $n\bar{n}$ cross section is presented, efficiency ~ 30%
- $e^+e^- \rightarrow p\bar{p}$, $\gamma\gamma$ backgrounds are subtracted
- Below the $n\bar{n}$ threshold $\sigma = 0.1 \pm 0.2$ nb
- Above the $n\bar{n}$ threshold $\sigma = 0.8 \pm 0.2$ nb

•BESIII has the unique possibility to measure this cross section with better precision and much wider energy range

Measurement of $J/\psi \to p\bar{p}$, $n\bar{n}$

- $p\,\bar{p}$ amplitude A_γ^p from BABAR data
- $n\,\bar{n}$ amplitude A_γ^n from FENICE data
- $A_\gamma^p - A_\gamma^n$ relative phase from pQCD



$$B(J/\psi \to n\bar{n}) = \left| \frac{A_{3g} + A_\gamma^n}{A_{3g} + A_\gamma^p} \right|^2 B(J/\psi \to p\bar{p}) = (1.4 \pm 0.2) \times 10^{-3}$$

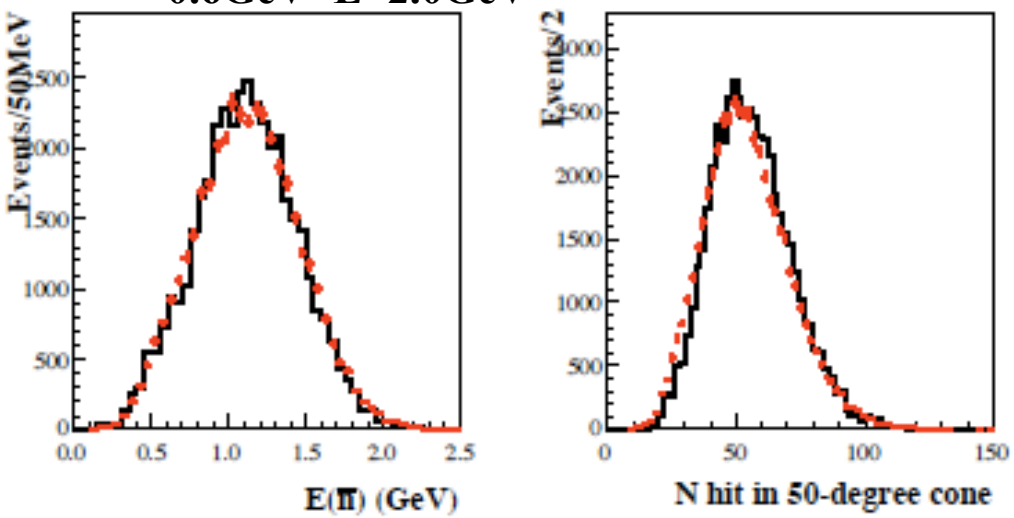
- **BESII at BEPC** [PLB591,42]: $BR(J/\psi \to p\bar{p}) = (2.26 \pm 0.01 \pm 0.14) \times 10^{-3}$
- **FENICE at ADONE** [PLB444,111]: $BR(J/\psi \to n\bar{n}) = (2.2 \pm 0.4) \times 10^{-3}$

$B(J/\psi \to p\bar{p}) \sim B(J/\psi \to n\bar{n}) \Rightarrow$ large $A_{3g}^N - A_\gamma^N$ relative phase ?

BESIII preliminary results: $J/\psi \to p\bar{p}$, $n\bar{n}$

nbar identification

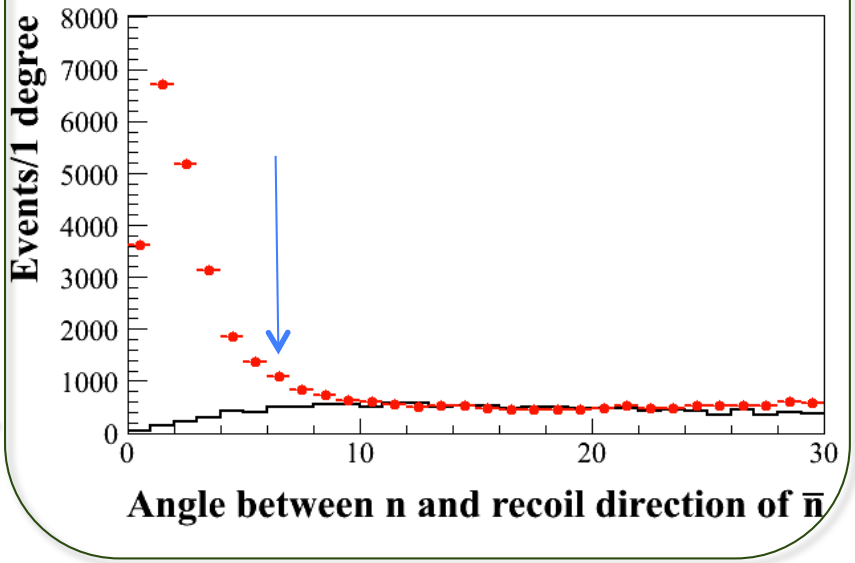
- **0.6GeV>E>2.0GeV**



- Comparison for $\bar{n}$ in $J/\psi \to n\bar{n}$ and $J\psi \to p\bar{n}\pi$:
  - deposited energy in EMC
  - number of hits in a 50^0 cone around the n shower

n identification

- **0.06GeV>E>0.6GeV**



Br($J/\psi \to n\bar{n}$) = $(2.07\pm0.01\pm0.14)\times10^{-3}$ ⟷ **Br($J/\psi \to p\bar{p}$) = $(2.112\pm0.004\pm0.027)\times10^{-3}$**

PDG: Br($J/\psi \to nn$) = $(2.2\pm0.4)\times10^{-3}$

PDG: Br($J/\psi \to pp$) = $(2.17\pm0.07)\times10^{-3}$

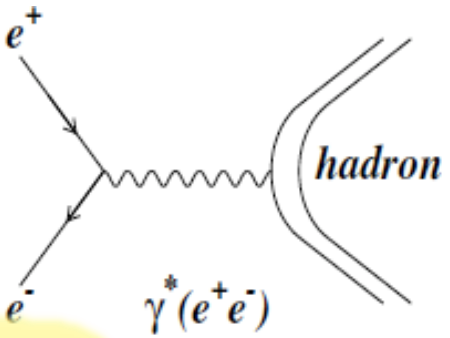
Br(J/ψ→ppbar) ~ Br(J/ψ→nnbar)
suggests a large phase (~90º) between strong and em amplitudes !

Italian Proposal to measure the phase between strong and e.m. amplitudes with a scan across J/ψ

- According to pQCD [$\Gamma_{J/\psi} \sim 93$KeV] the strong amplitude (via 3 gluons) and the E.M. amplitude (via virtual photon) in J/ψ decays should be almost real (phase~0^0)
- So far experimental data, including preliminary BESIII result, suggests that in J/ψ decays the strong amplitude (via 3 gluons) and the E.M. amplitude (via virtual photon) are orthogonal (phase~90^0), but need of SU(3) model.

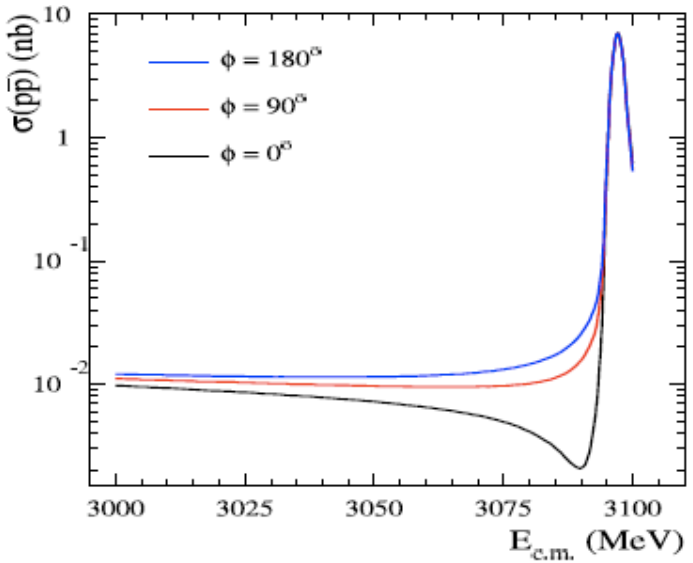
Imaginary amplitudes hard to be explained !

A model-independent way to measure the phase is through the non-resonant continuum amplitude:

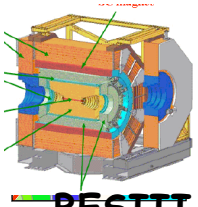


Look for interference pattern between resonant amplitude and the non resonant one with a c.m. energy scan:

- **No interference $\phi = 90^o, 180^o$ (imaginary strong amplitude!)**
- **Maximum interference, $\phi = 0$, real strong amplitude**



NEXT DATA TAKING !



Composizione del gruppo LNF e richieste per il 2012

Ricercatori: TOT=4, FTE=3.8 → 2.0 con disposizione del 5/7/2011 !!!!

R. Baldini Ferroli, M.Bertani (resp. loc. e naz.), A. Calcaterra (resp. ZDD), A. Zallo

Richieste ai LNF per 2012 per costruzione secondo modulo ZDD :

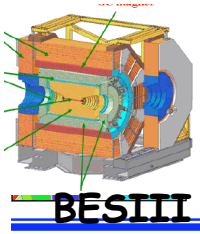
Supporto tecnico servizio esperimenti alte energie (supervisor M.Anelli): 0.5 F.T.E.

Servizio progettazione: 1 mesi/uomo per progettazione supporti e movimentazione

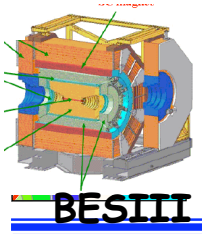
Servizio elettronica: : 2 mesi/uomo per circuiti FEE

Meccanica: 1 mese/uomo per realizzazione support

Capitolo	**Richieste (K€)**
Missioni estere	56.0
Missioni interne	4.0
Consumo	5.0
Apparati tot	80
trasporti	5.0
Totale LNF	150.0



spares



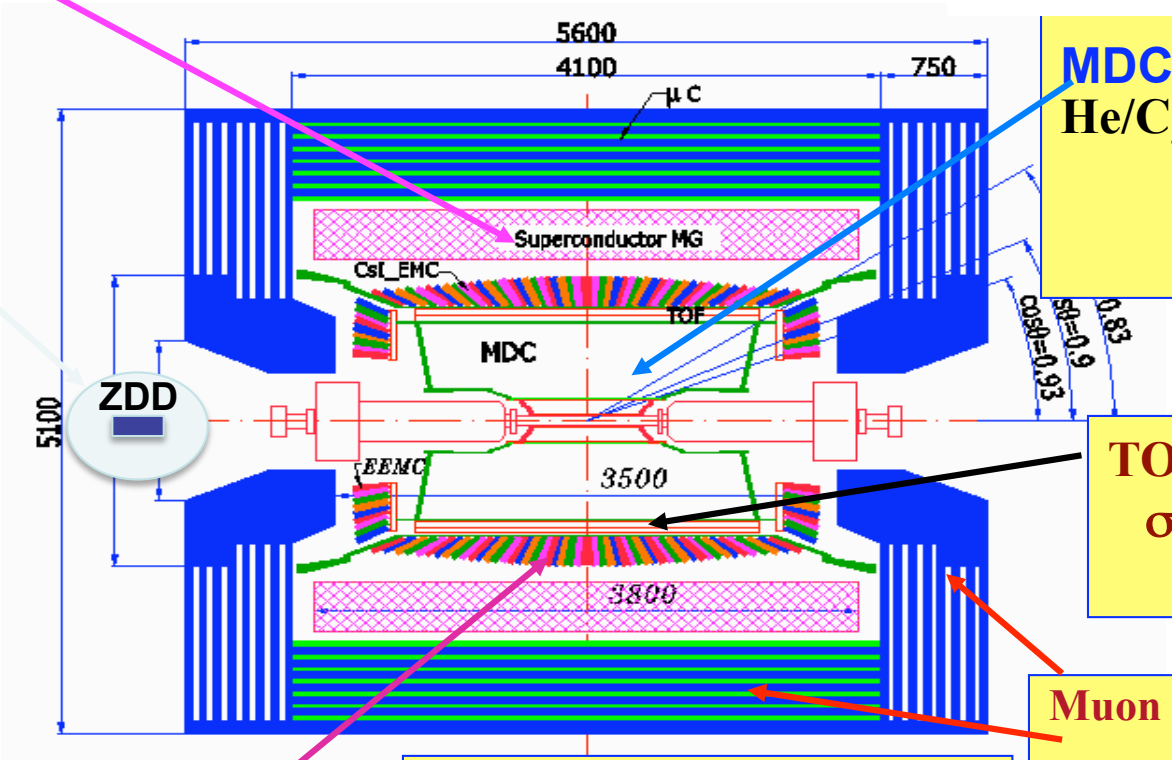
BESIII Detector

BESIII detector: all new !

CsI calorimeter
Precision tracking
Time-of-flight + dE/dx PID

Magnet: 1 T Super conducting

Zero Degree Detector new (2011)



MDC: small cell & Gas:
He/C_3H_8 (60/40), 43 layers
σ_{xy}=130 μm
σ_p/p = 0.5% @1GeV
dE/dx=6%

TOF:
σ_T = 100 ps Barrel
110 ps Endcap

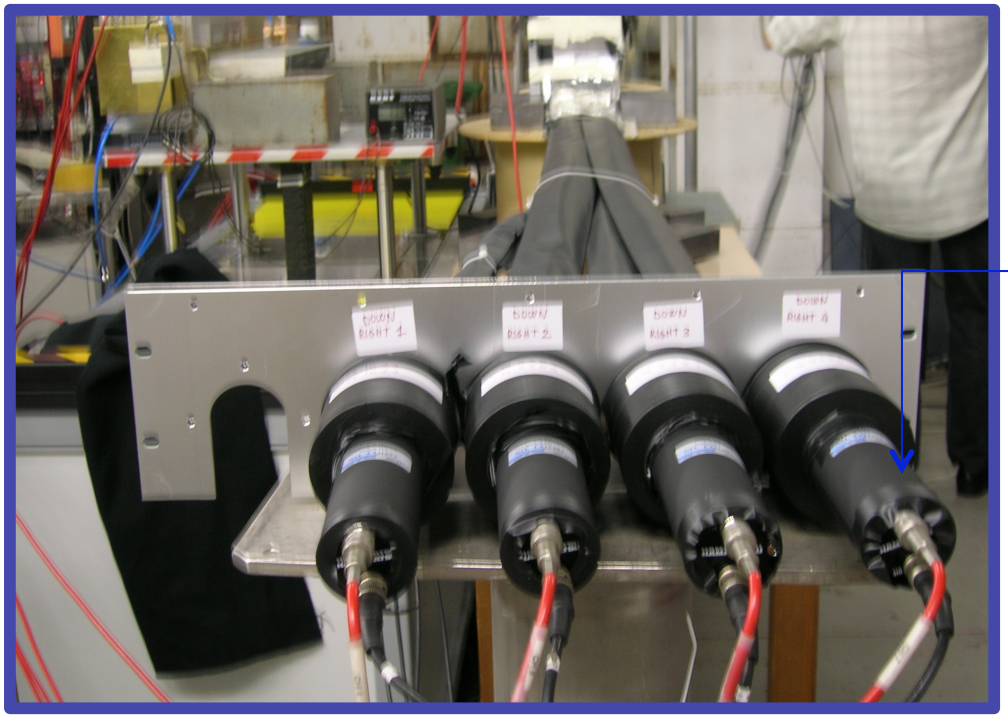
Muon ID: 9 layers RPC
8 layers for endcap

EMC: CsI crystal, 28 cm
ΔE/E = 2.5% @1 GeV
σz = 0.6 cm/√E

Data Acquisition:
Event rate = 4 kHz
Total data volume ~ 50 MB/s

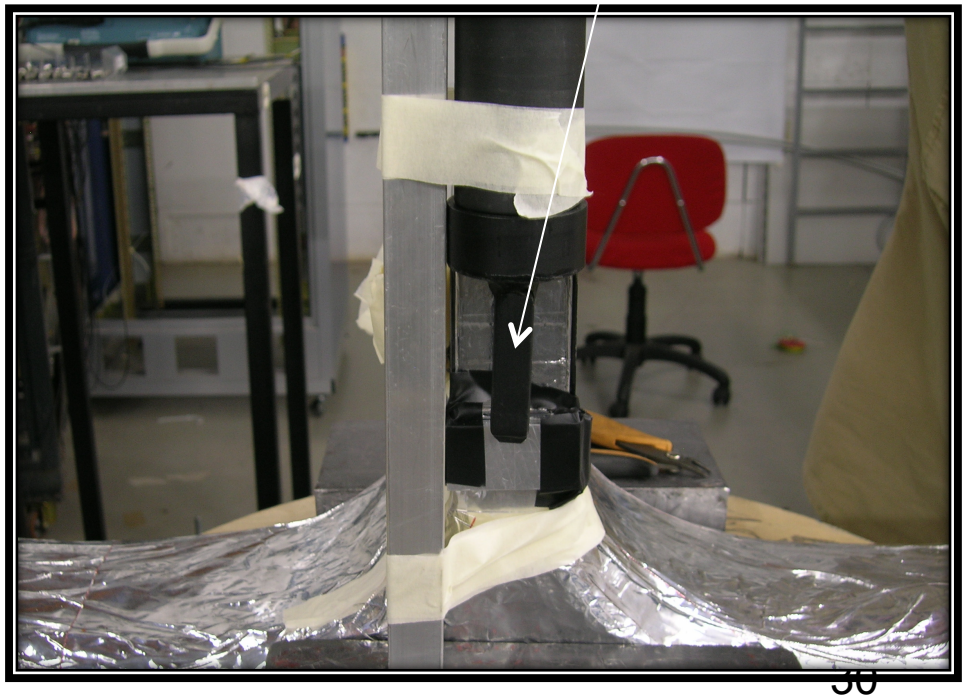
The detector is hermetic for neutral and charged particle with excellent resolution, PID, and large coverage.

BTF test beam



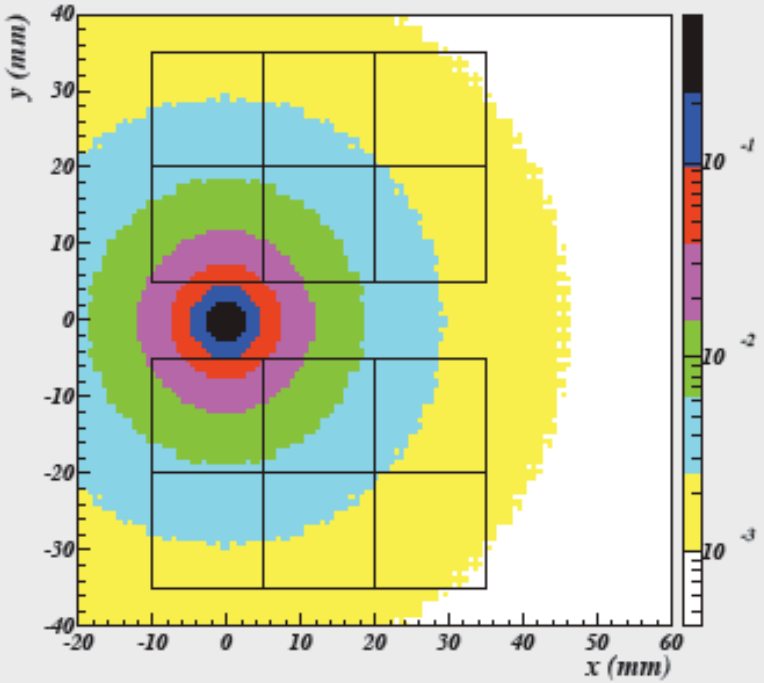
Hamamatsu H10826 SEL

trigger finger scintillator
((60x11x4) mm^3



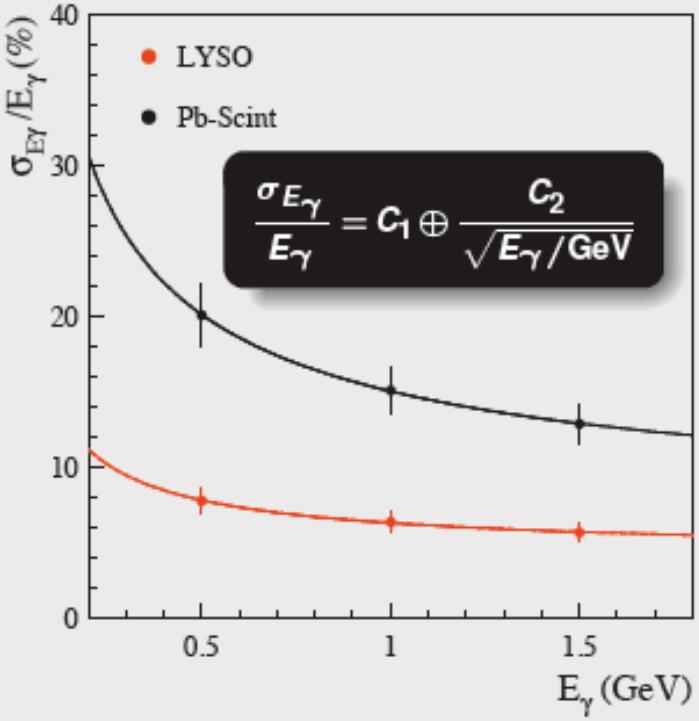
Energy resolution, the ISR case

ISR angular distribution on ZDD



E_γ (GeV)	LYSO $\sigma_{E_\gamma}/E_\gamma$	Pb-Scint $\sigma_{E_\gamma}/E_\gamma$
1.5	5.7%	12.9 %
1.0	6.4%	15.1 %
0.5	7.8%	20.1 %

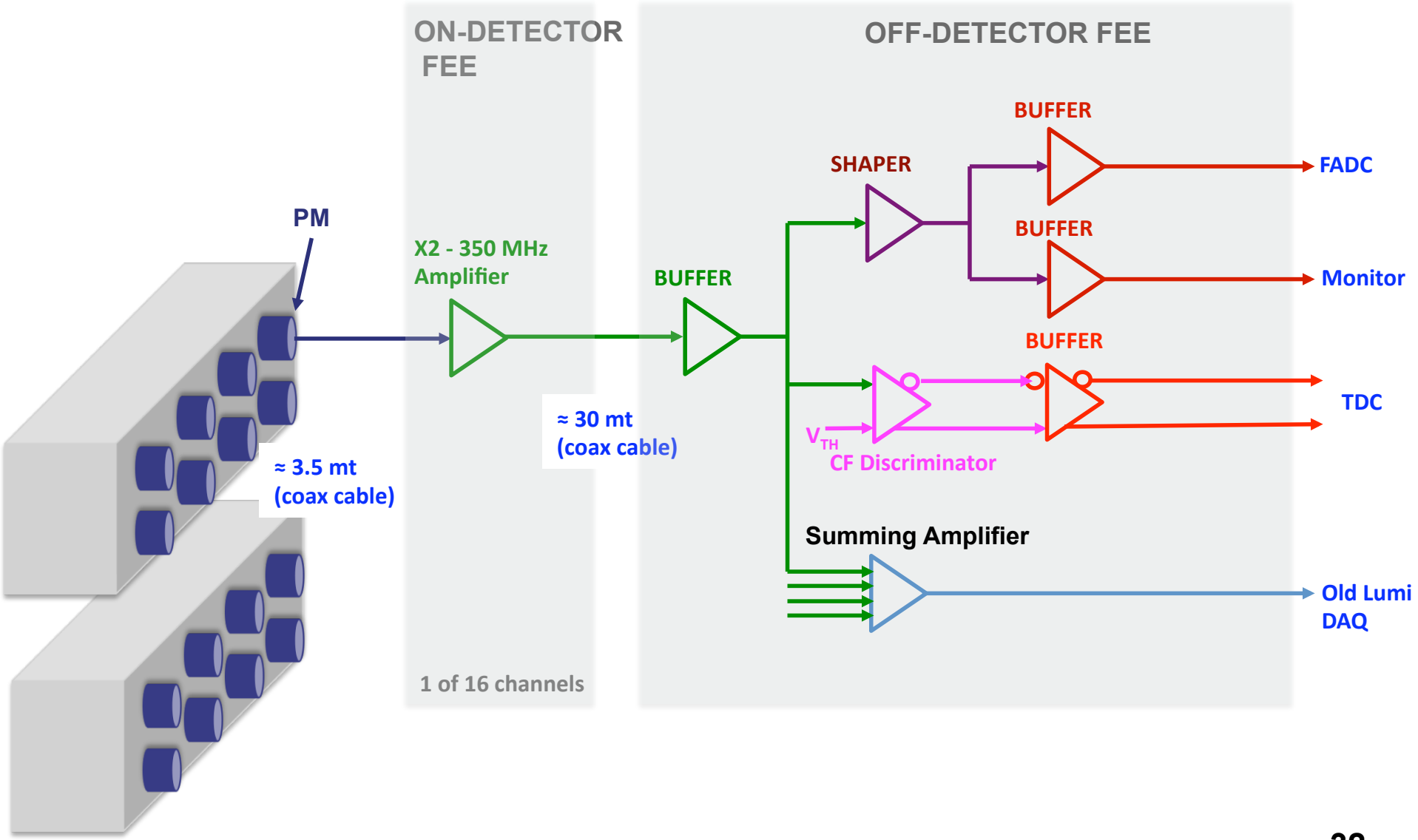
Energy resolution for ISR

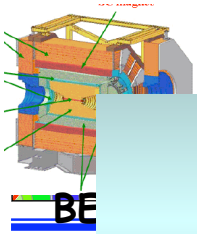


	LYSO	Pb-Scint
C_1	4.3%	6.9 %
C_2	4.6%	13.4 %

Front End Electronics

(by G.Felici, LNF-SEA)





Front-End electronics

- Close to the detector (~2m away) a mechanical structure will hold:
  - 16 PMs (8 up, 8 dw) and fiber bundles
  - cables: analog OUT (16 x 3 = 48)
  - discriminators OUT (16), PM power IN (16)
- ~20 kgs of electronics

Observation of $h_c(^1P_1)$

- Test of isospin violation:

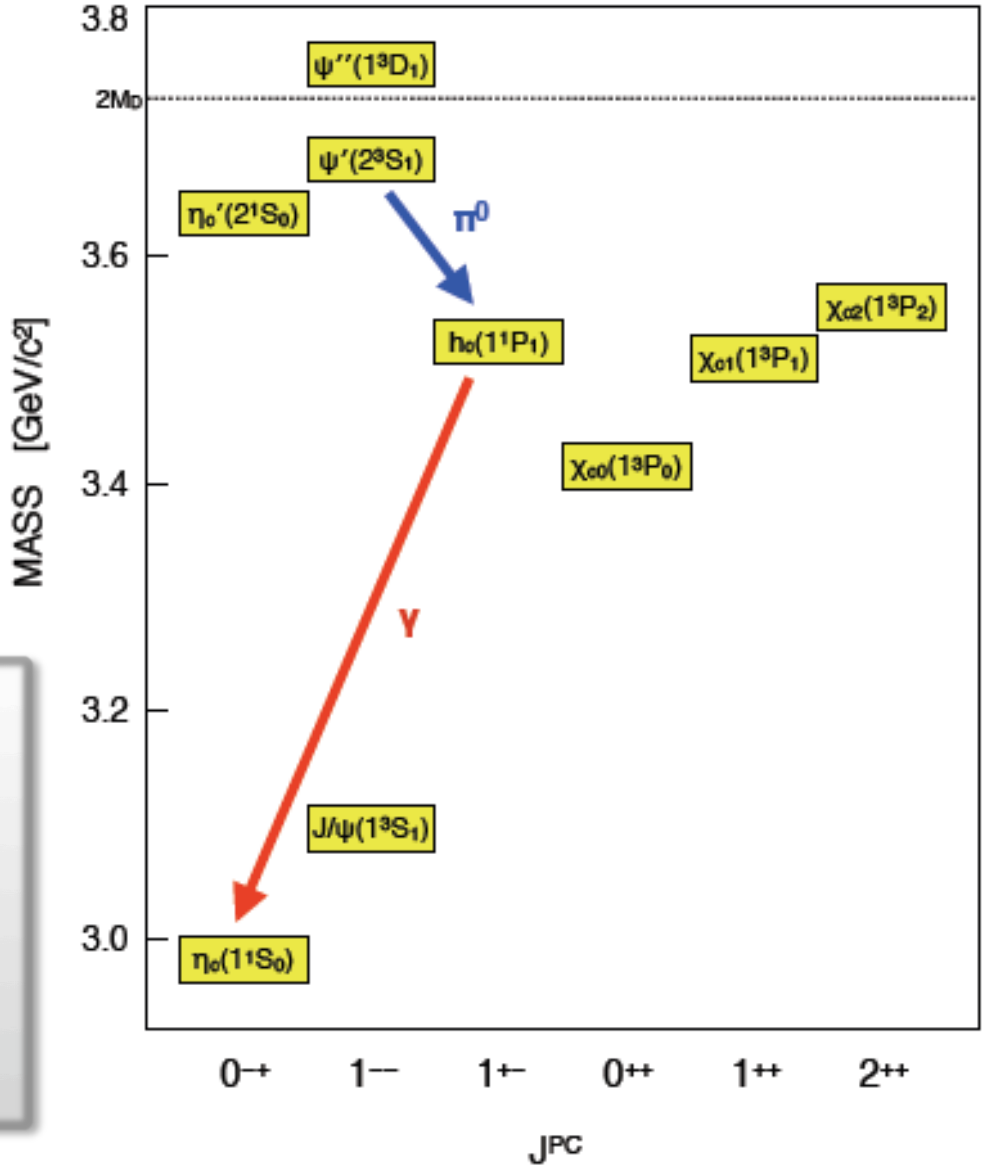
  $B(\psi' \rightarrow \pi^0 h_c)$

- Measure E1 transition:

  $B(h_c \rightarrow \gamma \eta_c)$

- Hyperfine mass splitting of 1P states (spin spin interaction):

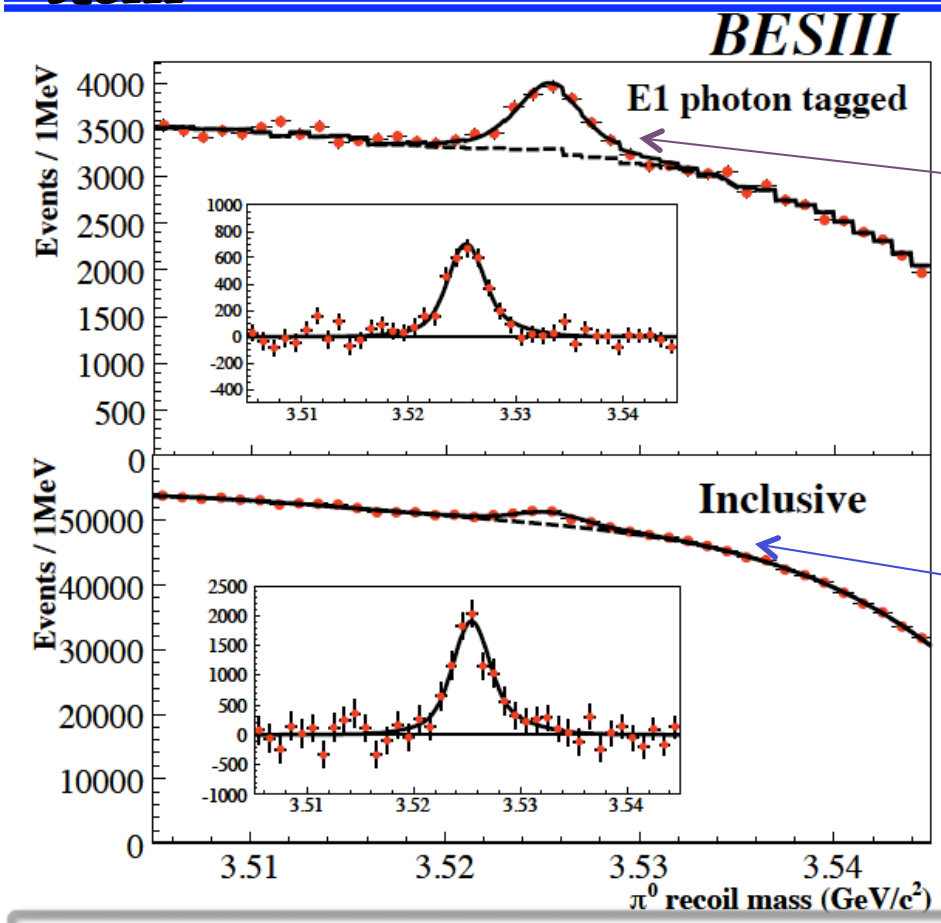
  $\Delta M_{hf}(1P) = \langle M(1^3P) \rangle - M(1^1P_1)$



- First evidence by E835 in $p\bar{p} \rightarrow h_c \rightarrow \gamma\eta_c$ [PRD72,092004(2005)]
- CLEOc accessed [PRL101 182003(2008)]:

  $B(\psi' \rightarrow \pi^0 h_c) \times B(h_c \rightarrow \gamma \eta_c)$
- BESIII access both B and B, $M(h_c)$, $\Gamma(h_c)$ [PRL104 132002(2010)]

The $h_c(^1P_1)$ in $\psi`$ decays in BESIII



PRL104 132002(2010)]

❖**Tag the E1 photon yields:**

$B(\psi` \rightarrow \pi^0 h_c) \times B(h_c \rightarrow \gamma \eta_c) =$

$= (4.58 \pm 0.40 \pm 0.50) \times 10^{-4}$

(consistent with CLEOc)

❖**Inclusive analysis provides:**

$B(\psi` \rightarrow \pi^0 h_c = 8.4 \pm 1.3 \pm 1.0) \times 10^{-4}$

(first measurement)

Combining the two results leads: $B(h_c \rightarrow \gamma \eta_c) = (54.3 \pm 6.7 \pm 5.2)\%$ *(first measurement)*

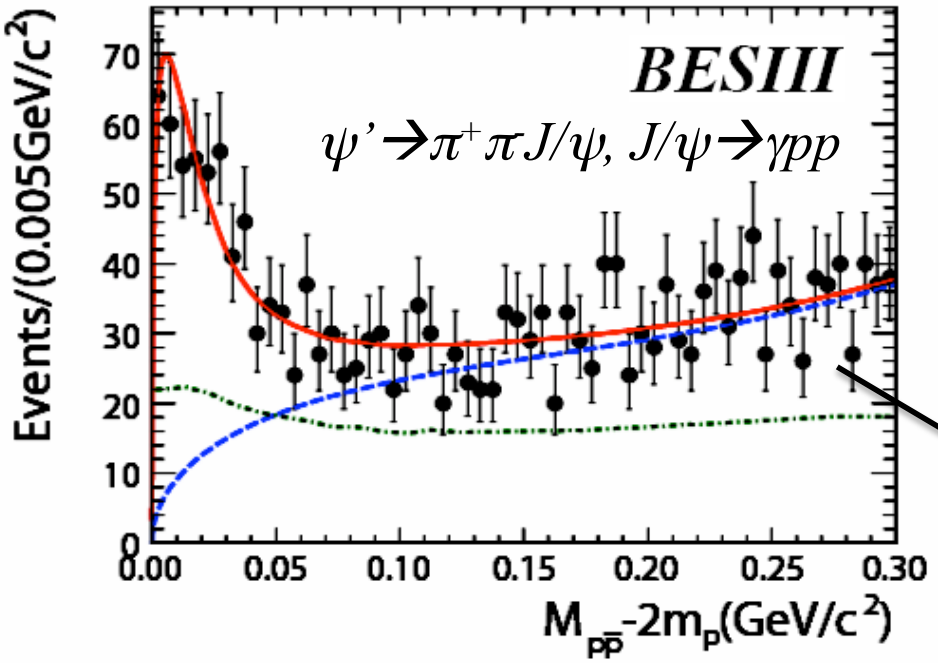
$M(h_c) = 3525.40 \pm 0.13 \pm 0.18$ MeV/c^2 *(consistent with CLEOc)*

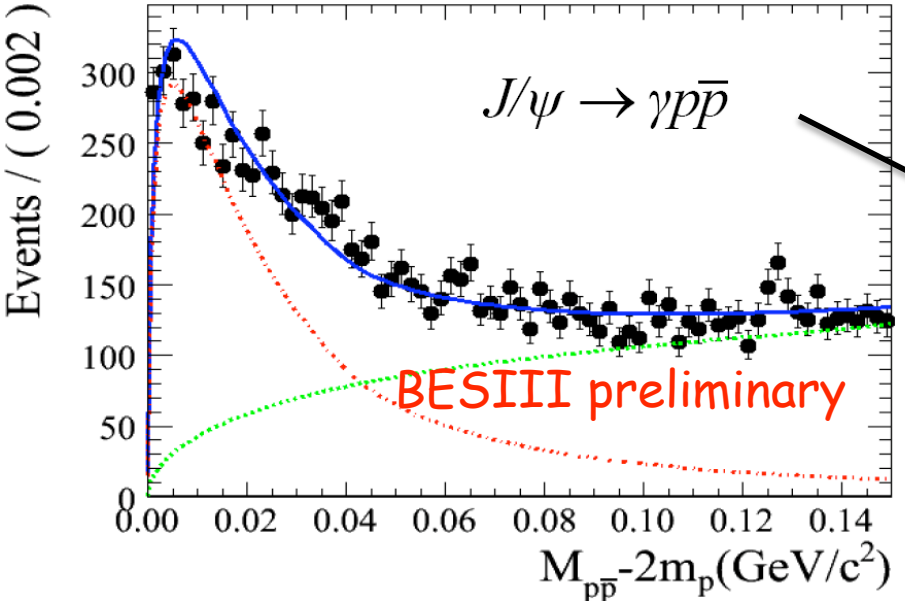
$\Gamma(h_c) = 0.73 \pm 0.45 \pm 0.28$ MeV/c^2 *(first measurement)*

$\Delta M_{hf}(1P)$ [MeV/c^2]$=0.10 \pm 0.13 \pm 0.18$ *consistent with zero, no strong spin spin interaction*

X(1860): the anomalous enhancement at $p\bar{p}$ threshold

CPC 34, 421 (2010)





- **Observed at BESII in $J/\psi \to \gamma p\bar{p}$ PRL91,022001(2003)**
- **M = 1859 MeV/c²**
- **Γ < 30 MeV/c² (90% CL)**
- **JPC=0-+**
- **Confirmed by CLEOc**

At BESIII $\psi' \to \pi^+\pi J/\psi,\ J/\psi \to \gamma p\bar{p}$ [CPC 34,421 (2010)]

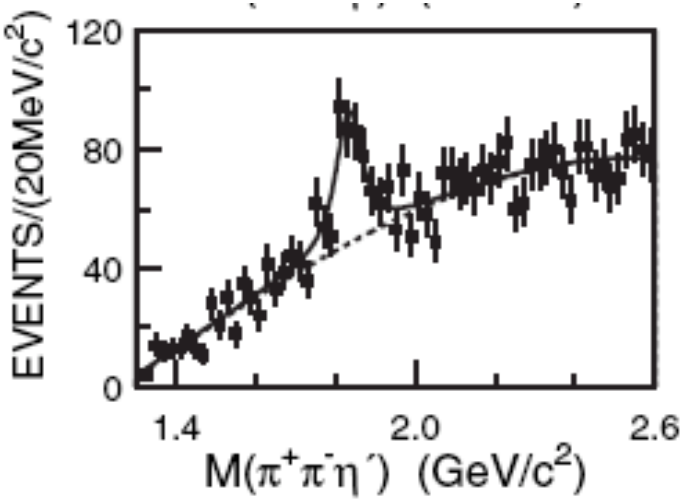
- **$M=1861\ ^{+6}_{-13}\ ^{+7}_{-26}$ MeV/c²**
- **Γ < 38 MeV/c² (90% CL)**

- **Preliminary BESIII:, $J/\psi \to \gamma p\bar{p}$**
- **M=1861.6 ± 0.8 (stat) MeV/c²**
- **Γ < 8 MeV/c² (90% CL)**

ppbar bound state, baryonium ?
multiquark ? glueball ?

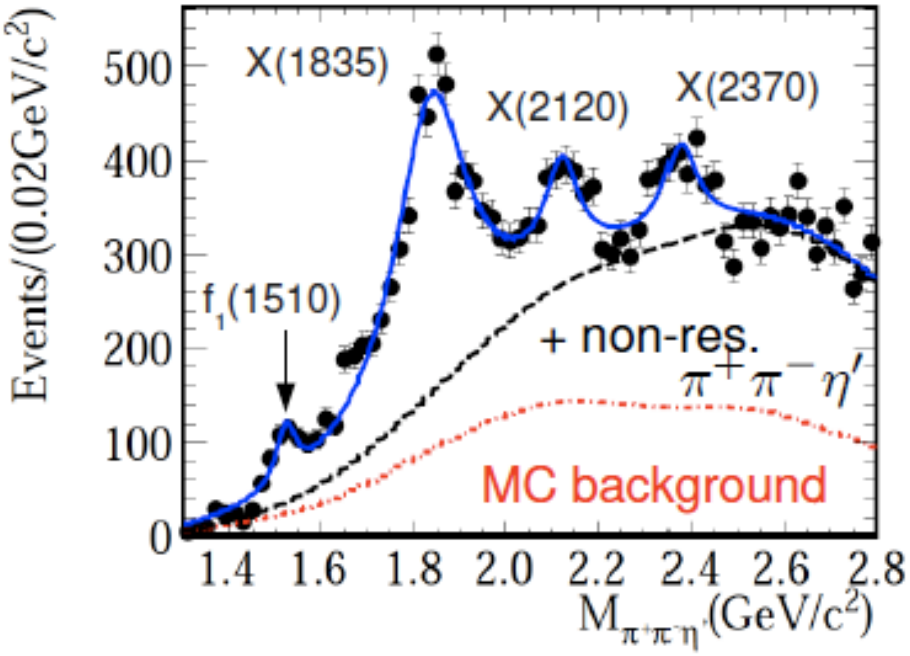
Confirmation of X(1835), and new observation of X(2120), X(2370) in $J/\psi \to \gamma\eta'\pi^+\pi^-$

[PRL 106, 072002 (2011)]



BESII *result [PRL95, 262001 (2005)]*

- M = 1833.7±6.1(stat)±2.7(syst) MeV/c^2
- Γ = 67.7±20.3(stat)±7.7(syst) MeV/c^2
- Significance: ~7.7σ

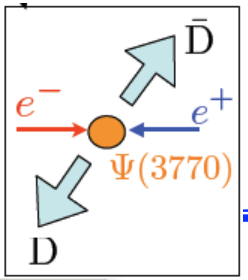


- **BESIII** ***[PRL 106, 072002 (2011)]*** confirms the existence of **X(1835)** with much higher statistical significance (>20σ).
- Two additional new resonances, **X(2120)** and **X(2370)**, are observed with significance larger than 7.2σ and 6.4σ, respectively.

a glueball ?

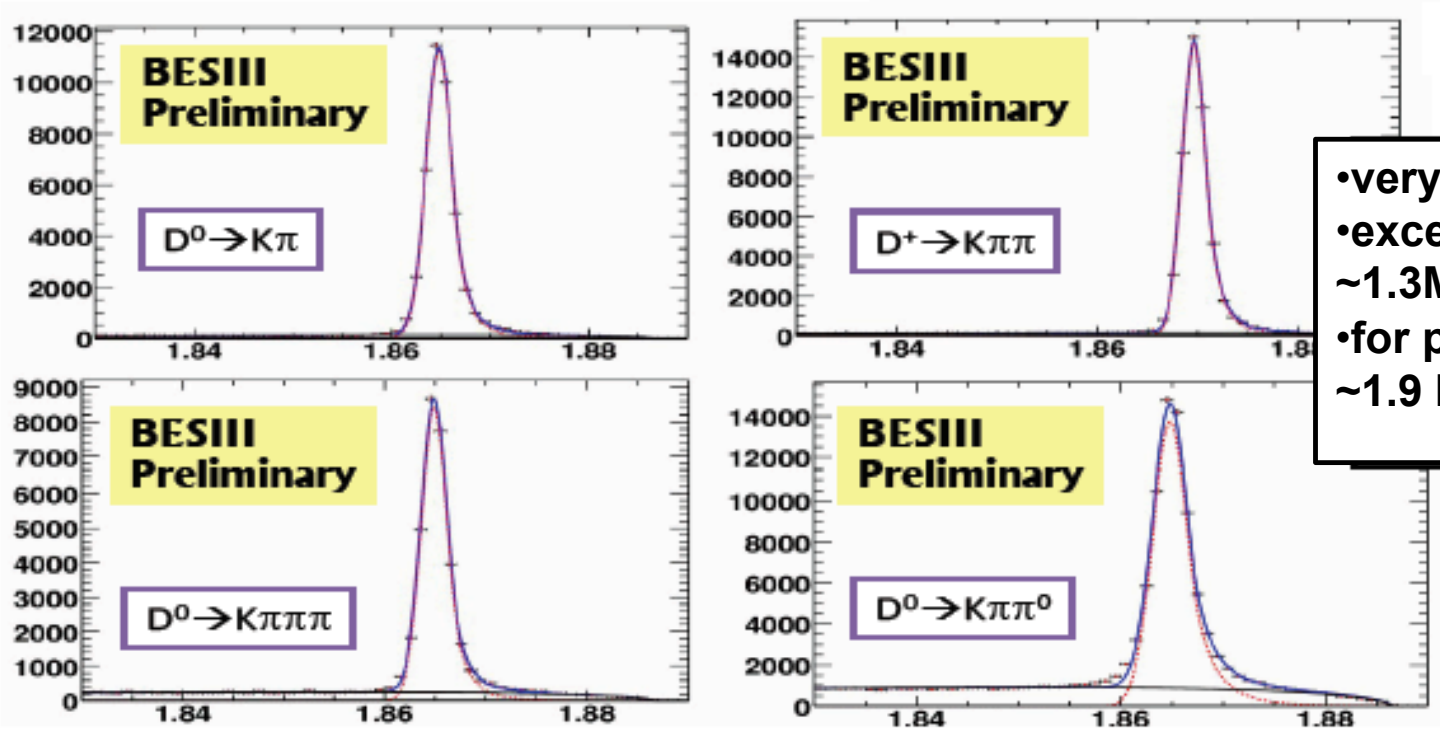
LQCD predicts a 0^{+-} glueball at ~2.3GeV!

Open charm with BESIII
stay tuned !



D-tagging:
- o use Ψ(3770)->D$\bar{D}$ to produce two quantum correlated D mesons
- o production nearly at rest -> optimum signal to background

Physics:
- o D-tagging as perfect tool to study...
- o mixing+CPV in charm sector
- o hadronic decays (Dalitz analysis)
- o (semi) leptonic decays, etc ...



- very clean
- excellent resolution ~1.3MeV
- for pure charged ~1.9 MeV with a π^0

$$M_{BC} = \sqrt{E_{beam}^2 - |p_D|^2}$$

(using only 420 pb^{-1}...)