High Luminosity J/ψ Physics

Tau-Charm workshop

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- glueballs theory predictions (since 1994)
  - A COMPELLING REASON TO DO TCF
    - New York Times article (Alan Weinstein’s requirement)
  - hybrid predictions

- glueball candidates (since 1994)

- Next BES run

- TCF potential

- summary

Glueball theory predictions

GLUEBALLS and SUPERGRAVITY connection

• Juan Maldacena conjectured duality between superstring and supersymmetric theories. Witten proposed to extend this to pure QCD

• In superstring theory, the calculation of glueball masses are possible
  •THIS IS THE ONLY STRING THEORY calculation???!!!!!
  • THIS tests the duality and the calculation

• Supergravity wave eqns. can predict relative glueball masses

• => search for two glueball and excited glueball states
  • if first state found, then excited states could be FIRST tests of SUPERGRAVITY (Csaki et al. model)
  • 0^{++} Glueball Masses = 1.61, 2.38, 3.11, 3.82, 4.52, 5.21 GeV
  • 0^{-+} Glueball Masses = 1.83, 2.67, 3.42, 4.14, 4.85, 5.55 GeV

Glueball Theory from Lattice Gauge Theory

- Lattice Gauge Theories Improving Calculations
  - complete spectra for PC=++,-+,+-,--
  - recent state of the art from Morningstar & Peardon
- Scalar Glueball
  - IBM calculation, mass = 1.75±.07 GeV
  - UKQCD calculation, mass = 1.55 ±.05 GeV
  - Γ mass width estimate, ~100 MeV (Sexton)
- Tensor Glueball
  - mass ratio prediction more precise
  - $M(2^{++})/M(0^{++}) = 1.39$
  - masses in 2.2-2.4 GeV
- IBM & UKQCD actually agree, Teper (Jerusalem talk)
  - mass extrapolations were different
  - $M(0^{++})$ =1.61±.07 ±.13 GeV
  - $M(2^{++})$ =2.26±.12 ±.18 GeV
  - $M(0^{-+})$ =2.19±.26 ±.18 GeV

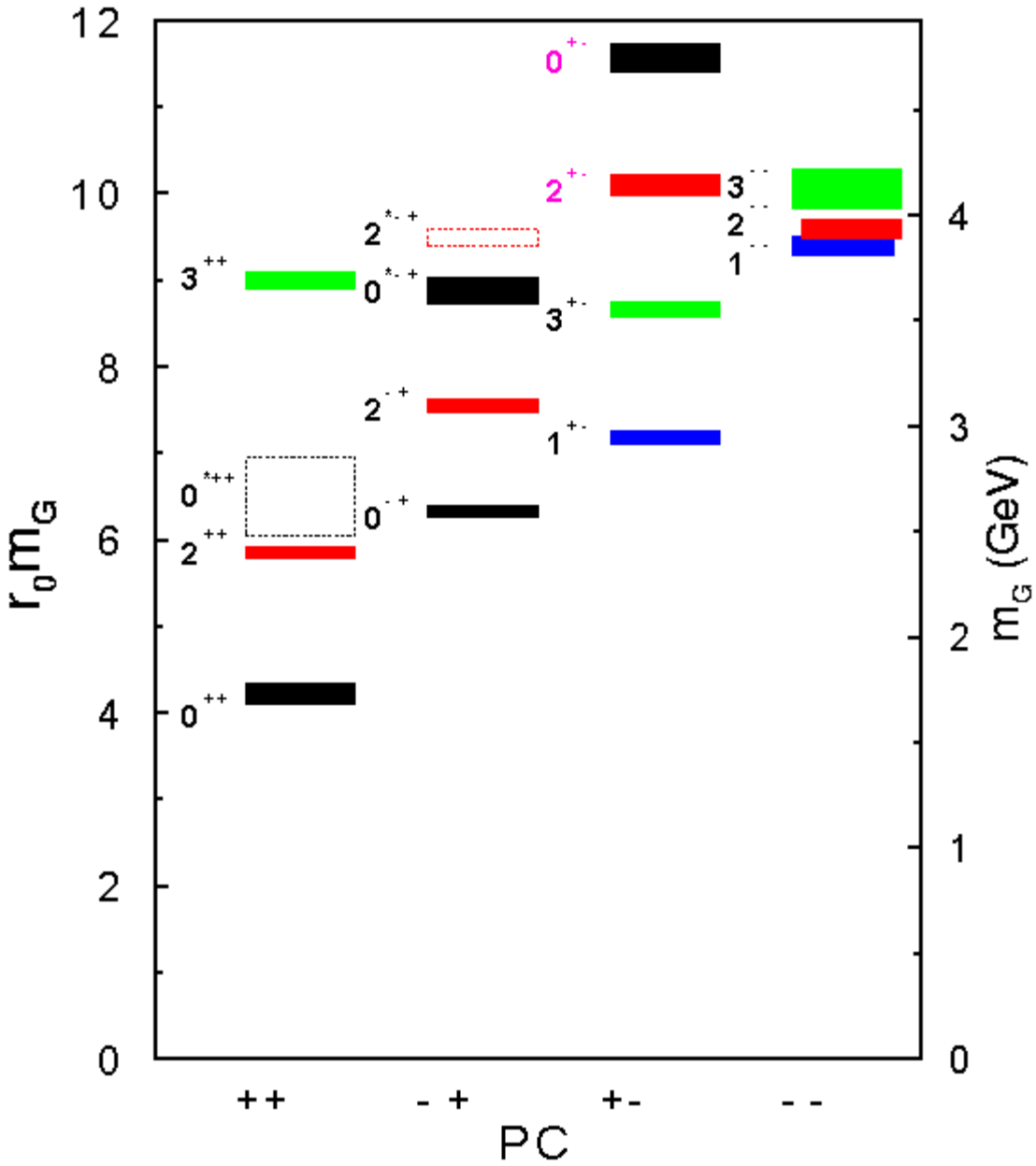
IBM Glueball Prediction

(Sexton, Vaccarino, Weingarten, PRL, 4563,25 (95))

- mass 1740 (71) MeV
- width 108 (29) MeV into two pseudoscalars
- 2 year calculation on 6-7 Gflop GF11 IBM Parallel computer
- Featured in New York Times article

Recent LATTICE QCD CALCULATIONS
(Morningstar & Peardon)

- Spatially coarse, temporally fine lattices improve efficiency
- SU(3) glueball spectrum
- single and double glueballs observed
- 13 glueballs below 4 GeV obtained
- scalar, m=1730 (50) (80)
- tensor, m = 2400 (25) (120)
- pseudoscalar, m= 2590 (40) (130)
- ratio, tensor/scalar mass = 1.39(4)



J^{PC}	Mass
0^{++}	1730±50±80
2^{++}	2400±25±120
0^{-+}	1730±50±80

Recent Glueball Mass spectrum

Morningstar & Peardon, HEP-LAT/9901004, Jan 7, 1999

Gluonic Content of Isoscalar Mesons
(by Close, Farrar & Li, Phys.Rev.D55:5749-5766,1997)

• Using pQCD and Radiative J/ψ decay rates, a form factor, ⟨gg|R⟩, of gluonic coupling to resonance R is calculated.

$$A(J/y \rightarrow g\ R) = \frac{1}{2}\sum \frac{d^4k}{(2p)^4}\frac{1}{k_1^2}\frac{1}{k_2^2}\left\langle \left(c\bar{c}\right)_V | g\ g^a g^b \right\rangle \left\langle g^a g^b | R \right\rangle$$

Prediction relates radiative BR, glueball mass and gluonic width:

10^3 br(J/ψ → γ 0^{++}) ≅ (M/1.5GeV) ($\Gamma_{R\rightarrow gg}$/96MeV)
10^3 br(J/ψ → γ 2^{++}) ≅ (M/1.5GeV) ($\Gamma_{R\rightarrow gg}$/26MeV)
10^3 br(J/ψ → γ 0^{-+}) ≅ (M/1.5GeV) ($\Gamma_{R\rightarrow gg}$/50MeV)

• Qualitative Picture fits for 100 MeV wide scalar at 1700 and a narrow tensor at 2300

• Relative rates of 0++ and 2++ for qq resonances seen in Radiative J/ψ decays are explained. Br(R→gg) ≈ .1-.2

• Predictions:
  - $\Gamma(G_{2++}) = (4/15)\,\Gamma(R_{0++})$
  - br($f_J(1710) \rightarrow gg$) > 50% if spin 0
  - br($\xi(2.2) \rightarrow gg$) > 40% if spin 2
  - br($f_2(1270) \rightarrow gg$) ≈ 22%
  - br($f_2(1520) \rightarrow gg$) ≈ 22%
  - qq scalar $^3P_0$ is width > 500 MeV, too wide to be seen
  - various radiative Ψ rates predicted

Heavy Hybrid States ccg and bbg

- gluon plus qq state (original idea from Close, Chanowitz, Sharpe proposed in 1983)

- States $J^{PC}=1^{--},0^{-+},1^{-+},2^{-+}$

- Born-Oppenheimer Approximation for heavy quarks
  - heavy quarks form nuclei and fast gluon is electron

- NRQCD (CP-PACS collaboration, T. Manke etal.)
  - lightest ccg state is 1.323 above ground state => 4.42 GeV

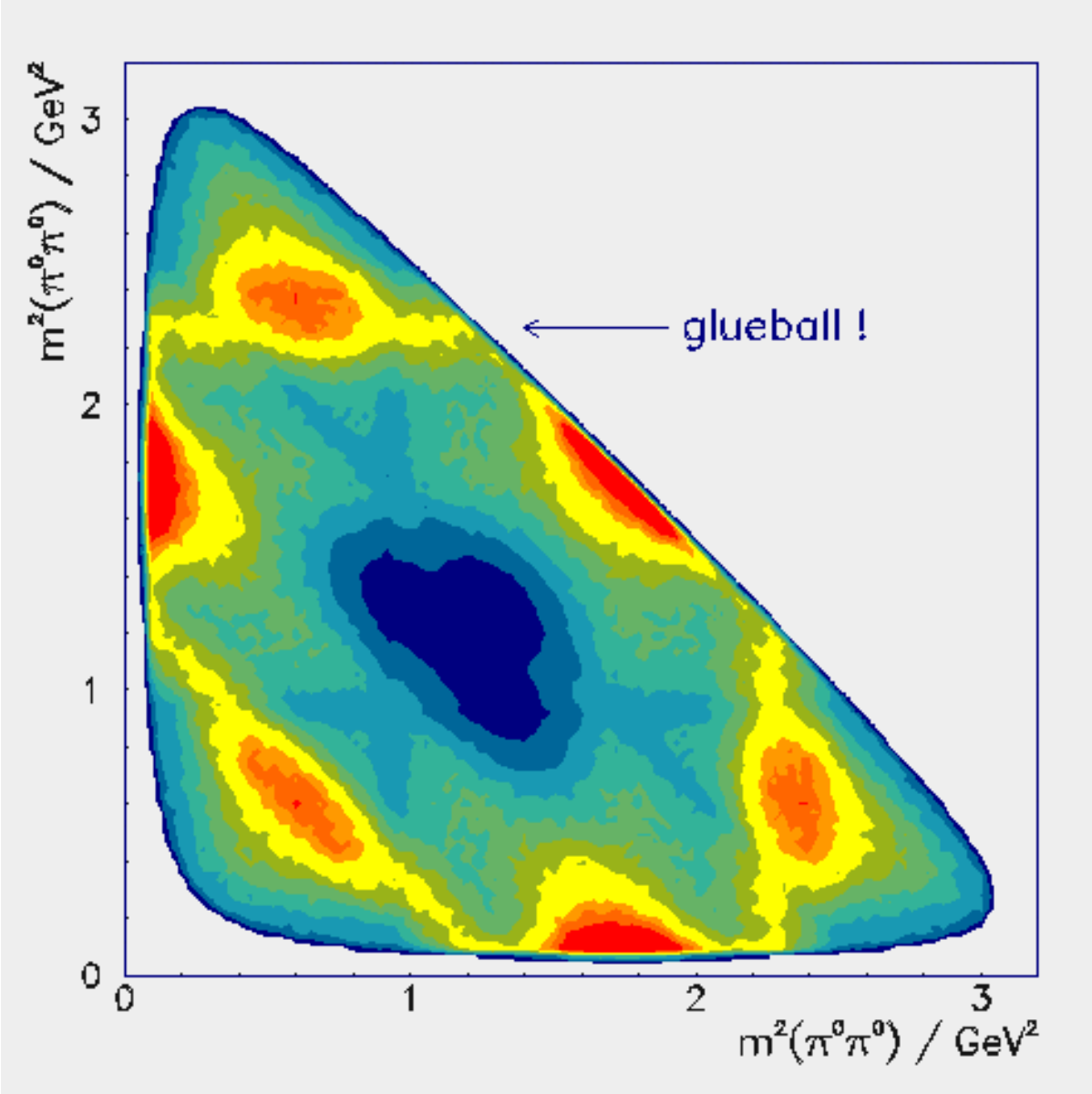
- MILC collaboration
  - obtain similar results

- ccg hybrid states expected in 4-4.4 GeV mass region.

Recent Experimental Results on Glueball Candidates

Experimental Results (since last tcf workshop)

- Crystal Barrel: in ppbar collisions
  - clear evidence for a 0^{++} $\pi\pi/\eta\eta/\eta'\eta/KK$ resonance at 1.5 GeV
  - NO convincing evidence in radiative J/ψ
- E852 (BNL) in pp collisions
  - 1^{-+} Exotic $\eta\pi$ resonance at 1.37 GeV
  - 1^{-+} Exotic $\rho\pi$ resonance at 1.59 GeV
- $\xi(2.2)$
  - BES evidence for $\xi(2.2)$
    - KK,KsKs,$\pi\pi$,pp
  - L3 sees KsKs in gluonic jets
  - CLEO & L3 does not see in 2 photon production
  - No ppbar production in KK,KsKs,$\eta\eta$,$\pi\pi$,$\phi\phi$
- scalar signal in $f_J(1700)$ region
  - BES spin parity results
  - Mk3 spin party results (see Dunwoodie talk)



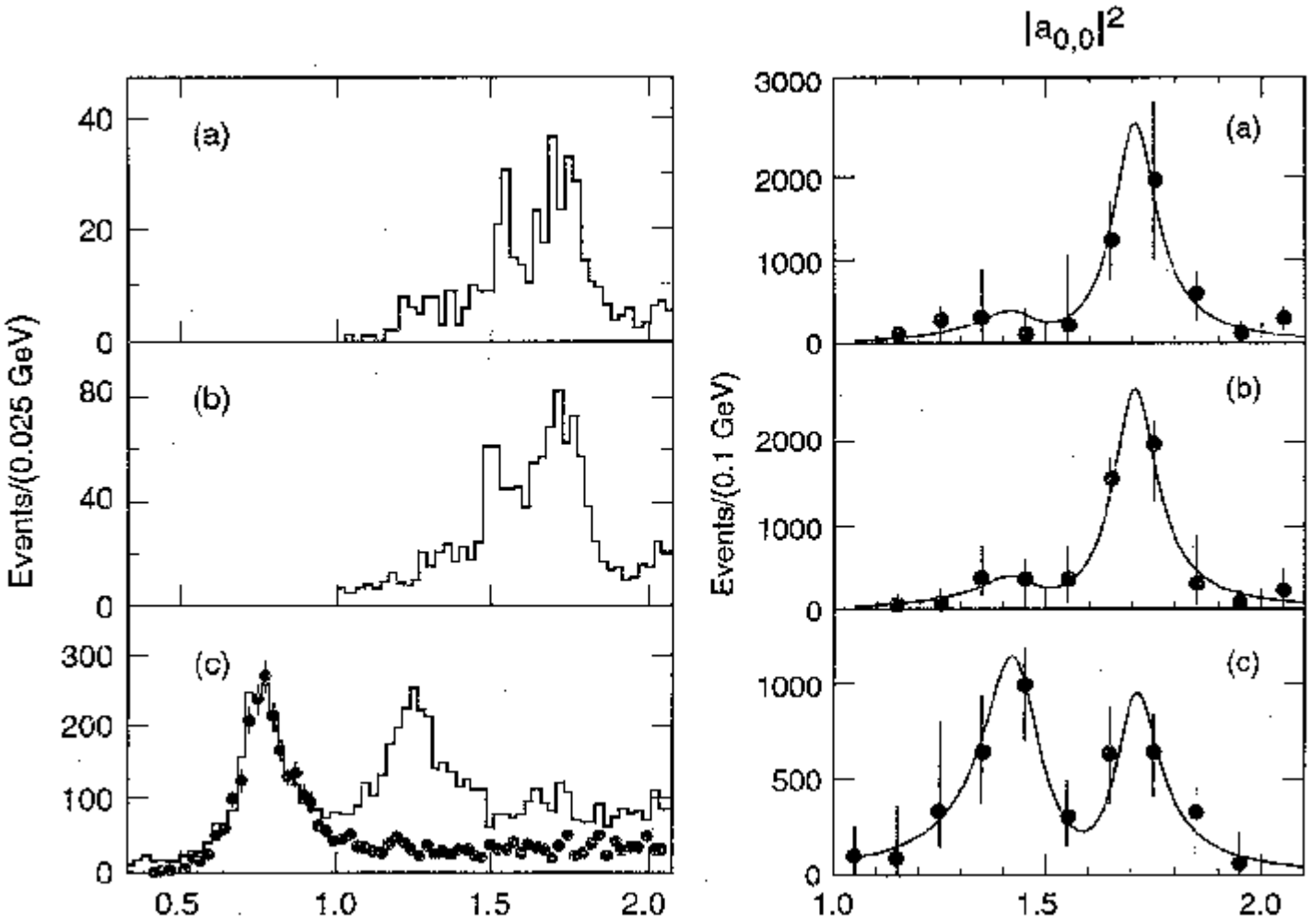
Crystal Barrel
$pp \rightarrow 3\pi^0$, 712K events

scalar resonance

M=1490 ±13 MeV
G=120 ±15 MeV

observed in $\pi\pi$,$\eta\eta$,$\eta'\eta$,
4π, some KK?

Unpublished Mark III RESULTS on $f_J(1710)$



Scalar Signal at 1700 MeV, width ~100 MeV

$f_J(1710)$ Results

Mark III (unpublished):

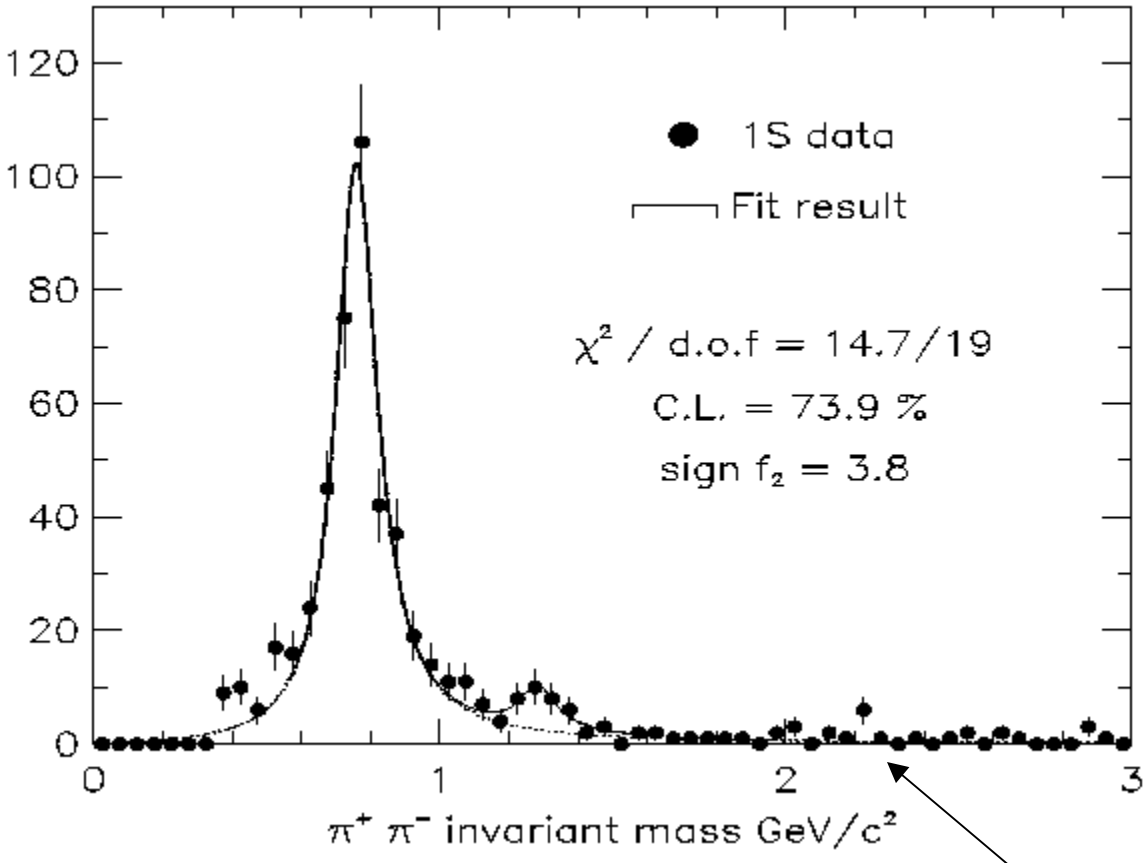
Mass	1704+16-23 MeV
Width	124+52-44 MeV
BR($\rightarrow$KK)	9.5+2.5-2.0 (10^{-4})

BES:

Mass	1781+-8+1--31 MeV
Width	85+-25+22-19 MeV
BR ($\rightarrow$KK)	.8+-.1 (10^{-4})

If Mark III results used and most of BR is into KK, then agreement with CFL formula, 10^3 br($J/\psi \rightarrow \gamma\, 0^{++}$) $\cong$ (M/1.5GeV) ($\Gamma_{R\rightarrow gg}$/96MeV) for 100% gluonic BR

CLEO Results on $\Psi(1s) \rightarrow \gamma\,\pi\pi$



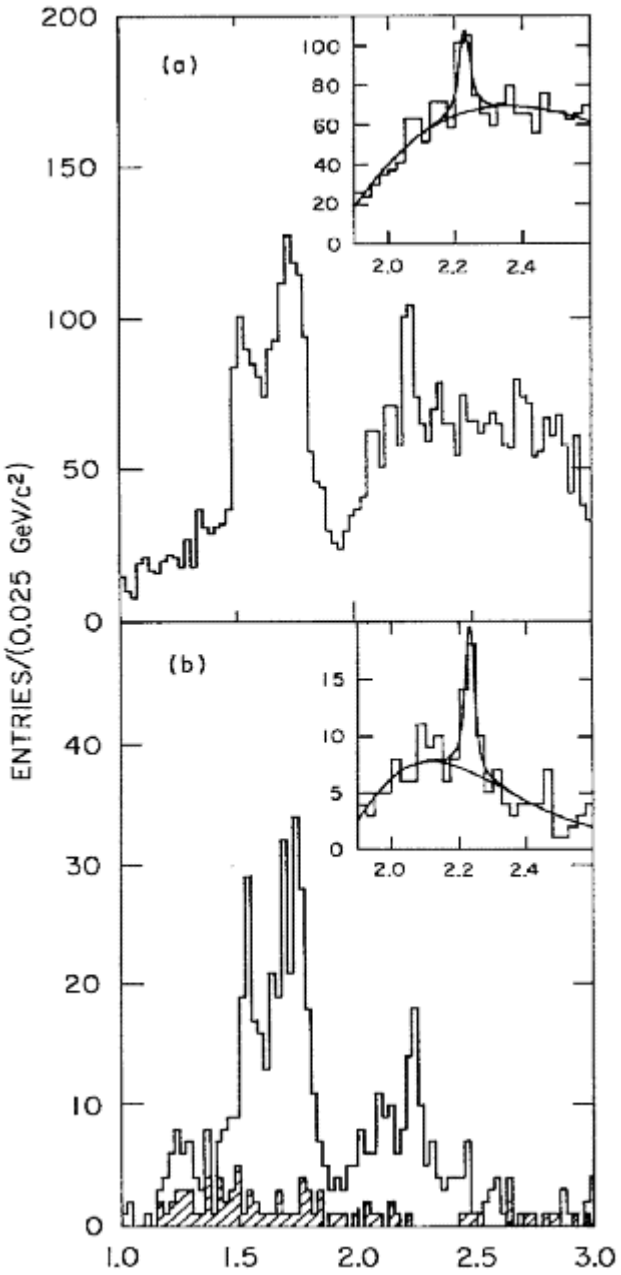
2.2 GeV

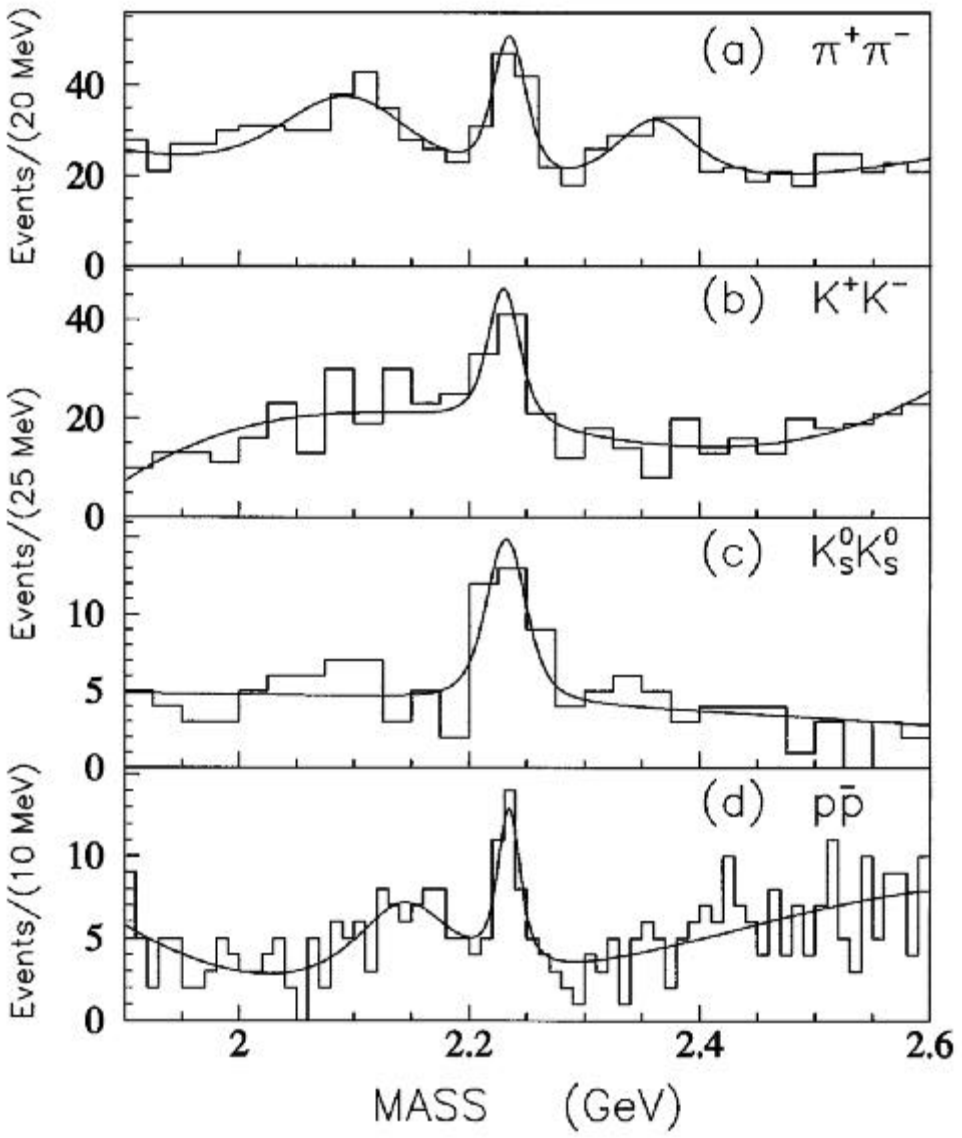
B factories are NOT the place to do glueball search.

Mark III

$\xi(2.2)$

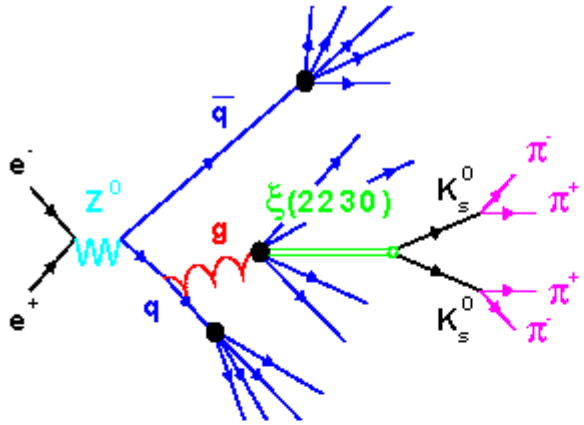
BES





10^3 br($J/\psi \to \gamma\, 2^{++}$) $\cong$ (M/1.5GeV) ($\Gamma_{R\to gg}$/26MeV)

Evidence for ξ(2.2) in L3 at LEP



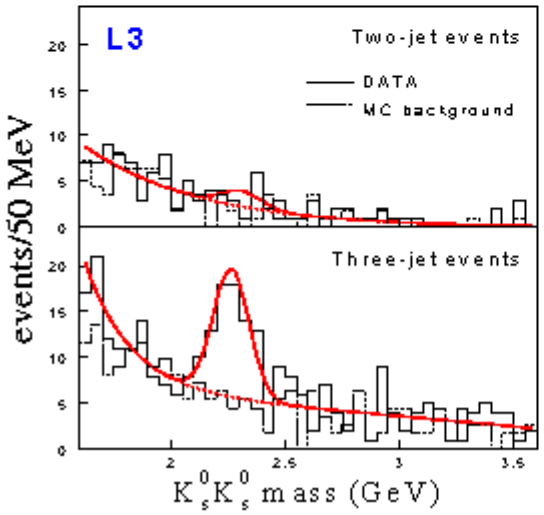
130 pb^{-1} LEP1 data

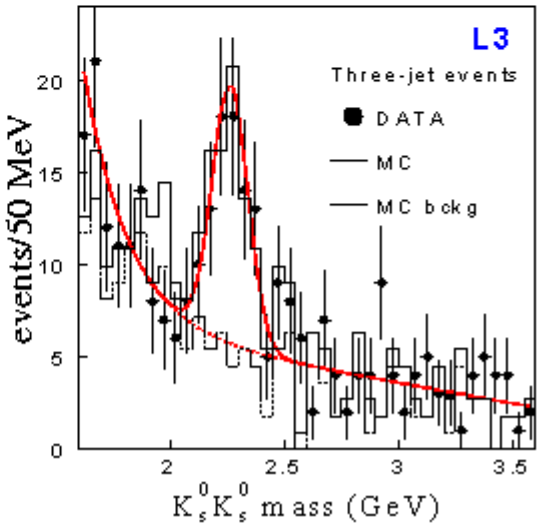
3.6M hadronic Z^0's

45% are 3-jet events

$m_{\pi^+\pi^-} = m_{K^0_s} \pm 50$MeV

combine $K^0_s K^0_s$ in jet





EMERGING PICTURE:

$f_J(1710)$ is the SCALAR GLUEBALL

$\xi(2.2)$ is the TENSOR GLUEBALL

Caveats:
what is Crystal Barrel 1500 scalar??
Is the pseudoscalar candidate the iota at 1.45 GeV??

Remarks:

- seen mainly radiative J/ψ
  - maybe in central production & gluonic jets?
- dominant decay is only KK?
- NOT seen in $\gamma\gamma$ or pp(LEAR) or ss(LASS) production
- masses agree with Lattice QCD predictions

BES Physics

BES Running

- current running on R scan

- Next running: concensus for J/ψ Physics
  - trigger rate 6 hertz
  - assume 50% running efficiency
  - => 200K events per day
  - => 200 days 40M J/ψ events (factor 6 over Mark3)

- ξ(2.2)
  - ~600 events in K+K-
  - ~120 events in KsKs
- $f_J(1710)$
  - 20-25% Scalar Signal error reduced by sqrt(6), 8-10% error

BES GOALS in next J/ψ run:

- spin-parity test of $f_J(1710)$
  - determine scalar content
  - find more decay modes, pp,ππ,ηη

- confirm ξ(2.2)
  - determine width, how narrow is it?
  - spin-parity test
  - find more decay modes pp,ππ,ηη,φφ,ωφ,ωω

- search for pseudoscalar candidates
  - ηππ, KKπ modes
  - in MarkIII there was something in >2 GeV region

Beijing Tau-Charm Factory

Charmonium Rates for a Beijing Tau-Charm Factory

Signal	Peak cross section	Instant. Rate for 10^{33}	#/day 50% eff.
J/ψ	~2600nb	2.6KHz	112M
ψ′	~800 nb	0.8KHz	34M
J/ψ monochr.	~16000 nb	16 KHz	688M
ψ′ monochr	~5000 nb	5 KHz	215M

This assumes ~1 MeV or 0.14 MeV for monochrometer.
See P. Yennie, Phys. Rev.Lett.,34, 239 (1975)

Existing J/ψ and Charmonium Data Sets

Collab	J/ψ	ψ′
BES	9M	3.5M
MkIII	6M	.3M
DM2	8M	-

In 30 days, projecting, produced,

$(3.4\text{-}21) \times 10^9$ J/ψ events

$(1\text{-}6.5) \times 10^9$ ψ′ events

Factor ×1000 increase

Tcf Detector Improvements over BES

- better neutral resolution, crystal calorimeter
  - improve radiative decays
  - 25%/sqrt(E) vs 1%/sqrt(E)+2%
  - total rate measurement

- better for forward acceptance
  - improve spin-parity tests
  - 70% vs 95% of 4π

- more computing power will improve spin-parity analysis

Off-line Data Handling for a billion events is manageable

- 10^9 events
  - assume 500 32 bit words/event or 2Kbytes/event=> 2 terrabytes

- ULTRA2 SCSI Disk access is 80 MB/s (ULTRA160 is 160MB/s)
  - => 7 hours to serially read disk files of 2 terrabytes
  - maximum SCSI disk size is ~50Gb (~$2.9K)

- Quantum DTL7000 tape drive
  - 10 MB/sec transfer, compressed, 70GB
  - => 56 hours to serially read 29 tapes for 2 terrabytes
  - tape drive unit cost ~$5K

- Data Storage and Management is a complex problem
  - BaBar, CDF, LHC will solve this problem

On-line Data Handling: daunting?

- 1-20 Khz DATA rate

- assume 1000 32 bit words or 4Kbytes x 20 KHz => 80 Mb/s
  - ULTRA2 SCSI Disk is 80 MB/s => 47GB/10mins
  - DTL7000; 70Gb/tape at 10MB/s => FOUR tape drives/hour
    - $35-80 per tape at buycomp.com

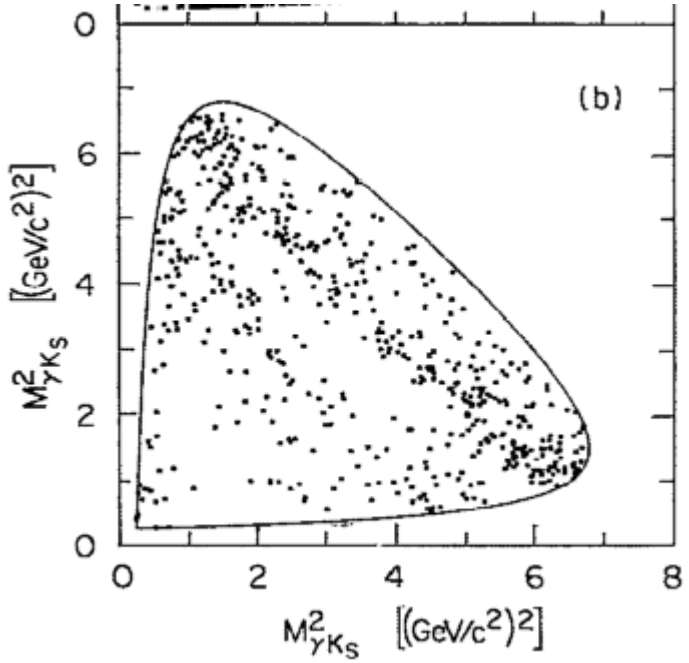
- 20 years ago, filling 1600BPI, 20MB IBM tapes, are comparable.

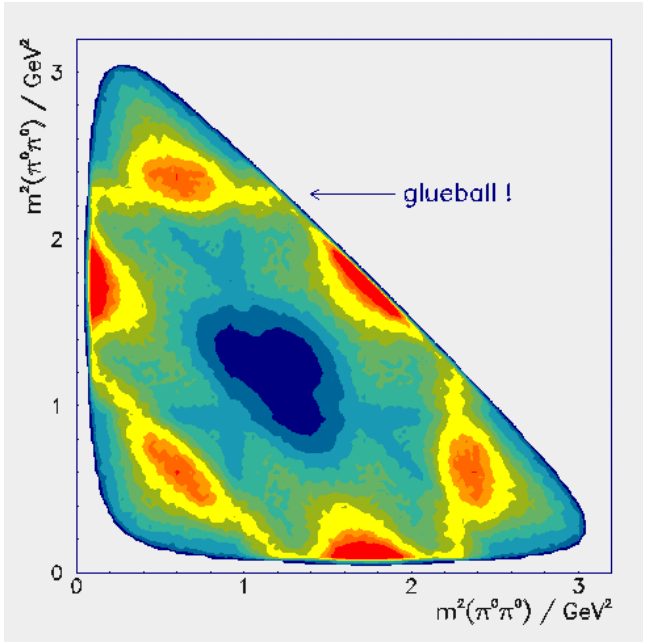
Offline Computing: challenging?

- assume reconstruction 10 sec/event on Intel/LINUX
- 10^9 events => 115 days to process on 1000 PC's
- 1000 PC's costs $1-2M

High Statistics, High Statistics, High Statistics

BES needs sufficient data such that 2-dimensional plots are NOT individual dots but COLOR LEGO as the CRYSTAL BARREL





High Statistics, High Statistics, High Statistics

Need high statistics to perform Crystal Barrel quality analysis.

Glueball Physics in TCF Program:

- $f_J(1700)$: tests for scalar glueball?
  - needs High Statistics
  - determine mass and width and partial waves
  - decay modes (KK,$\pi\pi$,$\eta\eta$)

- $\xi(2.2)$: tests for tensor glueball?
  - needs High Statistics
  - determine mass, spin and width (maybe narrow)
  - decay modes (KK,$\pi\pi$,$\eta\eta$,pp), maybe unusual decays $\phi\phi$,$\omega\omega$,$\phi\omega$

- Next search for "Balmer" series of Glueballs*
  - find pseudoscalar
  - find excited glueball states
  - test supergravity predictions

*quote from Helmut Koch

Glueball Politique & Self Criticism

glueball searches have been around for 20 years, so what??

- problems with old measurements
  - poor statistics
  - spin-parity problems and mistakes, lack of confirmation
  - lack of SU(3) singlet symmetry in candidates (mixing?)

- What is the smoking gun test??
  - Charmonium was conclusive due to a set of radiative transitions
  - $\Rightarrow$ need to find pattern of glueball decays
- Why has'nt Crystal Barrel received more acclaim?
  - Single piece of unsolved puzzle

- Social circumstances
  - glueball physics closer to nuclear physics community?
  - Lattice Gauge Theorists NOT well connected to experiments
  - experimentalists do not understand QCD (or string!) theorists

SUMMARY

- Next BES run
  - spin/parity, mass, width, new decay modes of $\xi(2.2)$ and $f_J(1710)$
  - search for pseudoscalar state near 2 GeV

- TCF
  - very high statistics in 1 month of running
  - search for pattern of glueball decays
  - Major opportunity to test Lattice QCD & String Theory Duality