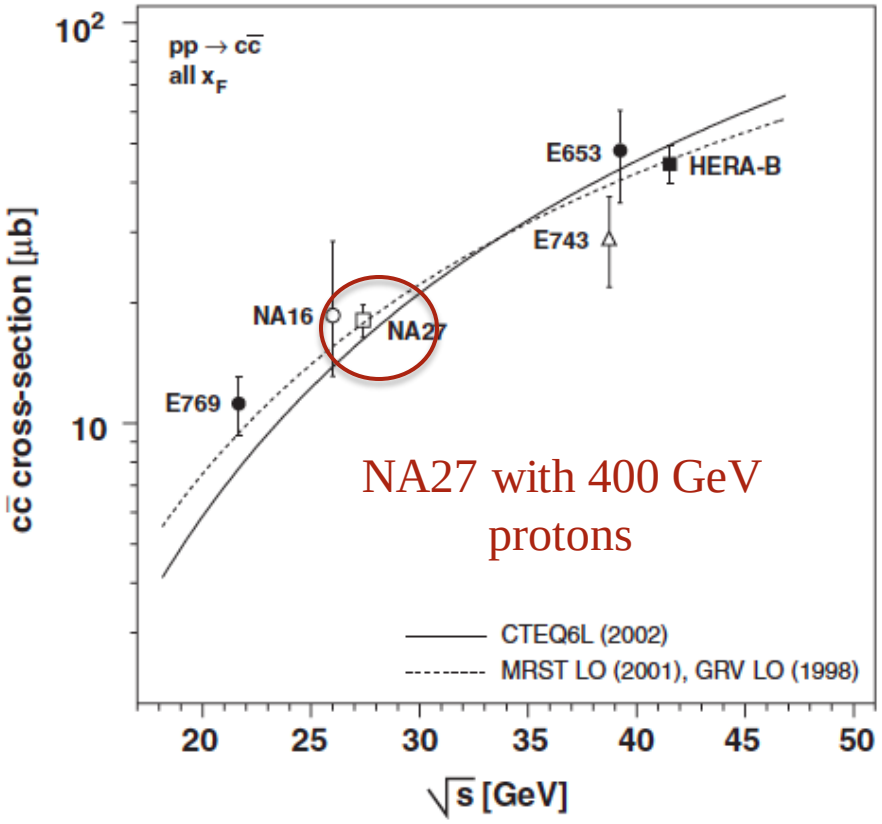
Measurement of angular and momentum distributions of charmed hadrons produced in p-Mo collisions

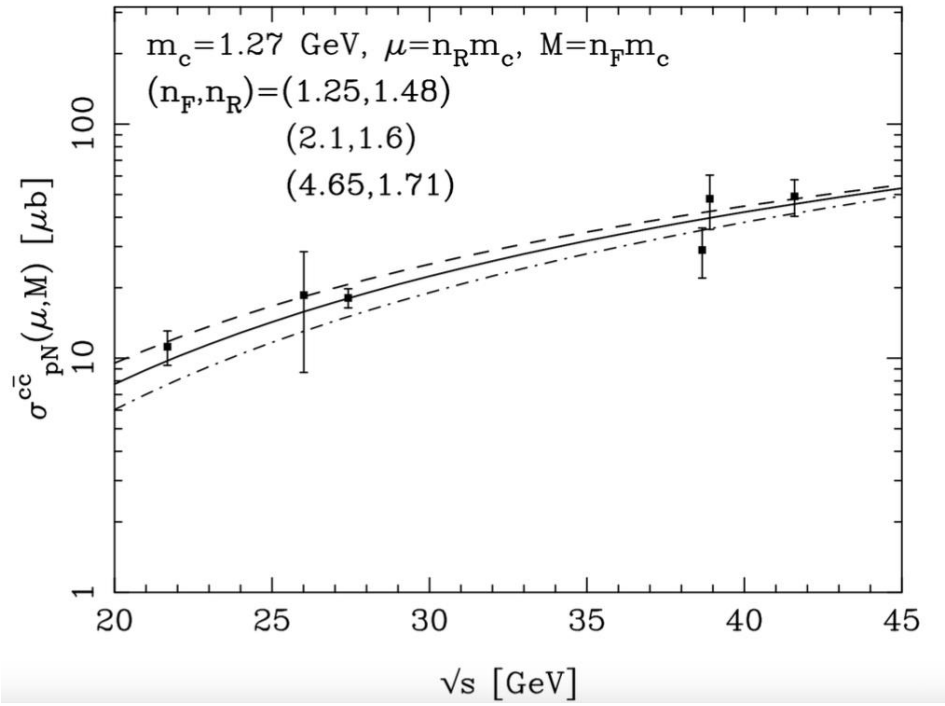
Giovanni De Lellis

The motivation is to reduce the uncertainty on the flux of particles originated from charmed hadrons: HNL and tau neutrinos, a significant fraction of the high energy (electron and muon) neutrinos in general

Charm production vs energy



NA27 with 400 GeV protons



Cacciari, Greco, Nason JHEP 9805 (1998) 007
Cacciari, Frixione, Nason JHEP 0103 (2001) 006

arXiv: 1504.04855 SHiP Physics Proposal

EUR ESEARCH

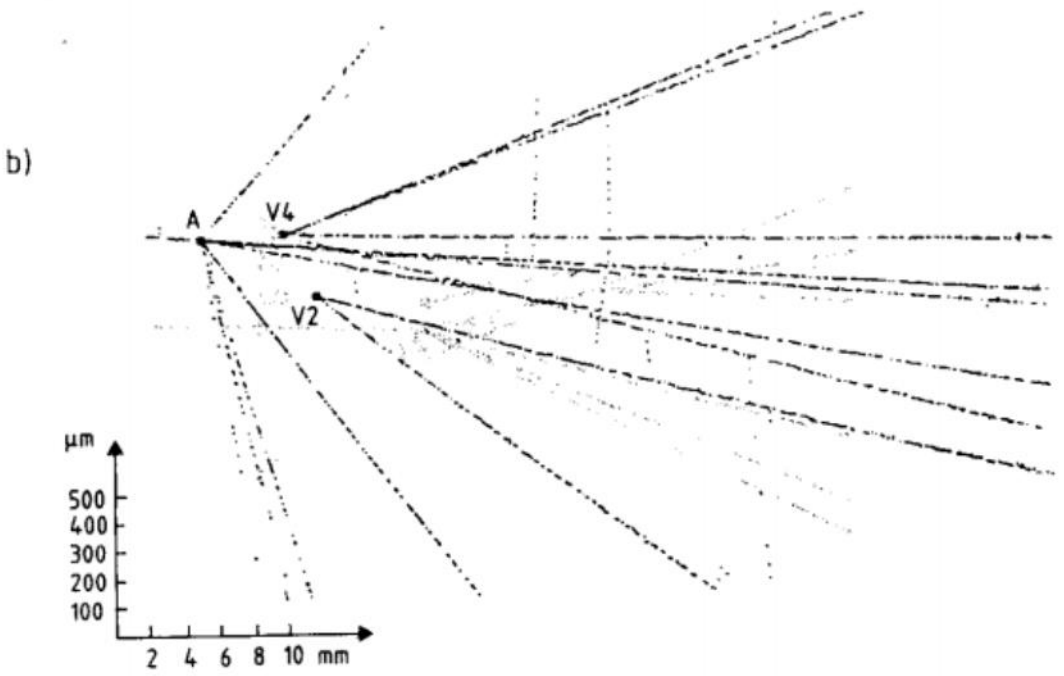
CERN/SPSC/79-101
SPSC/P 129/S
October 2, 1979

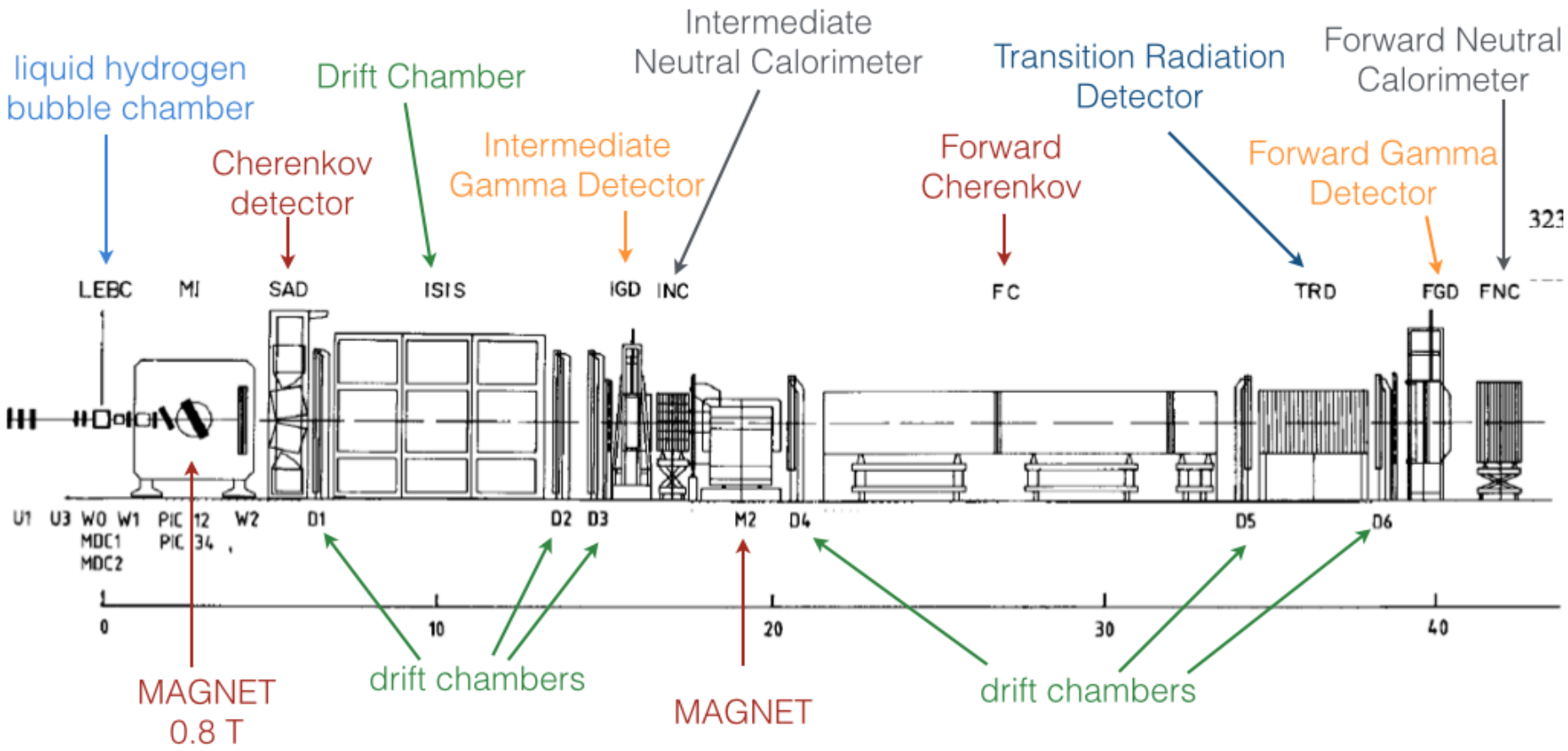
SUMMARY OF

PROPOSAL TO STUDY THE HADRONIC PRODUCTION AND THE PROPERTIES OF NEW PARTICLES WITH A LIFE-TIME 10^{-13} s < τ < 10^{-10} s USING LEBC-EHS

NA27 experiment

Amsterdam[1]-Brussels[2]-CERN[3]-Madrid[4]-Mons[5]-Nijmegen[6]-Oxford[7]-Padova[8]-Paris[9]-Rome[10]-Rutherford[11]-Serpukhov[12]-Stockholm[13]-Trieste[14]-Vienna[15] Collaboration




liquid hydrogen bubble chamber
Cherenkov detector
Drift Chamber
Intermediate Gamma Detector
Intermediate Neutral Calorimeter
Forward Cherenkov
Transition Radiation Detector
Forward Gamma Detector
Forward Neutral Calorimeter
LEBC
MI
SAD
ISIS
IGD
INC
FC
TRD
FGD
FNC
U1 U3 W0 W1 PIC 12 W2
MDC1
MDC2
PIC 34
D1
D2 D3
M2
D4
D5
D6
0
10
20
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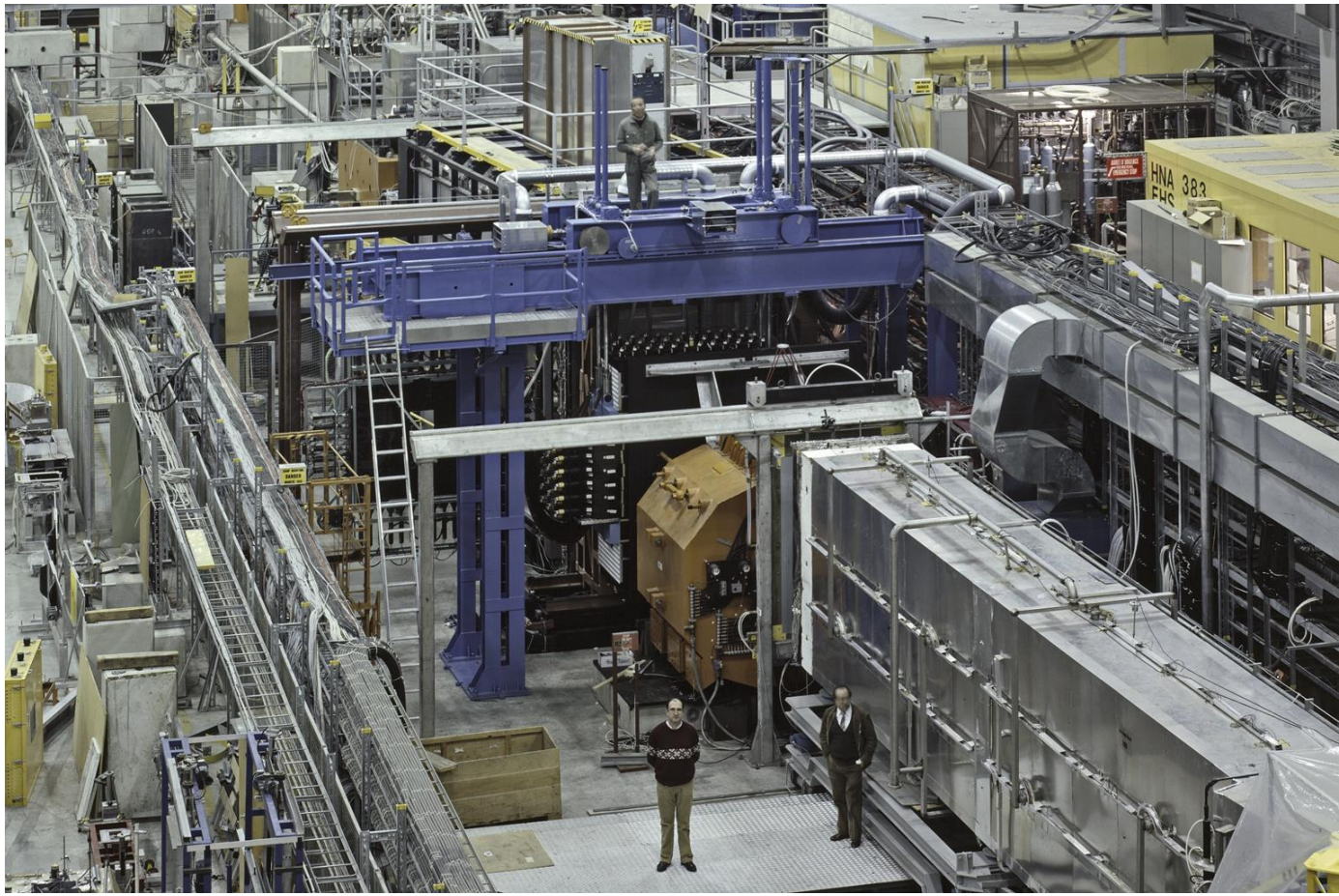
40
MAGNET 0.8 T
drift chambers
MAGNET
drift chambers



- 400 GeV run by NA27, M. Aguilar-Benitez, et al., Z. Phys. C 40 (1988) 321.
- A total of 98 neutral D0 and 119 charged hadrons (including Λ_c) were found

Impact on ν_τ YIELD

$$N_{\nu_\tau+\bar{\nu}_\tau} = 4N_p \frac{\sigma_{c\bar{c}}}{\sigma_{pN}} f_{D_s} Br(D_s \to \tau) = 2.85 \times 10^{-5} N_p = 5.7 \times 10^{15}$$

$\sigma_{c\bar{c}} = 18.1 \pm 1.7$ μbarn

Physics Reports 433 (2006) 127

$\sigma_{c\bar{c}} \propto A$

$\sigma_{pN} \propto A^{0.71}$

$Br(D_s \to \tau) = (5.54 \pm 0.24)\%$ *PDG 2014*

$f_{D_s} = (7.7 \pm 0.6^{+0.5}_{-0.4})\%$ *JHEP 1309 (2013) 058*

Branching ratio Ds → tau

$\Gamma(\tau^+\nu_\tau)/\Gamma_{\text{total}}$ Γ_{21}/Γ

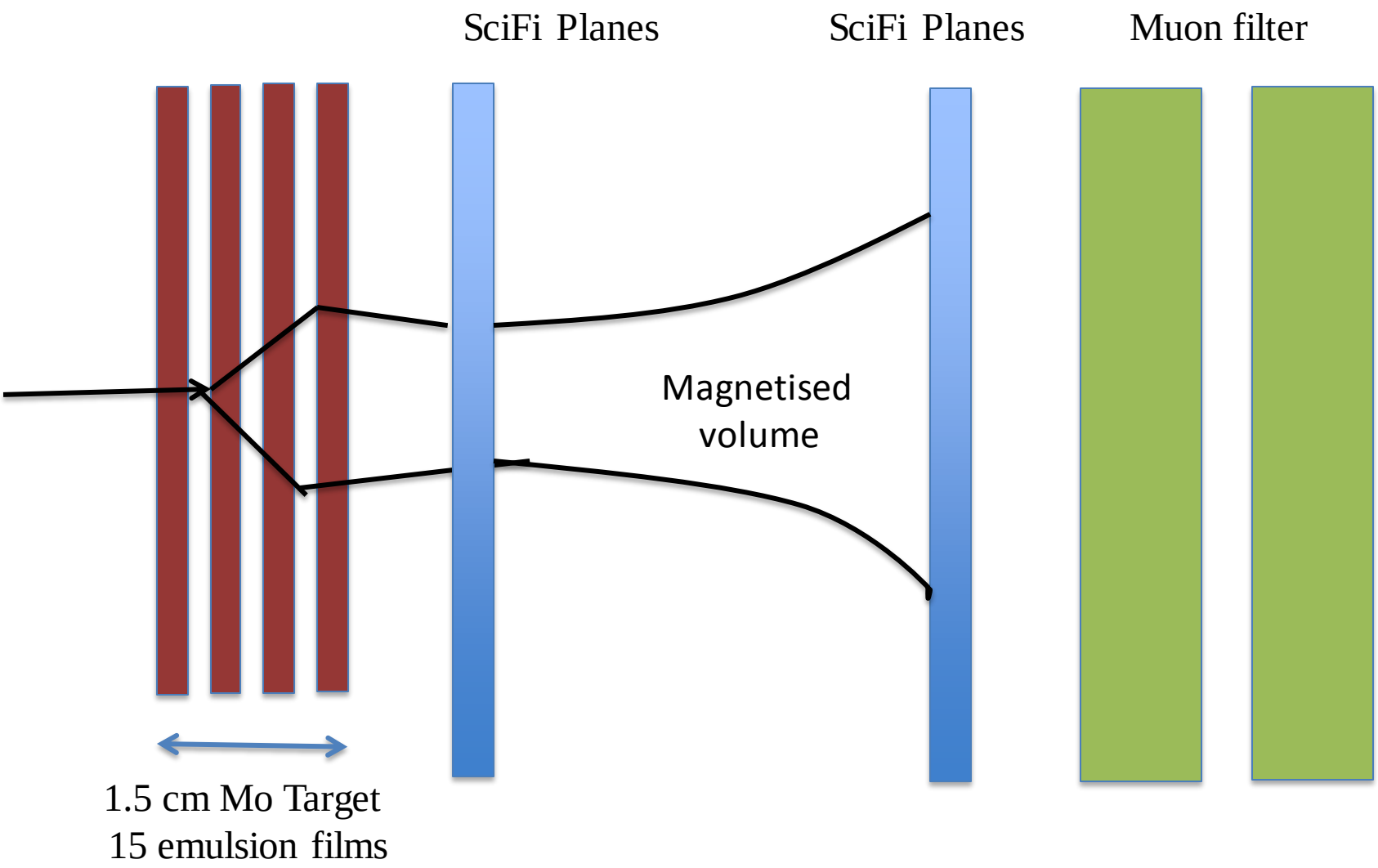
See the note on "Decay Constants of Charged Pseudoscalar Mesons" above.

VALUE (units 10^{-2})	EVTS	DOCUMENT ID		TECN	COMMENT
5.55±0.24 OUR AVERAGE					
$5.70\pm0.21^{+0.31}_{-0.30}$	2.2k	[1] ZUPANC	13	BELL	e^+e^- at $\Upsilon(4S)$, $\Upsilon(5S)$
$4.96\pm0.37\pm0.57$	748 ± 53	[2] DEL-AMO-SA..	10J	BABR	$e^-\bar{\nu}_e\nu_\tau$, $\mu^-\bar{\nu}_\mu\nu_\tau$
$6.42\pm0.81\pm0.18$	126 ± 16	[3] ALEXANDER	09	CLEO	$\tau^+\to\pi^+\bar{\nu}_\tau$
$5.52\pm0.57\pm0.21$	155 ± 17	[3] NAIK	09A	CLEO	$\tau^+\to\rho^+\bar{\nu}_\tau$
$5.30\pm0.47\pm0.22$	181 ± 16	[3] ONYISI	09	CLEO	$\tau^+\to e^+\nu_e\bar{\nu}_\tau$

- BES III measurement planned during the coming winter, a dedicated run at the Ds+ Ds- mass
- Compared to CLEO, gather ~5 times larger statistics → reduce the statistical uncertainty by a factor of 2. First results available by the end of 2016
- Hard to improve (BELL2?)

- Proton target
  - 10% p interactions → $\exp(-x/\lambda) = 0.9$ → $x/\lambda = -\ln(0.9) \sim 0.1$ → $x = 0.1\ \lambda = 1.5$ cm Mo target interleaved with nuclear emulsions
- Charm yield ~ 1.7×10^{-3}
- Fraction of charmed hadrons decaying inside the target, $\langle E_{Ds} \rangle = 45$ GeV → Fl = 3.3 mm, assume 7.5 mm on average in the target → ~exp(-2.3) ~0.10 → ~ 90% decay inside
- Charm tagging in the emulsion (topological, secondary vertex detected within the expected flight length) ~ 50%
- Charm momentum measurement by a spectrometer, followed by a muon filter
- Overall factor ~ 7.7×10^{-5}
- 10^9 protons → 77000 detected charm pairs

Schematics of the detector



Protons and (emulsion) analysis time

- 10^9 protons from SPS
- Assume $10^4/cm^2$ in emulsions → 10^5 cm^2 x 15 films = 1.5 x 10^6 cm^2
- Current speed per system ~ 100 cm^2/h → 1.5 x 10^4 hours → analysis time ~ 2 months for 10 systems