Proposta di esperimento
CSNV INFN

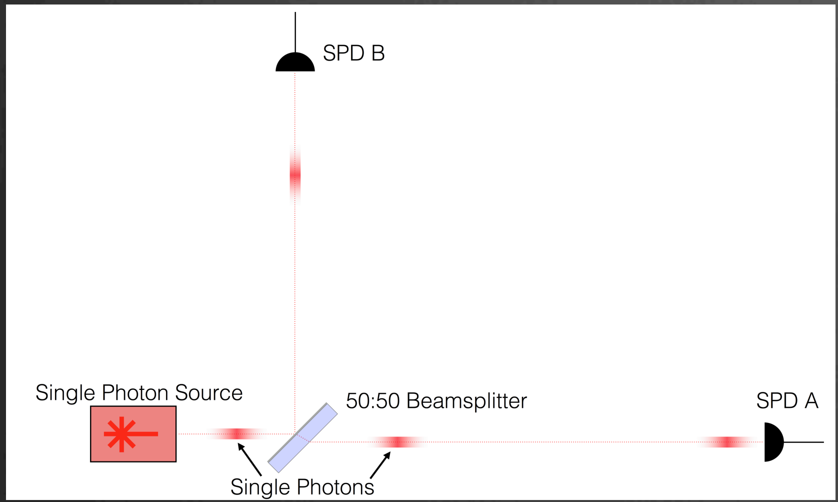
COLLAPSE

O. Nicrosini, CdS 13 luglio 2015

Partecipanti

Name	%	Position	Responsibility
Bajoni Daniele	100	Assoc. Prof., University of Pavia	Local Coordinator
Galli Matteo	100	Assoc. Prof., University of Pavia	Participant
Nicrosini Oreste	50	Dir. Research, INFN	National Coordinator
Pirzio Federico	50	Assist. Prof., University of Pavia	Participant
Reali Giancarlo	100	Full Prof., University of Pavia (retired)	Participant
Rimini Alberto		Prof. Emeritus, University of Pavia	Participant
Simbula Angelica	100	PhD student, University of Pavia	Participant
Total FTE	5,00		

Schema concettuale



No impulsi laser, necessario regime di fotone singolo (LIDAR)

$|\Psi> = 1/\sqrt{2}\,(|\gamma(A)> + |\gamma(B)>)\,|D_A(0)>\,|D_B(0)> \rightarrow$

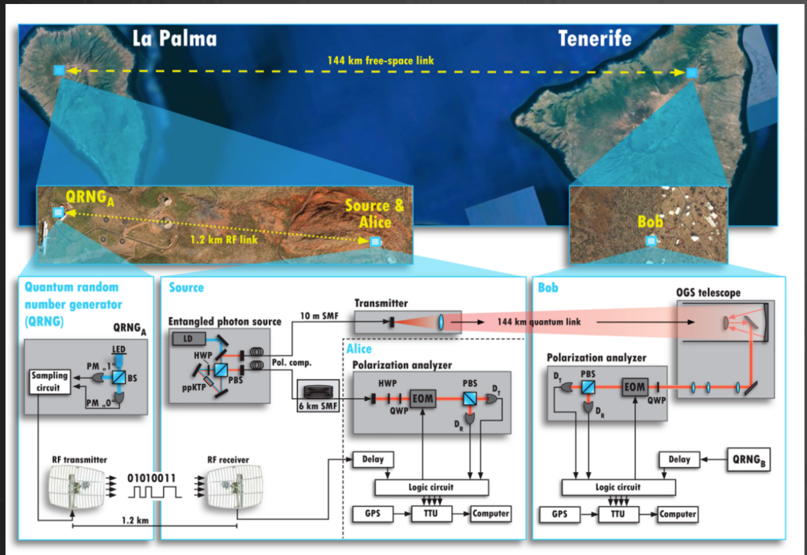
$|D_A(+)>\,|D_B(0)>$, p=1/2

$|D_A(0)>\,|D_B(+)>$, p=1/2

Postulato di riduzione: “immediatamente” dopo il completamento della misurazione lo stato del sistema è uno dei termini della sovrapposizione.

La presente proposta riguarda un esperimento in grado di stabilire se il collasso della funzione d’onda di singola particella richieda un tempo finito, in particolare quando la funzione d’onda sia costituita di parti distanti.

Stato dell'arte



Correlazioni EPRB (*spooky action at a distance…*) e violazione della disuguaglianza di Bell (CHSH) ben esplorate;

Anche su distanze geografiche:
T. Scheidl *et al.*,
"Violation of local realism with freedom of choice",
Proc. Natl. Acad. Scie. U.S.A.,
107:19708-19713, 2010.

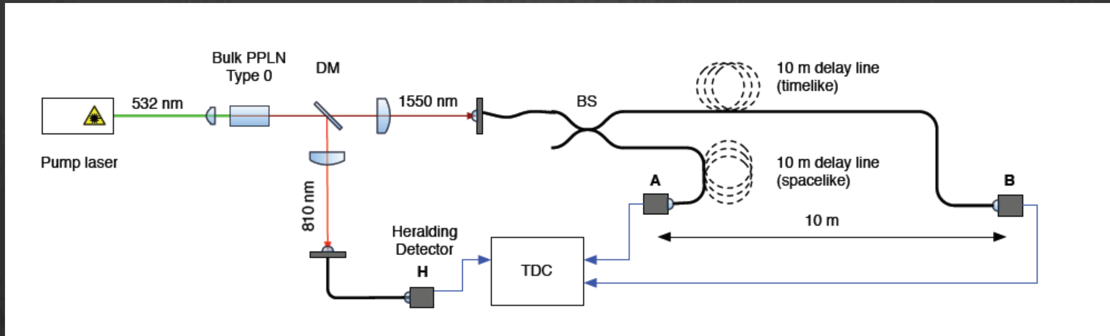
Juan Yin *et al.*,
"Lower bound on the speed of nonlocal correlations without locality and measurements choice loopholes",
Physical Review Letters ,110:260407, Jun 2013.

$V_{SA}/c \geq 1.37 \times 10^4$

Stato dell'arte (ii)

Ma…

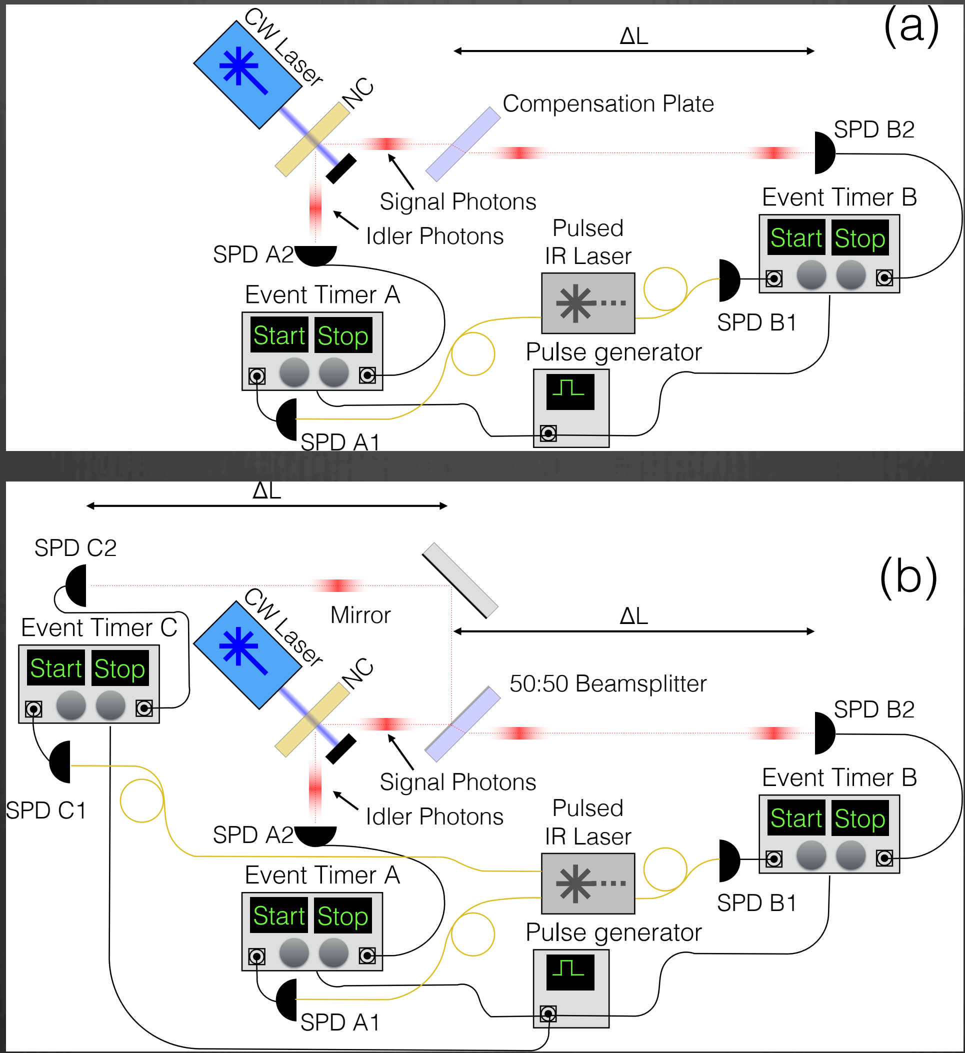
- "collasso" di funzione d'onda di particella singola sorprendentemente meno studiato;
- A. Einsten, Conferenza Solvay del 1927: particella che, dopo diffrazione da fenditura, incide su array di rivelatori può eccitarne solo uno alla volta (conservazione dell'energia) anche nel caso in cui eventi di rivelazione sono separati space-like (!)
- → *antibunching*
- il fotone deve "materializzarsi" a un detector o all'altro



T. Guerreiro, B. Sanguinetti, H. Zbinden, N. Gisin and A. Suarez,
"*Single-photon space-like antibunching*",
Physics Letters A, 376:2174-2177, Jun 2012.

NO tempi assoluti!

Set-up sperimentale



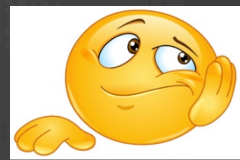
Fibra ottica anche
fotoni singoli

Dettagli in Proposal

Possibili risultati

- <u>NO RITARDO</u>: lower bound su velocità collasso (*c'*);
- assumendo ~ 40 ps il tempo di reazione di SPD, ~ 30 m la distanza di SPD's dalla sorgente ("capannoncino") il limite che si può porre è

$$c'/c \sim 5000$$



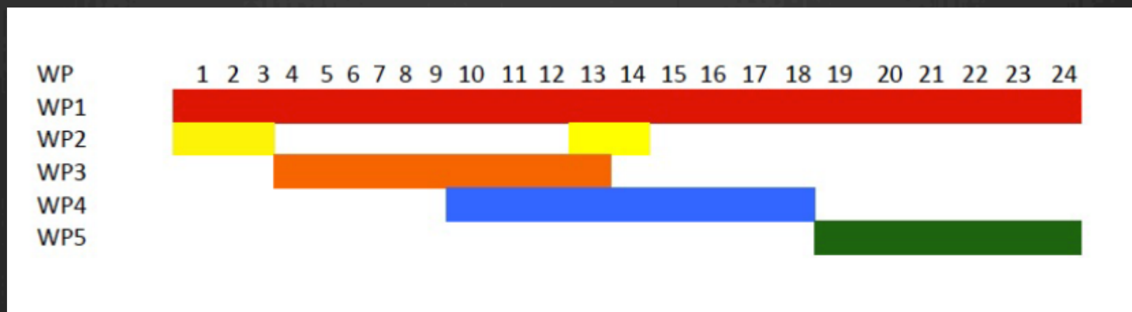
- <u>SI RITARDO</u>: *new physics effect!!*

- Standard QM non modellizza collasso, lo assume come postulato; *that's fine, FAPP*…

- Se si registra ritardo necessario generalizzare QM a descrivere collasso come processo fisico

WP e Gantt

WP	Description	Person(s) in charge
WP1	Scientific and administrative management	Oreste Nicrosini
WP2	Market survey and equipment acquisition	Daniele Bajoni Oreste Nicrosini
WP3	Realization of the photon source characterization of the spectral properties of the emitted photons test of single-photon emission	Daniele Bajoni Matteo Galli Federico Pirzio Giancarlo Reali Angelica Simbula
WP4	Realization of experimental setup Sinchronization of the event timers	Daniele Bajoni Matteo Galli Federico Pirzio Giancarlo Reali Angelica Simbula
WP5	Experiment of arrival time of single photons to asses the collapse time of photon wave function	Daniele Bajoni Matteo Galli Oreste Nicrosini Federico Pirzio Giancarlo Reali Alberto Rimini Angelica Simbula



Milestones

- Month 9
  Realization of single photon source. Routing of signal and idler photons to different outputs. Characterization of output rate and multiple pair emission emission probability.

- Month 13
  Characterization of the purity of the heralded single photon state via a Hanbury Brown Twiss experiment. Source coupling with fibers.

- Month 15
  Realization of set-up for detection over large distance. Test of the clock system for the synchronization of separate event timing boards.

- Month 20
  Measurement of the delay time between events at source and detectors.

- Month 24
  Study of the delay time for varying the space distances between source and detectors.

Risorse esterne

Item	Institution	Market value	Q.	Total
SPD 40 ps resolution (IDQuantique)	Dip. III	3000	2	6000
Pulsed laser 1.5 microns (Pritel)	Dip. III	30000	1	30000
Oscilloscope 500 MHz (Tektronix)	Dip. III	11000	1	11000
Spectrophotometer + LN2 cooled CCD	Dip. Fisica	50000	1	50000
Fiber bonding machine	Dip. III	9000	1	9000
Total				154000

Richiesta finanziaria

Item	Dealer	Price	Q.	Total
First Year				
SPD high QE	IDQuantique	5902	1	5902
Power meter	Newport	4059	1	4059
Laser pump	Edmund Optics	5209	1	5209
Focusing objectives	Edmund Optics	11265	1	11265
Second Year				
Event timing board	PicoQuant	26657	2	53314
SPD 40 ps resolution	IDQuantique	3355	2	6710

Item	Dealer	Price	Q.	Total
First year				
pulse shaper	IDQuantique	234	3	703
usb camera	Edmund Optics	1218	1	1218
Periodicaly poled KTP	Raicol	2684	1	2684
Peltier oven for phase matching	Raicol	2318	1	2318
Workshop comsumables	RS components	1951	1	1951
Acquisition board	national Instruments	2718	1	2718
Optical and electronic materials	Thorlabs	37011	1	37011
Optical filters	Semrock	6411	1	6411
computer		732	1	732
Second Year				
Timing Boards DLL library	PicoQuant	927	1	927
Optical Materials	Newport	20235	1	20235
computer		732	2	1464

	First Year	Second Year	Total
Equipment	26436	60024	86460
Consumables	55745	22626	78371
Totals	82181	82650	164831

In Sezione: alcuni giorni-uomo officina meccanica per

- trasporto tavolo ottico
- costruzione due banchi in profilato di alluminio

Prospettive

In caso di no ritardo:

- Aumentare sensibilità → portare su distanze geografiche
- Due limiti fisici: assorbimento atmosferico e diffrazione
- Per assorbimento: alla lunghezza d'onda utilizzata (800 nm) trasparenza atmosferica massima (attenuazione=0.1 dB/Km in condizioni atmosferiche ottimali)
- Uso di telescopi riflettori (diametro ~ 30 cm) consente di andare a distanze di ordine 100 Km (attenuazione da diffrazione ~ 7 dB)
- Limite: $c' \sim 10^7\, c$.

Prospettive (ii)

In ogni caso:

- Problema della misurazione quantistica → possibile soluzione (realista): collasso spontaneo della funzione d'onda (modelli GRW/CSL)
- I modelli prevedono deviazioni dalla "texbook QM" (*new physics!!*)
- Possibile testbed: sovrapposizioni di stati di "mesosistemi"

Bibliografia

[1] Peter Shadbolt, Jonathan C.F. Mathews, Anthony Laing, and Jeremy L. O'Brien. Testing foundations of quantum mechanics with photons. *Nature Physics*, 10(10):278–286, Apr 2014.

[2] S.J. Freedman and J.F. Clauser. Experimental test of local hidden-variable theories. *Physical Review Letters*, 28:938–941, 1972.

[3] A. Aspect, P. Grangier, and G. Roger. Experimental realization of einstein-podolsky-rosen-bohm gedankenexperiment: A new violation of bell's inequalities. *Physical Review Letters*, 49:91–94, 1982.

[4] T. Scheidl, R. Ursin, J. Kofler, S. Ramelow, X-S. Ma, T. Herbst, L. Ratschbacher, A. Fedrizzi, N.K. Langford, T. Jennewein, and A Zeilinger. Violation of local realism with freedom of choice. *Proc. Natl. Acad. Scie. U.S.A.*, 107:19708–19713, 2010.

[5] Juan Yin et al. Lower bound on the speed of nonlocal correlations without locality and measurements choice loopholes. *Physical Review Letters*, 110:260407, Jun 2013.

[6] in M. Jammer. *The philosophy of quantum mechanics.* Wiley, New York, 1974.

[7] J.A. Wheeler and W.H. Zurek. *Quantum theory and measurement.* Princeton University Press, 1983.

[8] Thiago Guerreiro, Bruno Sanguinetti, Hugo Zbinden, Nicolas Gisin, and Antoine Suarez. Single-photon space-like antibunching. *Physics Letters A*, 376:2174–2177, Jun 2012.

[9] John F. Clauser. Experimental distinction between the quantum and classical field-theoretic predictions for the photoelectric effect. *Physical Review D*, 9(4):853–860, Feb 1974.

[10] G. Roger P. Grangier and A. Aspect. Experimental evidence for a photon anticorrelation effect on a beam splitter: A new light on single-photon interferences. *Europhysics Letters*, 1(4):173–179, Feb 1986.

[11] Maria Fuwa, Shuntaro Takeda, Marcin Zwierz, Howard M. Wiseman, and Akira Furusawa. Experimental proof of nonlocal wavefunction collapse for a single particle using homodyne measurements. *Nature Communications*, 6:6665, Mar 2014.

[12] Paul G. Kwiat, Klaus Mattle, Harald Weinfurter, Anton Zeilinger, Alexander V. Sergienko, and Yanhua Shih. New high-intensity source of polarization-entangled photon pairs. *Phys. Rev. Lett.*, 75:4337–4341, Dec 1995.

[13] Paul G. Kwiat, Edo Waks, Andrew G. White, Ian Appelbaum, and Philippe H. Eberhard. Ultrabright source of polarization-entangled photons. *Phys. Rev. A*, 60:R773–R776, Aug 1999.

[14] G. Brida, I. P. Degiovanni, M. Genovese, F. Piacentini, P. Traina, A. Della Frera, A. Tosi, A. Bahgat Shehata, C. Scarcella, A. Gulinatti, M. Ghioni, S. V. Polyakov, A. Migdall, and A. Giudice. An extremely low-noise heralded single-photon source: A breakthrough for quantum technologies. *Applied Physics Letters*, 101(22):–, 2012.

[15] Fabian Steinlechner, Pavel Trojek, Marc Jofre, Henning Weier, Daniel Perez, Thomas Jennewein, Rupert Ursin, John Rarity, Morgan W. Mitchell, Juan P. Torres, Harald Weinfurter, and Valerio Pruneri. A high-brightness source of polarization-entangled photons optimized for applications in free space. *Opt. Express*, 20(9):9640–9649, Apr 2012.

[16] Alessandro Fedrizzi, Thomas Herbst, Andreas Poppe, Thomas Jennewein, and Anton Zeilinger. A wavelength-tunable fiber-coupled source of narrowband entangled photons. *Opt. Express*, 15(23):15377–15386, Nov 2007.

[17] M Razavi, I Sllner, E Bocquillon, C Couteau, R Laflamme, and G Weihs. Characterizing heralded single-photon sources with imperfect measurement devices. *Journal of Physics B: Atomic, Molecular and Optical Physics*, 42(11):114013, 2009.

[18] G.C. Ghirardi, A. Rimini, and T. Weber. A unified dynamics for micro and macro systems. *Phys. Rev. D*, 34:470, 1986.

[19] G.C. Ghirardi, O.Nicrosini, A. Rimini, and T. Weber. Spontaneus localization of a system of identical particles. *Nuovo Cimento B*, 102:383, 1988.

[20] A. Bassi, Kinjalk Lochan, Seema Satin, Tejinder P. Singh, and Hendrik Ulbricht. Models of wave-function collapse, underlying theories and experimental tests. *Rev. Mod. Phys.*, 85:471–527, 2013.

[21] K.C. Lee et al. Entangling macroscopic diamonds at room temperature. *Science*, 334:1253–1256, 2011.